A. Experimental Practices, and
B. Graphing and Analysis with Igor Pro

Week of Aug. 29, 2011

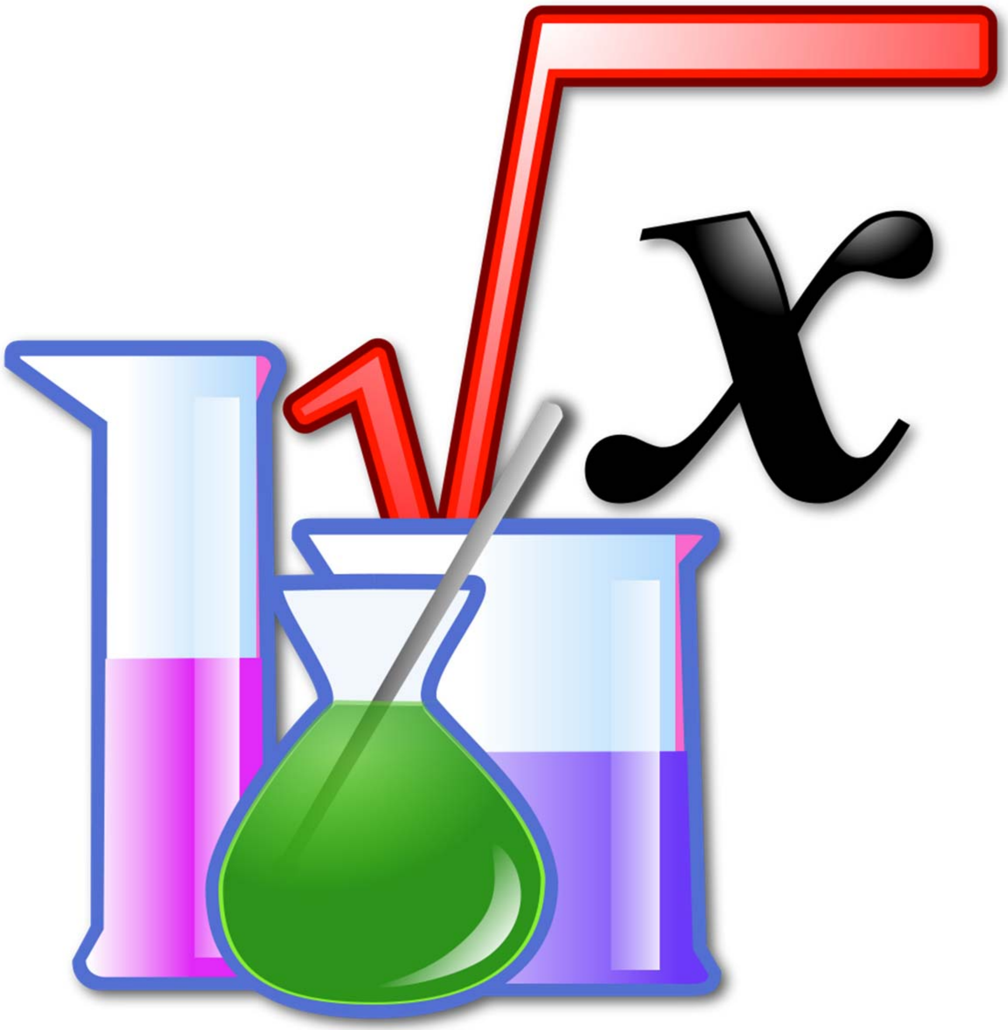
IGOR Pro

- *Runs on Mac OS X and Windows*
- *Fast Display of Large Data Sets*
- *Interactive Data Exploration*
- *Journal–Quality Graphics*
- *Powerful Curve Fitting*
- *Extensive Data Analysis & Statistics*
- *Image Processing*
- *Data Acquisition Support*
- *Built-In Programming Environment Supports Analysis and Automation*
- *Customizable User Interface*
- *Used by Scientists and Engineers Worldwide Since 1989*

Molecular and Condensed Matter Lab (Physics 4580)
PV Materials and Device Physics Lab (PHYS 6/7280)

The University of Toledo
Instructors: Randy Ellingson, Mike Heben

Experimental Methods and Practices



http://en.wikipedia.org/wiki/Scientific_method

Experimental Methods and Practices

<u>From sciencebuddies.org:</u>

Key Info
The scientific method is a way to ask and answer scientific questions by making observations and doing experiments.

