Oslo - Stockholm - Utrecht - Brussels - Copenhagen - Helsinki

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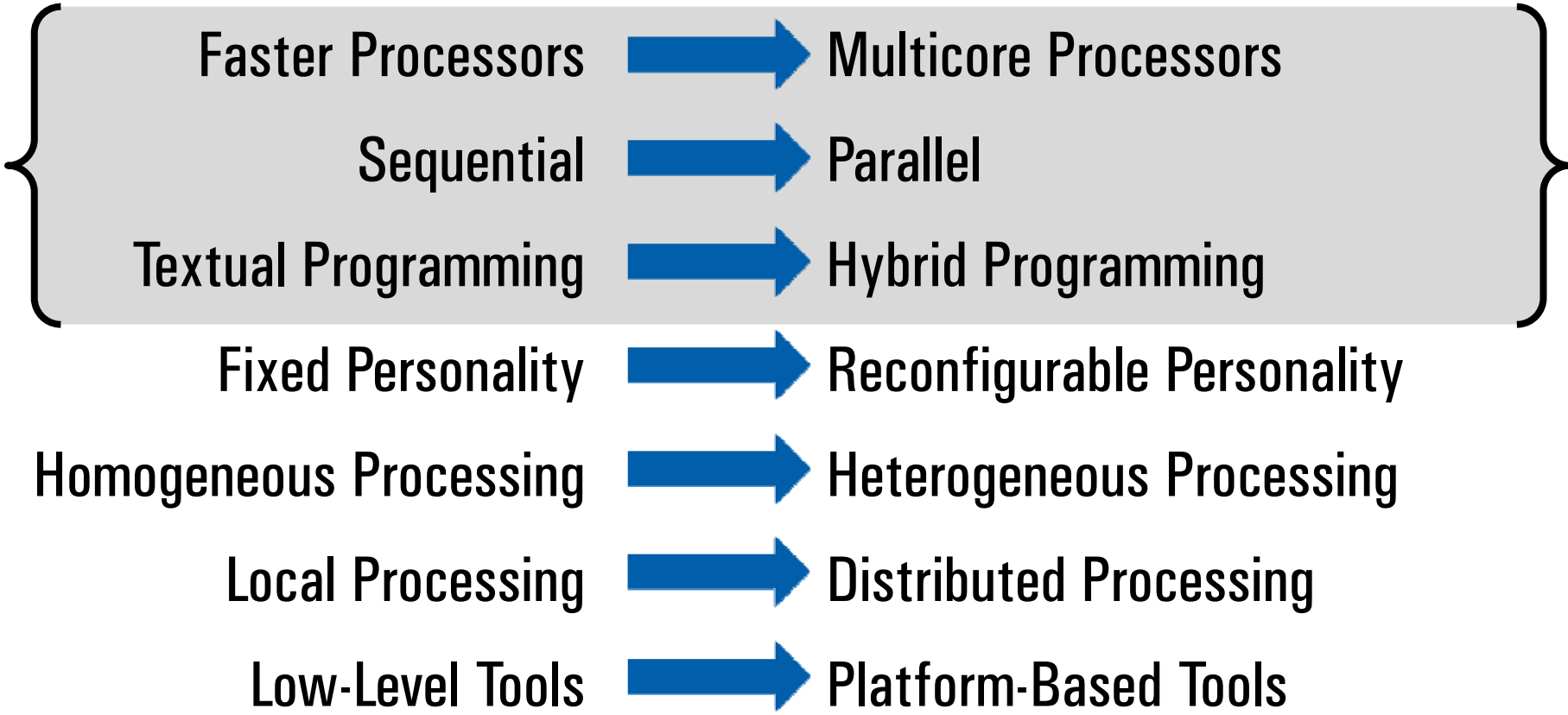
NATIONAL INSTRUMENTS

FROM DESIGN TO TEST WITH NEW GRAPHICAL AND TEXTUAL TOOLS

Agenda

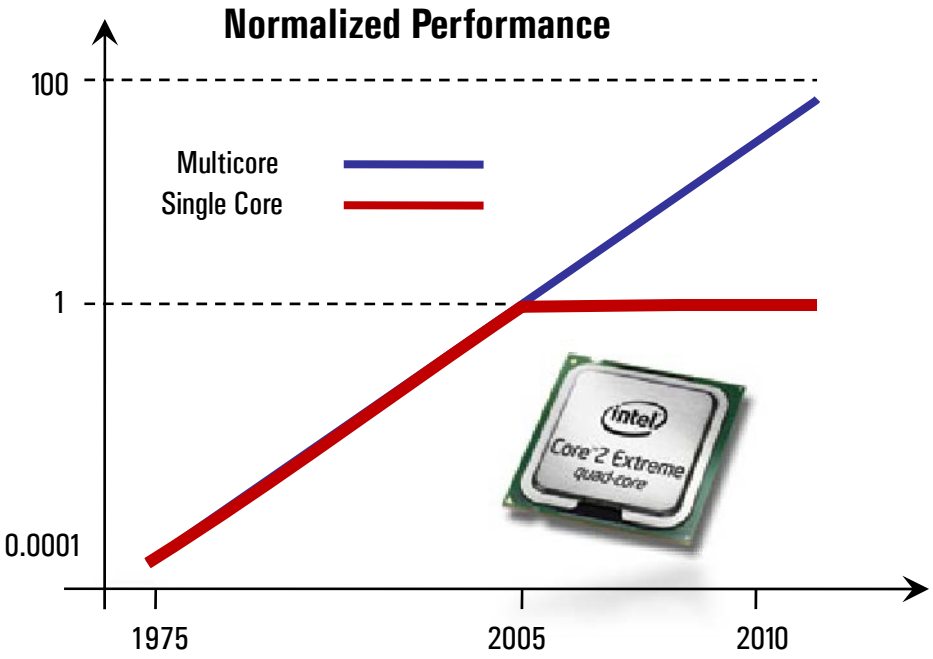
- Trends in Algorithm Design
- The Algorithm Engineering Approach
- Application Areas
  - Signal Processing
  - Control Design
- Conclusion

Trends in Algorithm Design



Parallel Architectures Promise Performance

Which further complicates programming and software development, particularly for domain experts.



"To fully exploit the power of processors working in parallel ... new software must deal with the problem of concurrency."

– **Bill Gates**, Microsoft

"But a parallel programming model ... will not emerge for five to 10 years, according to experts from Microsoft Corp."