The steps of the scientific method are to:

- **Ask a Question**
- **Do Background Research**
- **Construct a Hypothesis**
- **Test Your Hypothesis by Doing an Experiment**
- **Analyze Your Data and Draw a Conclusion**
- **Communicate Your Results**

It is important for your experiment to be a fair test. A "fair test" occurs when you change only one factor (variable) and keep all other conditions the same.

http://www.sciencebuddies.org/science-fair-projects/project_scientific_method.shtml

Key Elements of the Scientific Method

1. Define the question
2. Gather information and resources (observe)
3. Form hypothesis
4. Perform experiment and collect data
5. Analyze data
6. Interpret data and draw conclusions that serve as a starting point for new hypothesis
7. Publish results
8. Retest (frequently done by other scientists)

The iterative cycle inherent in this step-by-step methodology goes from point 3 to 6 back to 3 again.

http://en.wikipedia.org/wiki/Scientific_method

Thoughts on the Scientific Method

Ibn al-Haytham (Alhazen, 965–1039), pointed out the emphasis on seeking truth:

Truth is sought for its own sake. And those who are engaged upon the quest for anything for its own sake are not interested in other things. Finding the truth is difficult, and the road to it is rough.

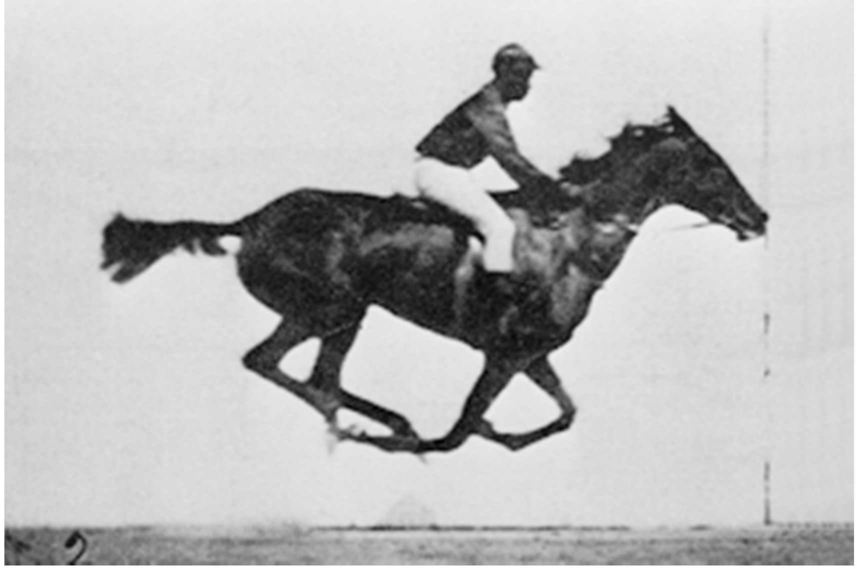
According to William Whewell (1794–1866), "invention, sagacity, genius" are required at every step in scientific method. It is not enough to base scientific method on experience alone; multiple steps are needed in scientific method, ranging from our experience to our imagination, back and forth.

http://en.wikipedia.org/wiki/Scientific_method

Scientific Method: Beliefs and Biases

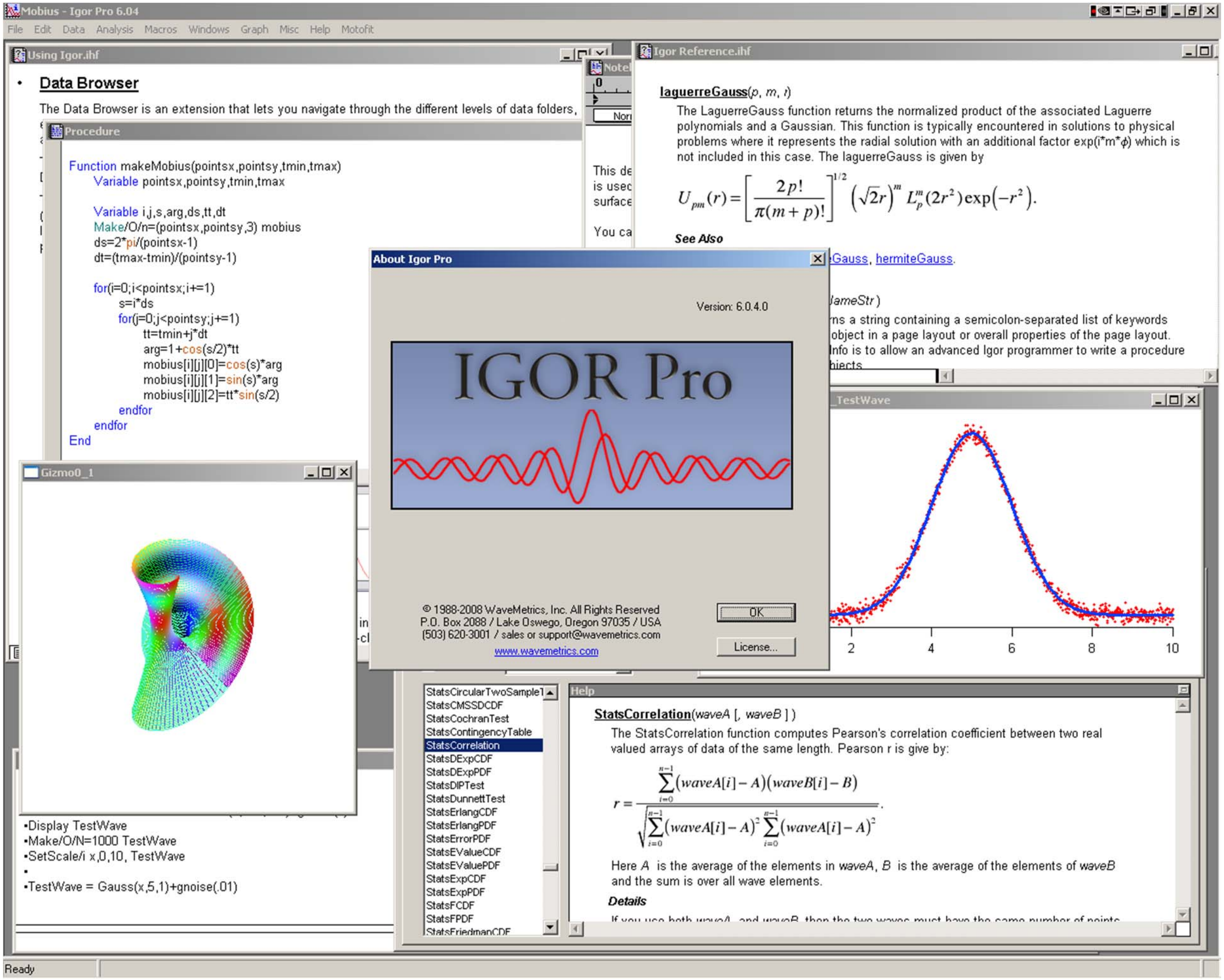
The Epsom Derby (1821) by Géricault, Jean Louis Théodore. Oil on canvas.