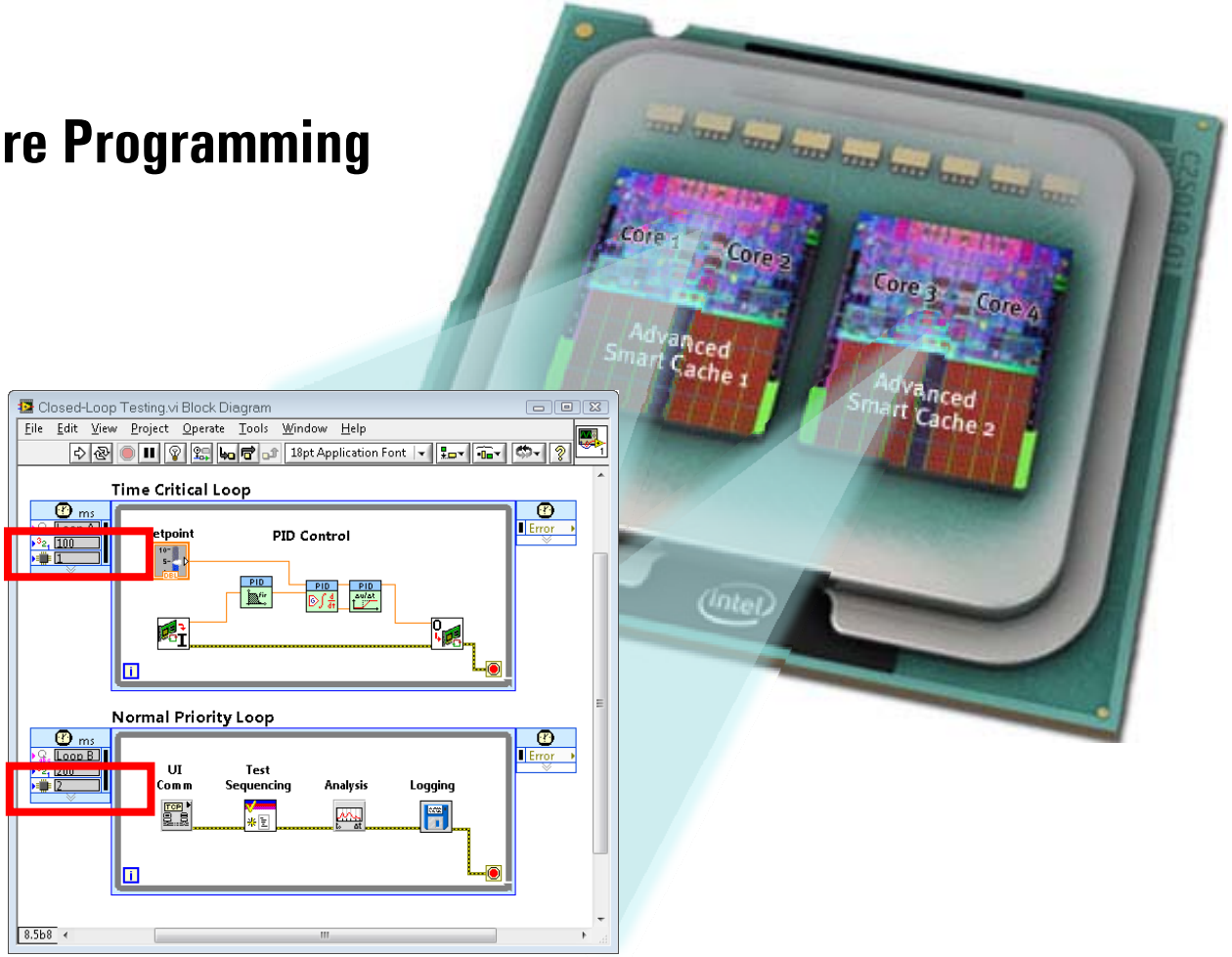
– **Rick Merritt**, *EE Times*

"The concurrency revolution is likely to be more disruptive than the OO revolution ... "

The Free Lunch Is Over - **Herb Sutter**, Microsoft

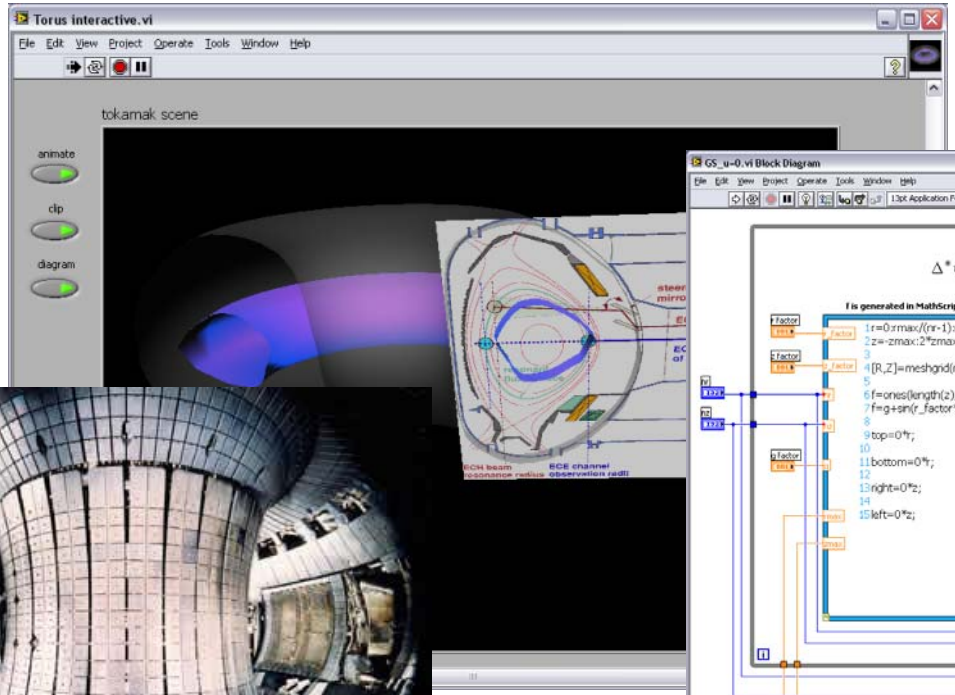
NATIONAL INSTRUMENTS LabVIEW™

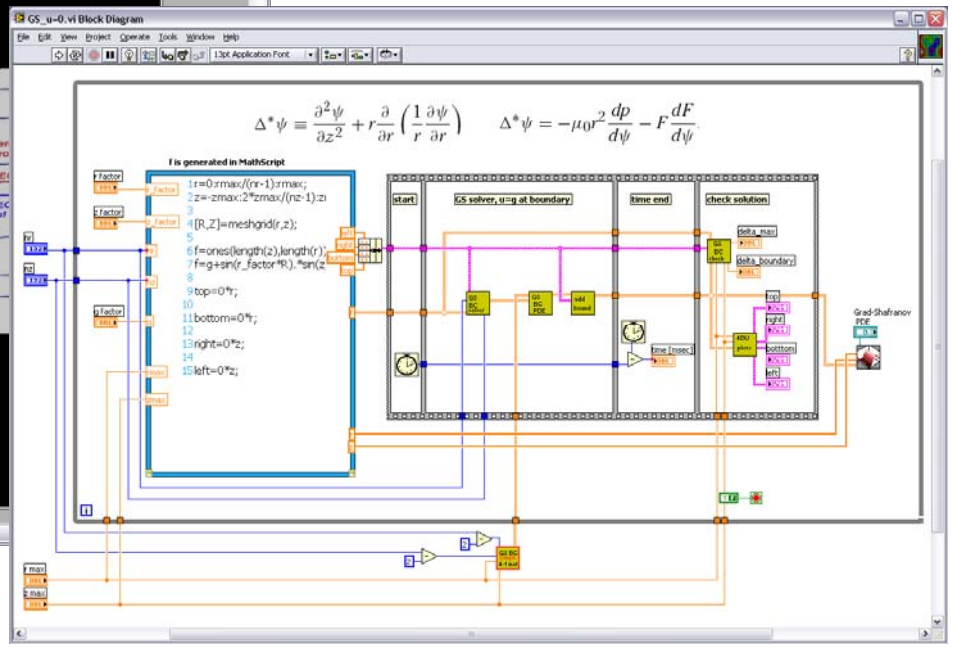
Parallel, Multicore Programming Made Easy



Assign timed loops to specific processor cores.

LabVIEW Multicore Performance Benefits





IPP Max-Planck-Institut für Plasmaphysik

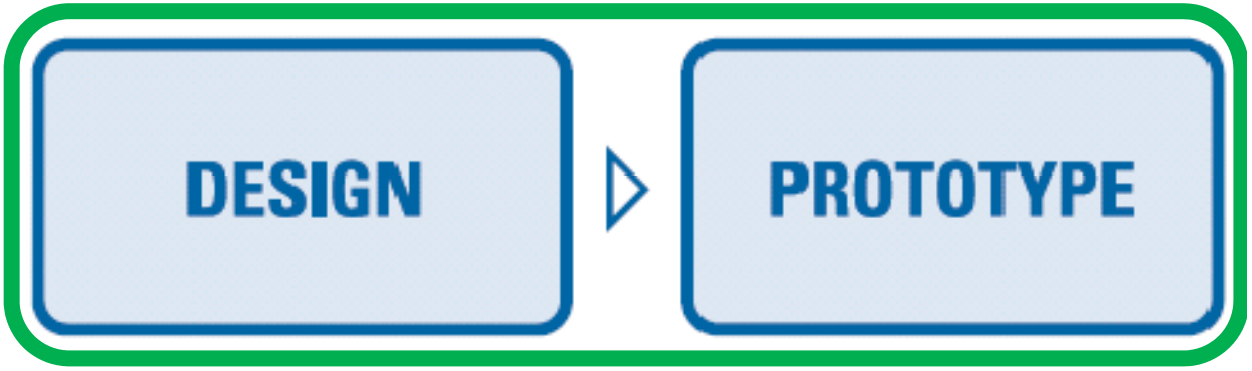
*"...with LabVIEW, we obtained a **20X processing speed-up** on an octal-core processor machine over a single-core processor..."*

Dr. Louis Giannone
Lead Researcher, Max-Planck-Institut für Plasmaphysik

Graphical System Design

What Is Algorithm Engineering?

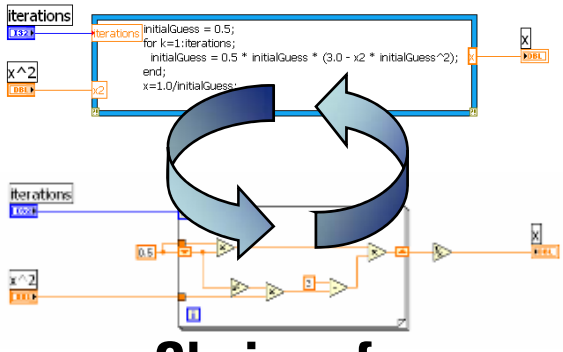
Algorithm Design + Algorithm Implementation (Prototyping)



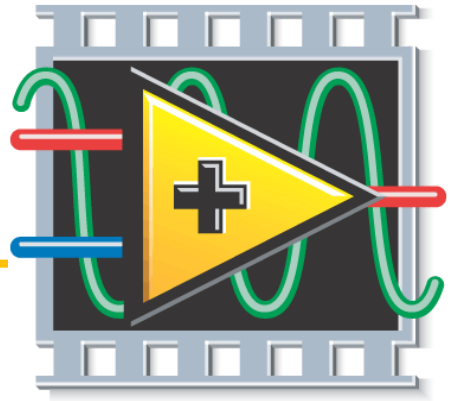
= ***Algorithm Engineering***

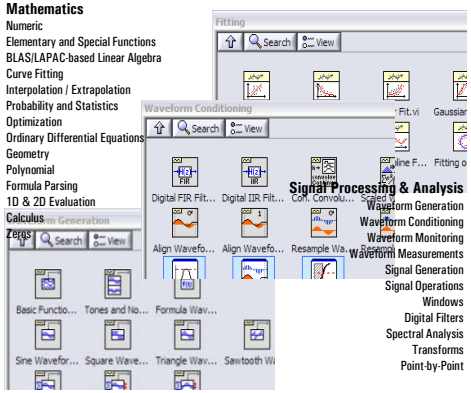
Design, implement, and prove
your algorithms quickly and easily