Eadweard Muybridge's (1830 – 1904) studies of a horse galloping



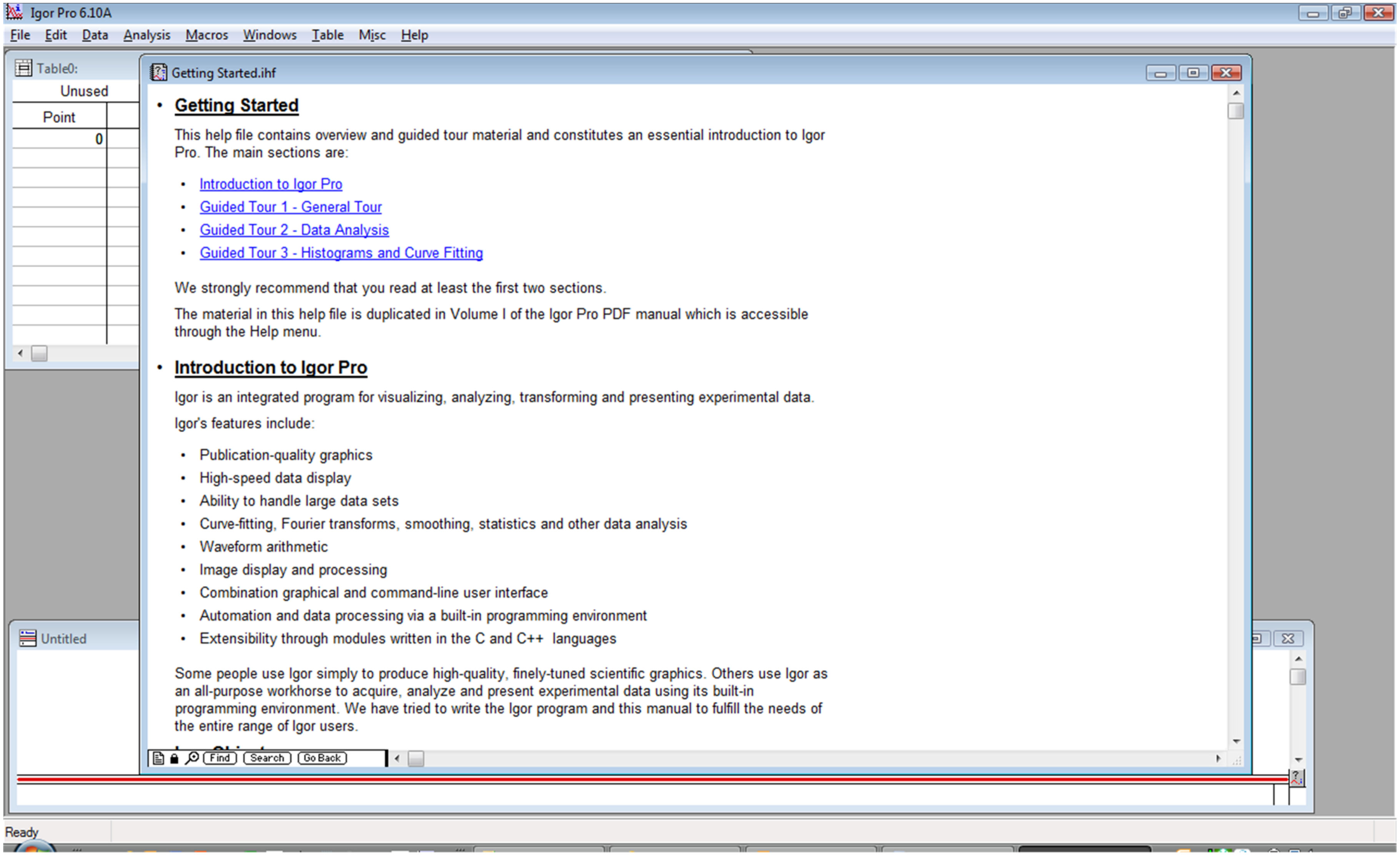
http://en.wikipedia.org/wiki/Scientific_method

Igor Pro 6.1



Mobius - Igor Pro 6.04
File Edit Data Analysis Macros Windows Graph Misc Help Motofit
Using Igor.ihf
Data Browser
The Data Browser is an extension that lets you navigate through the different levels of data folders,
Procedure
Function makeMobius(pointsx,pointsy,tmin,tmax)
Variable pointsx,pointsy,tmin,tmax
Variable i,j,s,arg,ds,tt,dt
Make/O/n=(pointsx,pointsy,3) mobius
ds=2*pi/(pointsx-1)
dt=(tmax-tmin)/(pointsy-1)
for(i=0;i<pointsx;i+=1)
s=i*ds
for(j=0;j<pointsy;j+=1)
tt=tmin+j*dt
arg=1+cos(s/2)*tt
mobius[i][j][0]=cos(s)*arg
mobius[i][j][1]=sin(s)*arg
mobius[i][j][2]=tt*sin(s/2)
endfor
endfor
End
Igor Reference.ihf
laguerreGauss(p, m, r)
The LaguerreGauss function returns the normalized product of the associated Laguerre polynomials and a Gaussian. This function is typically encountered in solutions to physical problems where it represents the radial solution with an additional factor exp(i*m*ϕ) which is not included in this case. The laguerreGauss is given by
See Also
hermiteGauss.
About Igor Pro
Version: 6.0.4.0
IGOR Pro
© 1988-2008 WaveMetrics, Inc. All Rights Reserved
P.O. Box 2088 / Lake Oswego, Oregon 97035 / USA
(503) 620-3001 / sales or support@wavemetrics.com
www.wavemetrics.com
OK
License...
Gizmo0_1
TestWave
2
4
6
8
10
•Display TestWave
•Make/O/N=1000 TestWave
•SetScale/i x,0,10, TestWave
•TestWave = Gauss(x,5,1)+gnoise(.01)
StatsCircularTwoSample
StatsCMSSDCDF
StatsCochranTest
StatsContingencyTable
StatsCorrelation
StatsDExpCDF
StatsDExpPDF
StatsDIPTest
StatsDunnettTest
StatsErlangCDF
StatsErlangPDF
StatsErrorPDF
StatsEValueCDF
StatsEValuePDF
StatsExpCDF
StatsExpPDF
StatsFCDF
StatsFPDF
Help
StatsCorrelation(waveA [, waveB])
The StatsCorrelation function computes Pearson's correlation coefficient between two real valued arrays of data of the same length. Pearson r is give by:
Here A is the average of the elements in waveA, B is the average of the elements of waveB and the sum is over all wave elements.
Details
Ready