LabVIEW for Algorithm Engineering

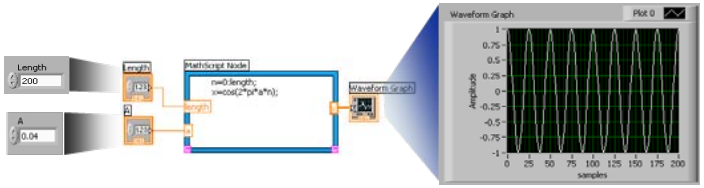


Choice of Computational Model





Extensive Built-In Functionality

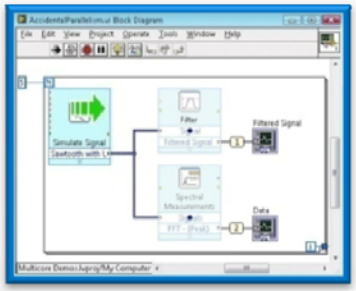


Simplified Interactivity

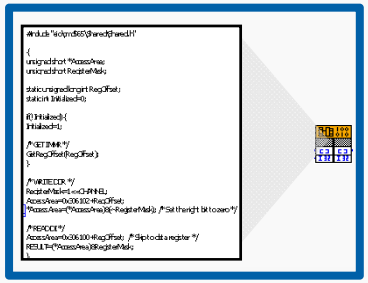
Tight HW Integration

High-Level Design Models

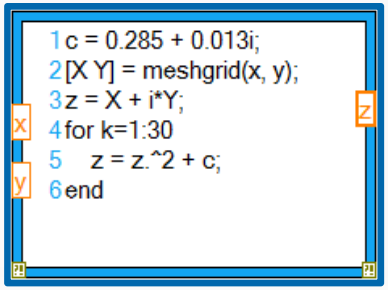
Data Flow



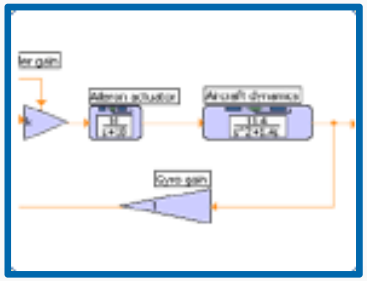
C Code



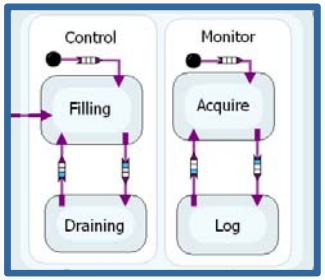
Textual Math



Simulation



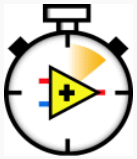
Statechart



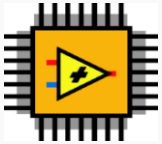
NATIONAL INSTRUMENTS LabVIEW™

Desktop

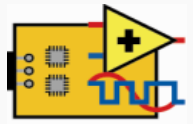
Real-Time



FPGA

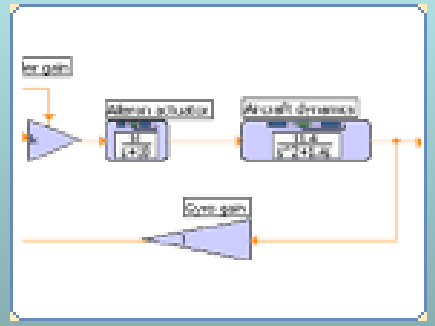


Microprocessors

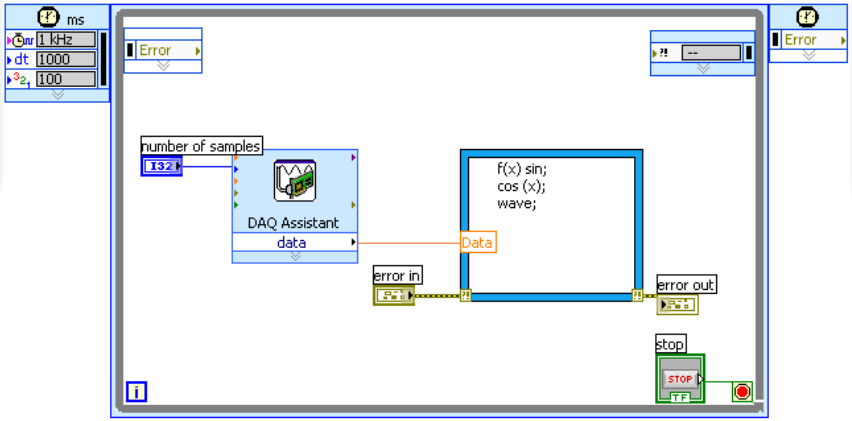


Benefits of LabVIEW Graphical System Design

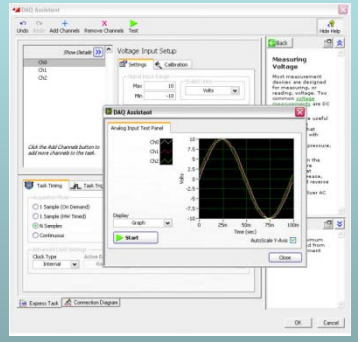
Simulation



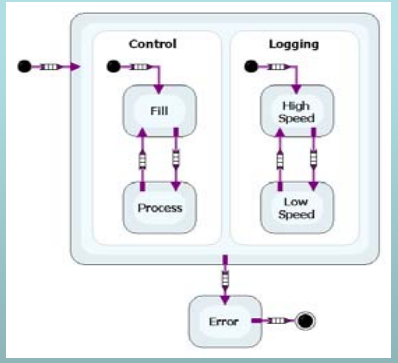
Graphical Data Flow

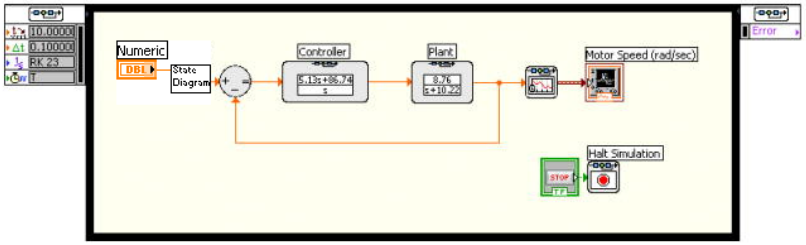


Configuration

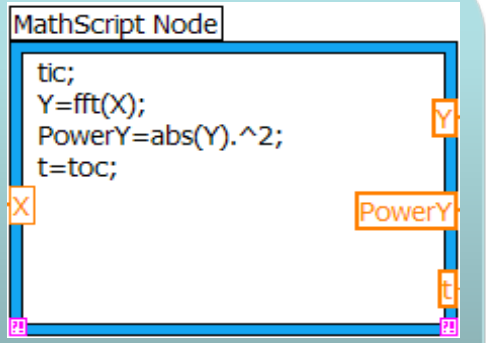


Statecharts



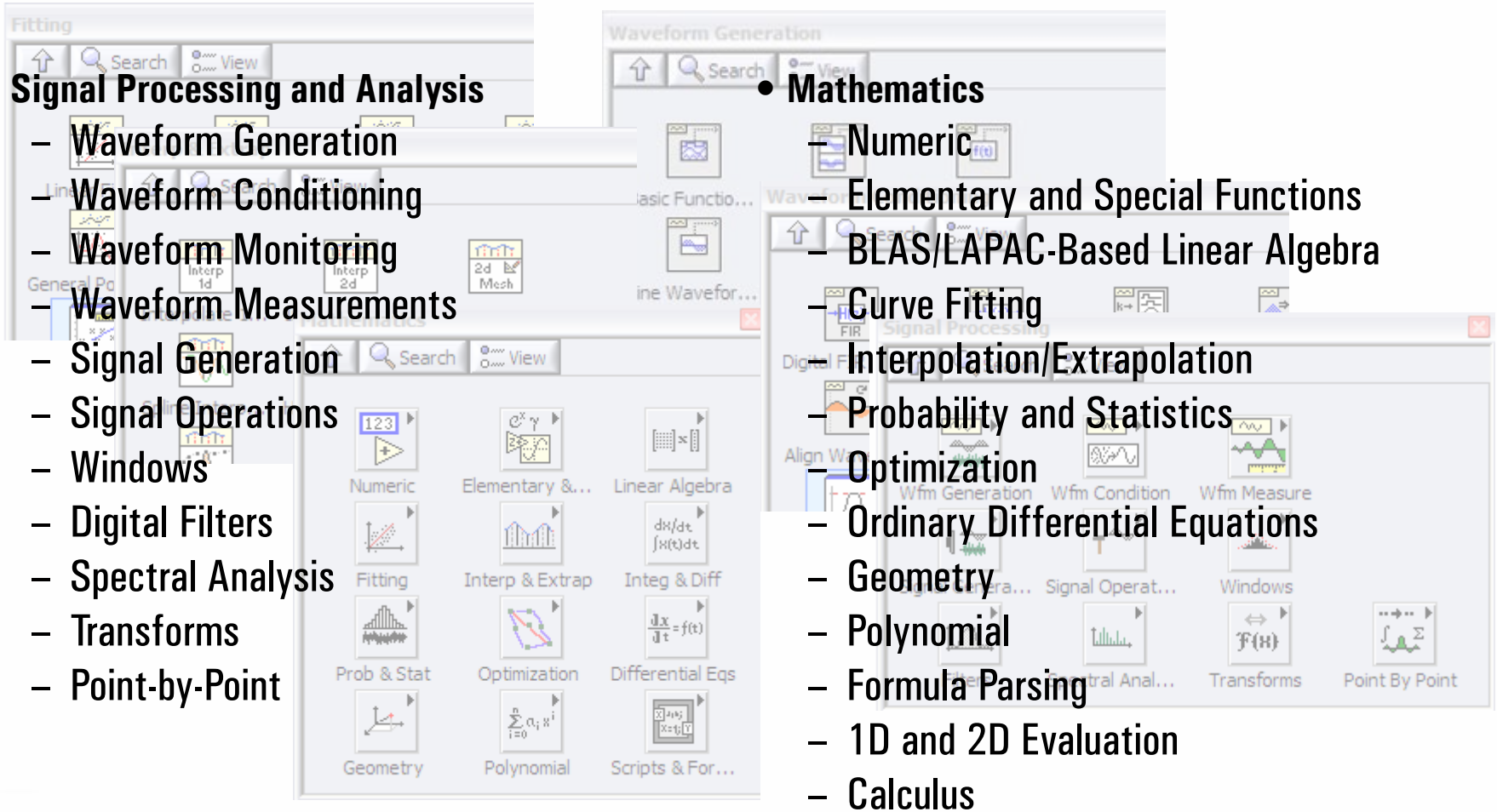


LabVIEW MathScript



NATIONAL INSTRUMENTS

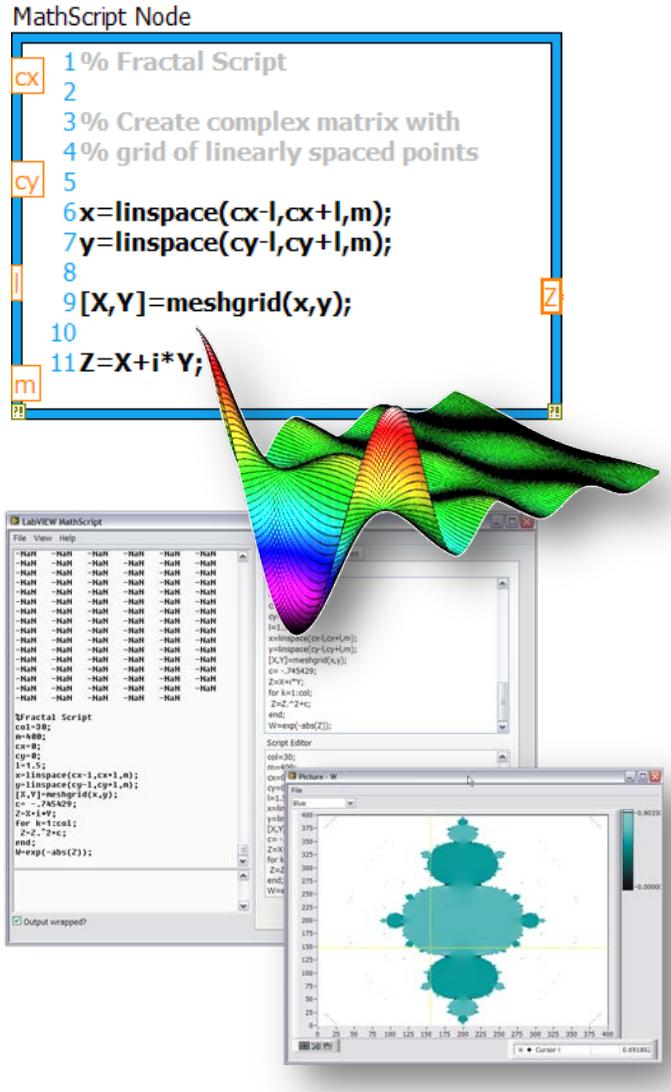
Built-In Graphical Tools (VIs) for Signal Processing, Analysis, and Math (Abridged List)



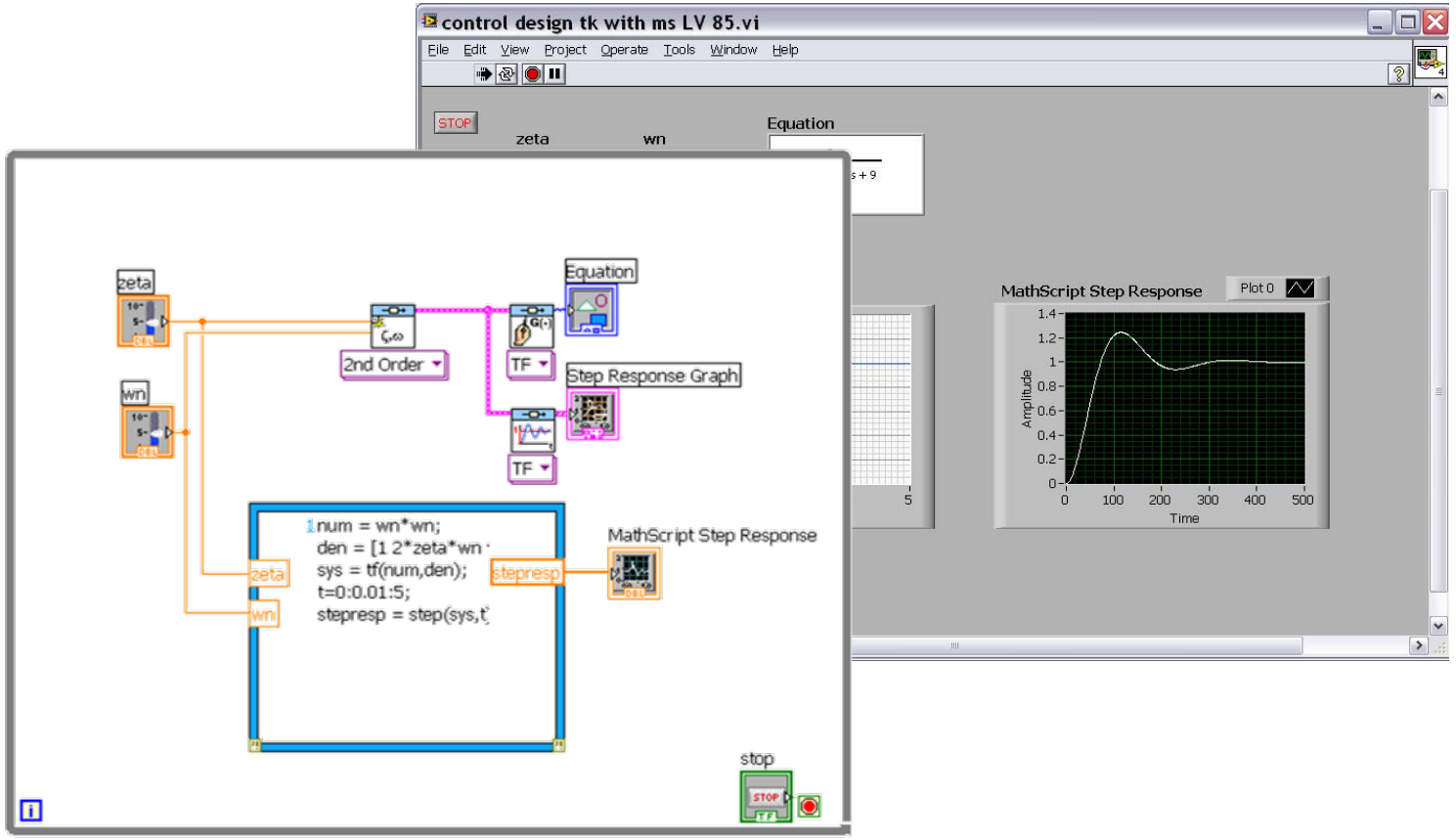
- **Signal Processing and Analysis**
  - Waveform Generation
  - Waveform Conditioning
  - Waveform Monitoring
  - Waveform Measurements
  - Signal Generation
  - Signal Operations
  - Windows
  - Digital Filters
  - Spectral Analysis
  - Transforms
  - Point-by-Point
- **Mathematics**
  - Numeric
  - Elementary and Special Functions
  - BLAS/LAPAC-Based Linear Algebra
  - Curve Fitting
  - Interpolation/Extrapolation
  - Probability and Statistics
  - Optimization
  - Ordinary Differential Equations
  - Geometry
  - Polynomial
  - Formula Parsing
  - 1D and 2D Evaluation
  - Calculus
  - Zeros

LabVIEW MathScript

- Text-based signal processing, control design, and math within LabVIEW
  - More than 700 built-in functions
  - Reuse many of your .m file scripts created with The MathWorks, Inc. MATLAB® software and others
  - Based on original math from NI MATRIXx
- A native LabVIEW solution
  - Interactive and programmatic interfaces
  - Does not require third-party software



Demo 1: The Combined Graphical and Textual Approach



Built-In LabVIEW MathScript Functions (Abridged List)

- **2D and 3D Plotting**
  X-Y (scatter) plots, mesh plots, 3D plots, surface plots, contour plots, subplots, stairstep plots, logarithmic plots, stem plots, vector field plots, tree plots and more

- **Probability and Statistics**
  Mean; median; Poisson, Rayleigh, chi-squared, Weibull, T, gamma distributions; covariance; variance; standard deviation; cross correlation; histogram; white noise distributions and other functions

- **Digital Signal Processing (DSP)**
  Signal Synthesis; Butterworth, Chebyshev, Parks-McClellan, windowed FIR, elliptic (Cauer), lattice and other filter designs; FFT (1D/2D), inverse FFT (1D/2D), Hilbert, and other transforms; Hamming, Hanning, Kaiser-Bessel and other windows; pole/zero plotting and others

- **Optimization**
  Quasi-Newton, quadratic, Simplex methods and more

- **Approximation (Curve Fitting / Interpolation)**
  Cubic spline, cubic Hermite and linear interpolation; exponential, linear, and power fit; rational approximation and others

- **Advanced Functions**
  Bessel, spherical Bessel, Psi, Airy, Legendre, Jacobi functions; trapezoidal, elliptic exponential integral functions and more

- **Ordinary Differential Equations**
  Adams-Moulton, Runge-Kutta, Rosenbrock, and other continuous ordinary differential equation (ODE) solvers

- **Basic Operations**
  Absolute value, Cartesian to polar and spherical and other coordinate conversions, least common multiple; modulo, exponentials, logarithmic functions, complex conjugates and more

- **Polynomial Operation**
  Convolution, deconvolution, polynomial fit, piecewise polynomial, partial fraction expansion and others

- **Trigonometric**
  Standard cosine, sine and tangent, Inverse hyperbolic cosine, cotangent, cosecant, secant, sine and tangent; hyperbolic cosine cotangent, cosecant, secant, sine, and tangent; exponential, natural logarithm and more

- **Linear Algebra**
  LU, QR, QZ, Cholesky, Schur decomposition, SVD, determinant, inverse, transpose, orthogonalization, solutions to special matrices; Taylor series; real / complex eigenvalues and eigenvectors; polynomial eigenvalues and more

- **Boolean and Bit Operation**
  AND, OR, NOT, and other logic operations; bitwise shift, bitwise OR and other bitwise operation

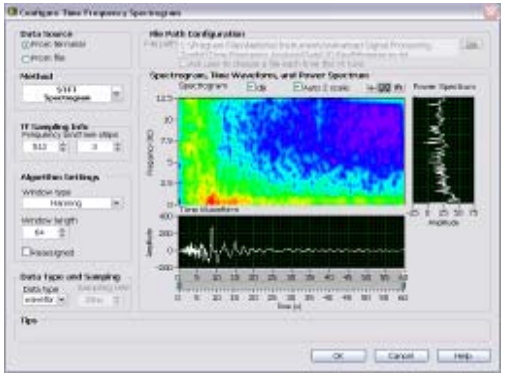
- **Matrix Operations**
  Hankel, Hilbert, Rosser, Vandermonde special matrices; inverse; multiplication; division; unary operations and others

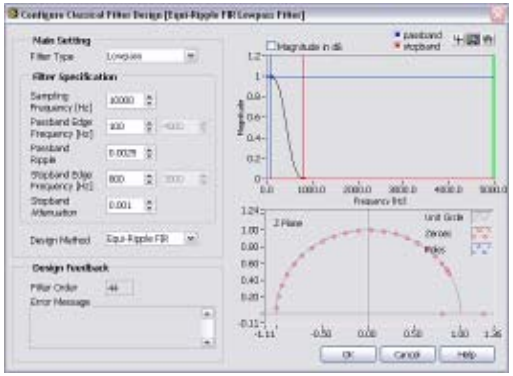
- **Data Acquisition / Generation**
  Analog and digital I/O using National Instruments devices

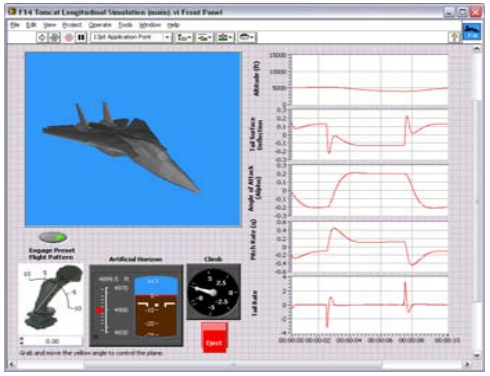
- **Vector Operations**
  Cross product; curl and angular velocity; gradient; Kronecker tensor product and more

- **Other**
  Programming primitives such as if, for, and while loops; unsigned and signed data type conversions; file I/O; benchmarking and other timing functions; various set and string operations

LabVIEW Tools for Signal Processing, Analysis, and Control



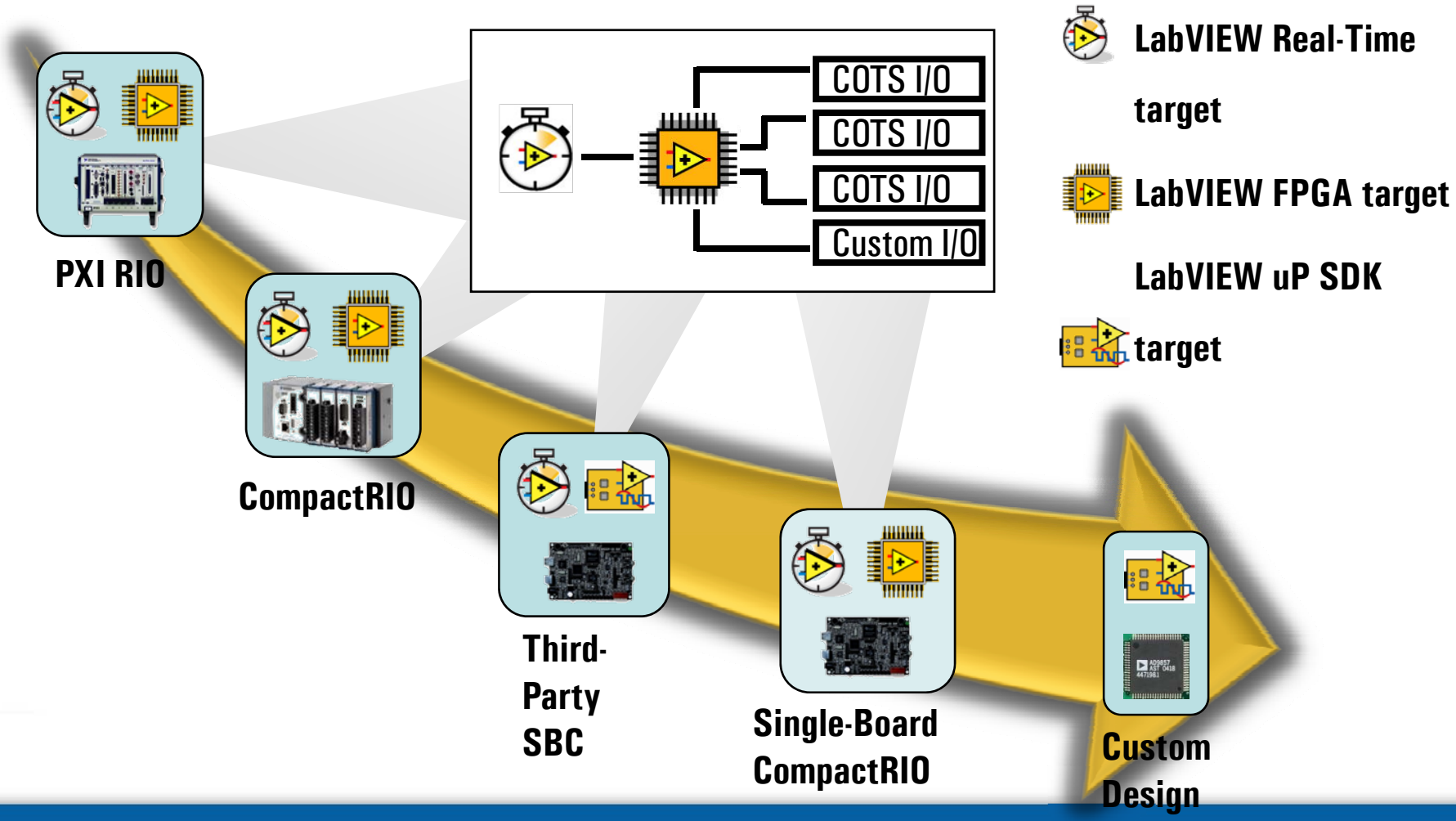




Advanced Signal Processing	Digital Filter Design	Control Design and Simulation Module

• Wavelets
• Time-series analysis (independent component analysis, principal component analysis, model-based spectral analysis, ...)
• Time-frequency analysis (Gabor, STFT, ...)
	• FIR/IIR filter design/analysis, quantization
	• Fixed-point modeling, fixed-point simulation, code generation (FPGA /ANSI C), ...
		• Model construction, conversion, and reduction
		• Time and frequency response
		• Dynamic characteristics
		• Classical control design
		  • *root locus, PID, lead/lag ...*
		• State-space control/estimation
		  • *LQR, LQG, pole placement, Kalman filter ...*

Standard Embedded Architecture, Standard Design Tool



Hybrid Approach Fosters Development of Train Wheel Defect Monitoring/Tracking in India

- On-track strain measurements analyzed for defect detection and train monitoring
- Successful prototypes based on CompactRIO and developed with LabVIEW MathScript
- Planned deployment to > 250 stations across India
- Co-effort of:
  - Indian Institute of Technology, Kanpur
  - Indian Railways
  - Research, Design and Standards Organization

THE HINDU

NI Platform for Signal Processing

LabVIEW Development Environment

- Textual (MathScript) Signal Processing and Analysis
- Graphical (Dataflow) Signal Processing and Analysis
- Connectivity to Third-Party Math Software
- Advanced Signal Processing Toolkit
- Digital Filter Design Toolkit
- Add-On Toolkits (Communications, S&V)

LabVIEW Real-Time | LabVIEW FPGA | LV mProcessor SDK

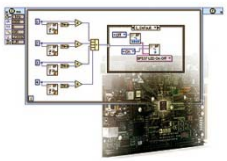
Targets


PC/Mac


PXI


cRIO, cDAQ

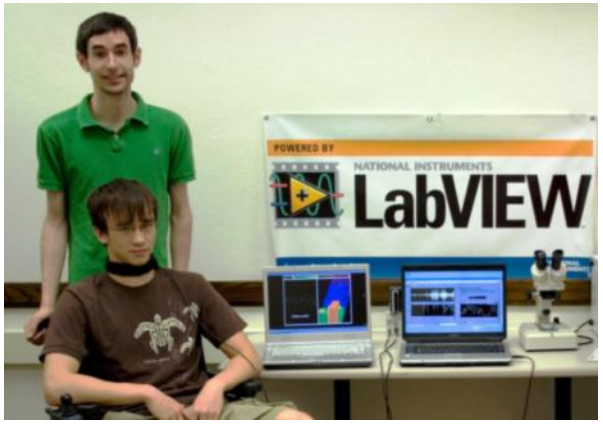

RIO/DAQ Devices


32-Bit mp

UIUC Innovators Develop Mind-Computer Interface with NI LabVIEW

Application: University of Illinois at Urbana-Champaign (UIUC) engineering students developed a device that translates thought into speech or commands for control over wheelchairs and other devices. They used LabVIEW to develop the signal processing algorithms for translation algorithms and implement prototypes.

NI Products: Signal Processing in LabVIEW, USB DAQ



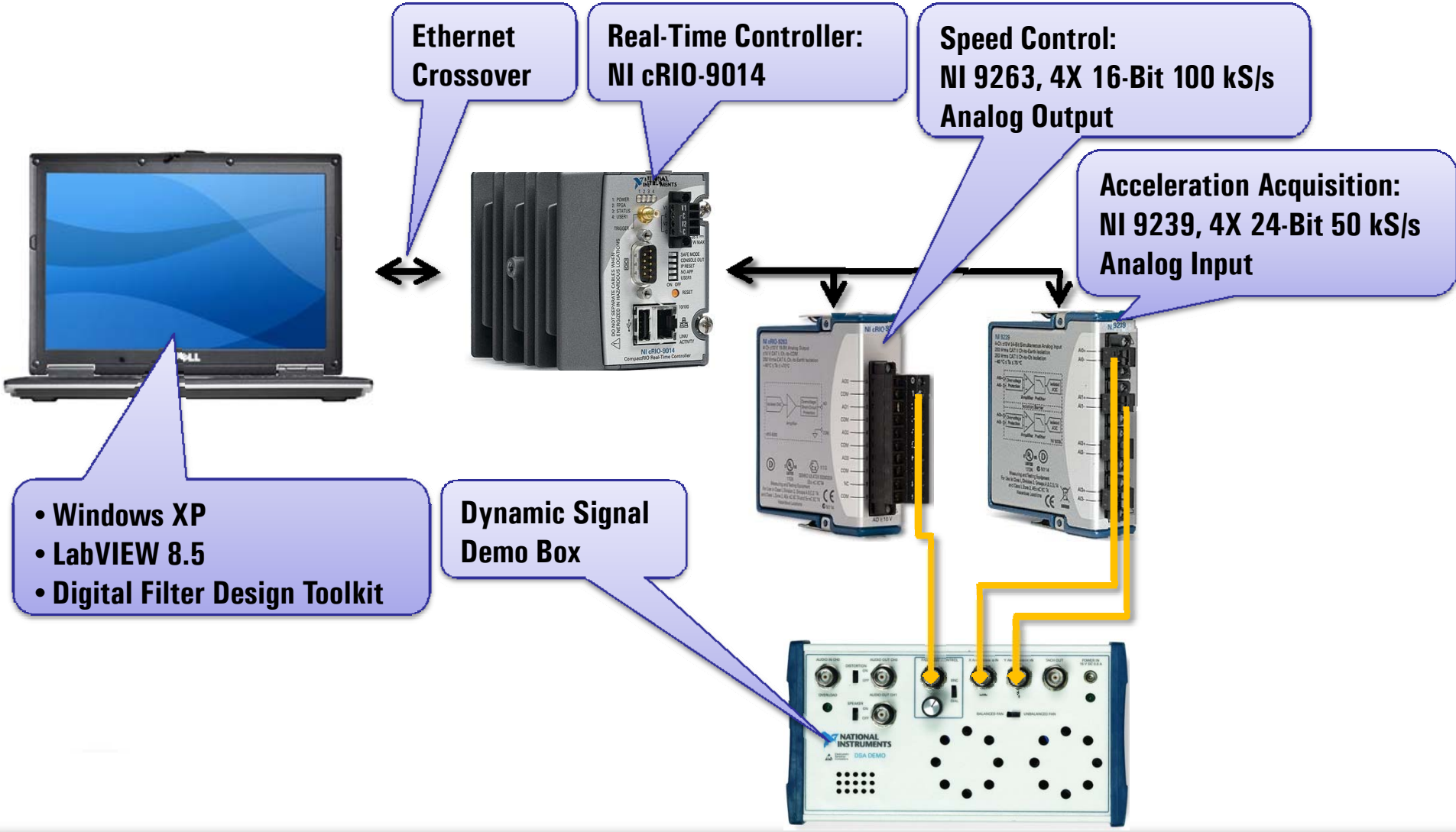
ambient

www.theaudeo.com

"Working with LabVIEW simplifies development and encourages innovation by offering an intuitive graphical programming approach that allows you to focus on innovation rather than programming details."

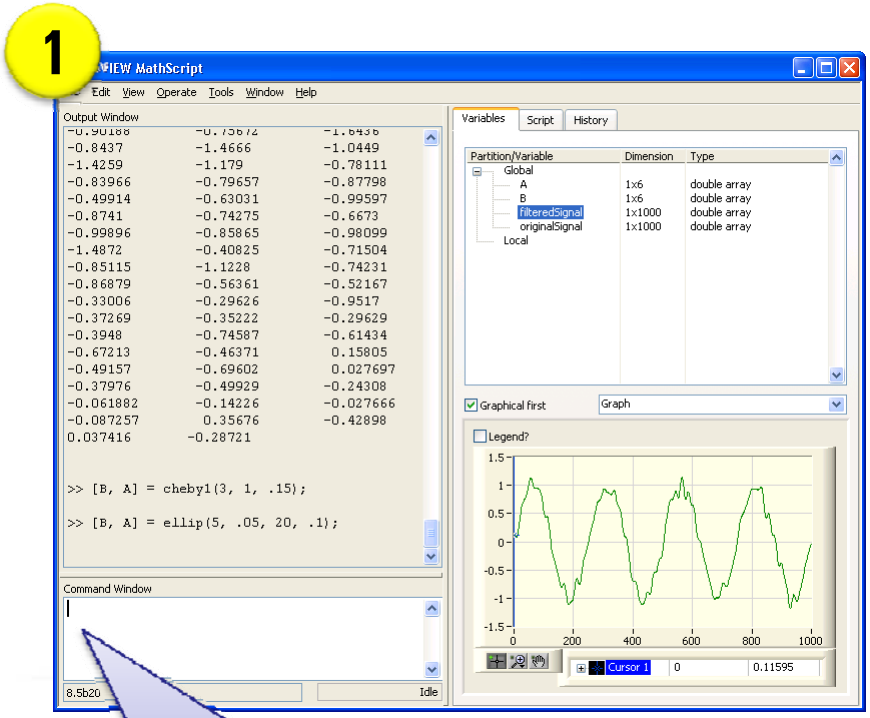
Michael Callahan, CEO, Ambient Corporation

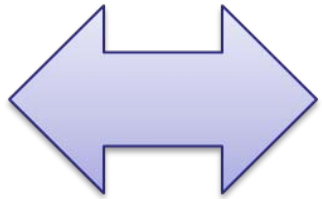
Signal Processing Demo: Hardware Setup

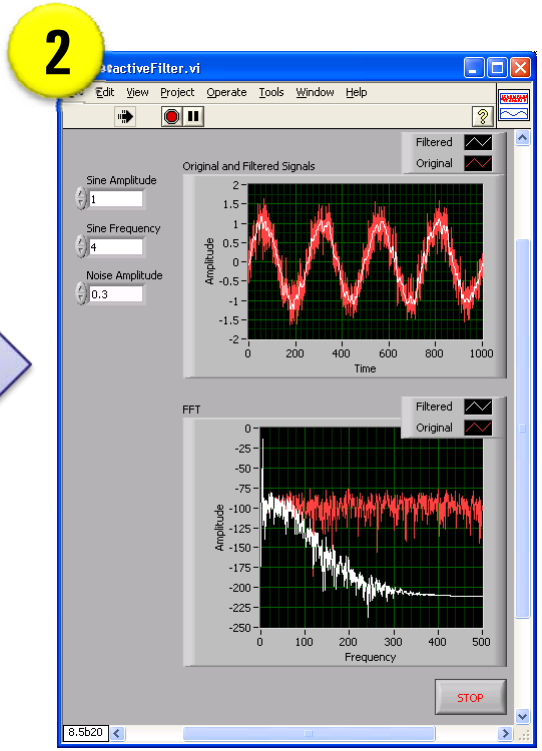


Demo 2: Flexible Interactivity

1. Type .m file script commands to define design
2. See results of applying design to live signals







NATIONAL INSTRUMENTS

Developing a DP System to Automatically Position a Split-Hopper Vessel

Application: Build a control system that will keep a ship at a fixed position and heading

Challenge: Develop a very advanced control system feed with DGPS, wind, current, gyroscope info

Products: PXI, CompactRIO, RT, Control Design Toolkit, LabVIEW Sim

Key Benefit: Use a common platform to develop controller and deploy system able to integrate third-party information systems

*"We used NI tools because its software allowed us to **reuse** the same code from **simulation to deployment** and its hardware was **reliable.**"*

Controller Design Process

Plant Model Development

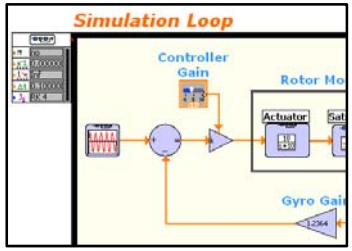
- Plant parameters
- Mathematical model
- System identification with I/O
- Online system identification

Plant Analysis

- Observability/controllability
- Stability
- Time and frequency response

Controller Design

- Classical control
- State-space control and estimation
- Model predictive control
- Nonlinear, adaptive, hybrid control



Implementation

- Code portability from simulation to deployment
- Deploy to RT, FPGA, uPC, SBC, PCs
- Any bus, any signal, any I/O

Controller Simulation and Validation

- Feasibility
- Design optimization
- 3D visualization
- Solvers – custom or standard
- Real-time prototyping

NI Platform for Control

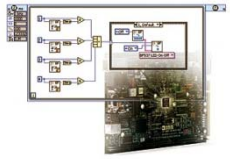
Control Design and Simulation Module	System ID Toolkit	NI Motion Control
LabVIEW Statechart Module	Simulation Interface Toolkit	PID and Fuzzy Logic Toolkit
LabVIEW Real-Time Module	LabVIEW FPGA Module	LabVIEW Microprocessor SDK

Targets

PXI

cRIO, cFP

RIO/DAQ Devices



32-Bit mp

Demo: DC Motor Control

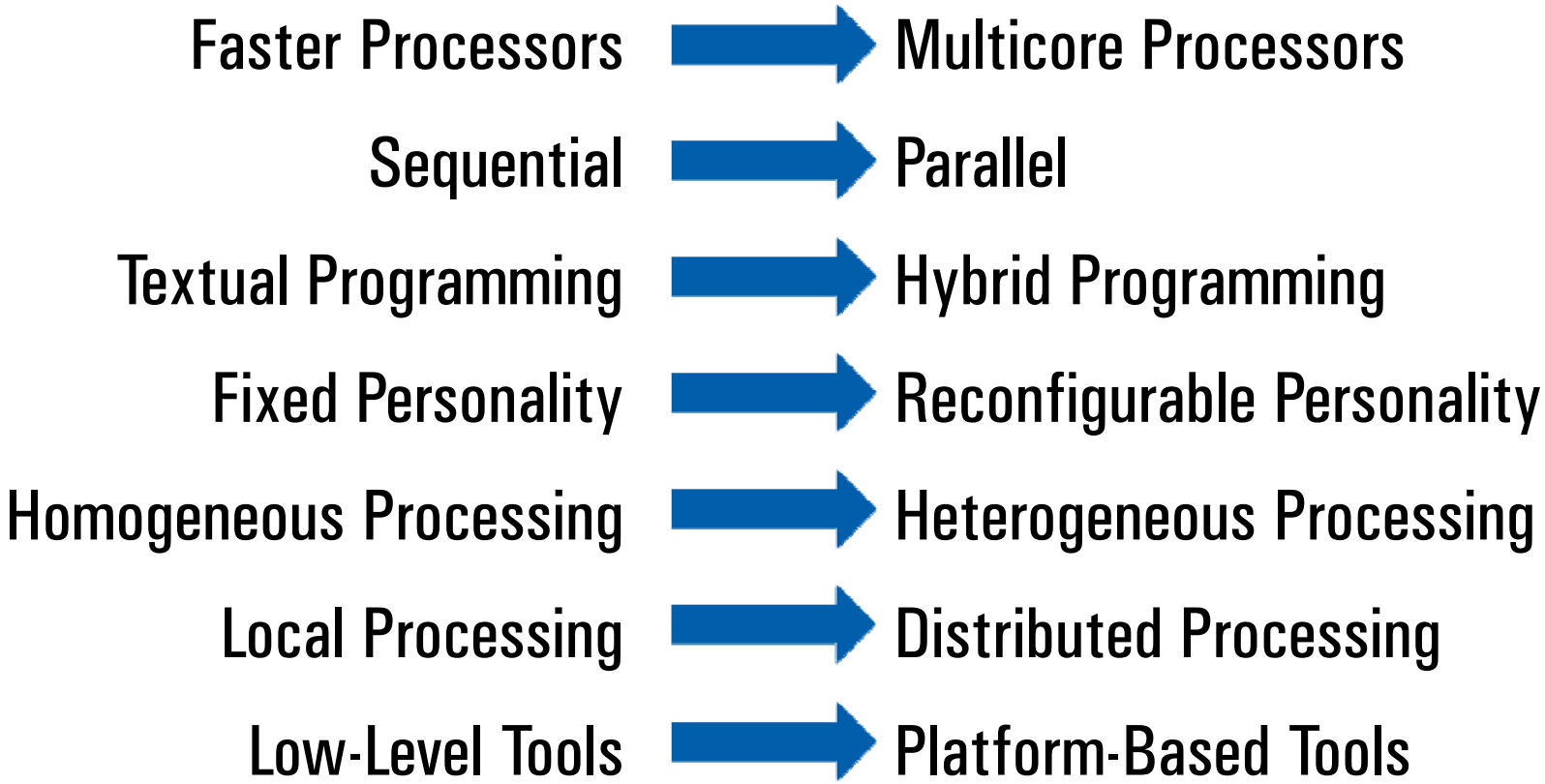
Ethernet
Crossover

NI 9505
Motor Drive Module

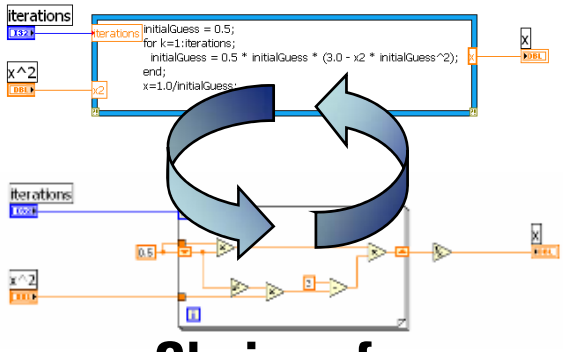
MicroMo 3242
Brushed DC Motor

- Direct connection to NI 9505 motor drive module
- Built-in quadrature encoder (512 CPR)

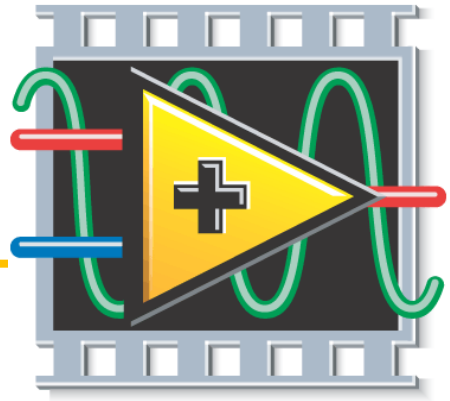
Trends in Algorithm Design

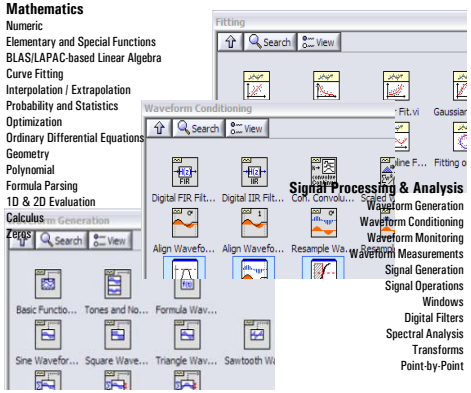


LabVIEW for Algorithm Engineering

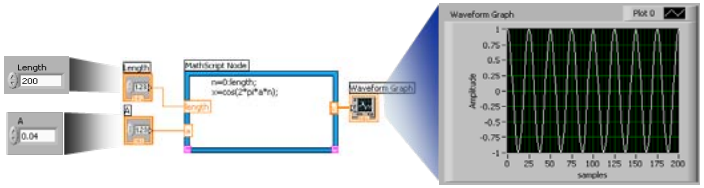


Choice of Computational Model





Extensive Built-In Functionality



Simplified Interactivity

Tight HW Integration