Igor Pro 6.1 (www.wavemetrics.com)



Error handling and propagation

- See handout (to be emailed)
- See also: http://teacher.pas.rochester.edu/PHY_LABS/AppendixB/AppendixB.html

Error (uncertainty) analysis

$$z = f(x, y)$$

$$\Delta z = \frac{\partial f(x, y)}{\partial x} \Delta x + \frac{\partial f(x, y)}{\partial y} \Delta y$$

For uncorrelated errors:

$$\Delta z = \left[\left(\frac{\partial f(x, y)}{\partial x} \Delta x \right)^2 + \left(\frac{\partial f(x, y)}{\partial y} \Delta y \right)^2 \right]^{\frac{1}{2}}$$

Error (uncertainty) analysis – example using Activity of ^{241}Am source

$$A = \frac{C}{\pi s^2 / 4\pi r^2} = \frac{C\left(4r^2\right)}{s^2}$$

Where *C* is count rate, *r* is the distance to the detector, and *s* is the radius of the detector.

$$\Delta A = \frac{\partial}{\partial C}\left(\frac{4Cr^2}{s^2}\right)\Delta C + \frac{\partial}{\partial r}\left(\frac{4Cr^2}{s^2}\right)\Delta r$$

$$\Delta A = \frac{4r^2}{s^2}\Delta C + \left(\frac{4C}{s^2}\right)\left(2r\right)\Delta r$$

In quadrature, if these errors are uncorrelated:

$$\Delta A = \left[\left(\frac{4r^2}{s^2}\Delta C\right)^2 + \left(\frac{8Cr}{s^2}\Delta r\right)^2\right]^{\frac{1}{2}}$$

Error (uncertainty) analysis – multiple value r.m.s. approach

Another approach to evaluating the uncertainty relies on a straightforward calculation of the root mean square and the standard deviation. In the case of your Activity measurements, you could compute the RMS value as well as the SD. You should still assess your uncertainty through error propagation, as the uncertainty may very well exceed the SD.

Definition of the root mean square from Wikipedia:

"…the square root of the arithmetic mean (average) of the squares of the original values…"

In the case of a set of *n* values $x_1, x_2, \ldots x_n$, the RMS value is given by:

$$x_{rms} = \sqrt{\frac{x_1^{\ 2} + x_2^{\ 2} + \cdots + x_n^{\ 2}}{n}}$$

The **standard deviation** is given as follows, where there are *N* values and μ is the arithmetic mean:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

LabVIEW Introduction

Adapted from a presentation prepared by

Imran Haider Malik of McGill University, Canada

January 16, 2006 for their Measurement Lab. MECH262-MECH261

http://www.cim.mcgill.ca/~paul/LabviewTut.pdf

Outline

- Introduction
- LabVIEW Introduction
- Data Acquisition (DAQ)
- Features of LabVIEW
- Example .vi
- LabVIEW Interface
- Lab Equipment
- Goals of this UT LabVIEW Lab
- List of Typical Measurements
- Conclusions.

LabVIEW

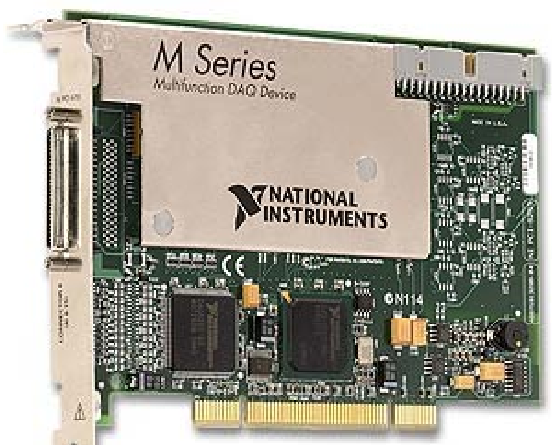
- Product of National Instruments (NI)
- Software for Virtual Instrumentation (.vi)
- Data Acquisition (DAQ)
- Graphical Programming
- Data Storage and Analysis for wide range of applications

Data Acquisition (DAQ)

Time dependent Signal Recording (Acquisition)

Components of DAQ:

- Physical value typically converted to voltage
- Signal conditioning (e.g., a filter – nowadays can be built-in with DAQ card)
- DAQ Card (can be USB)
- DAQ Software (DAQmx, LabVIEW)

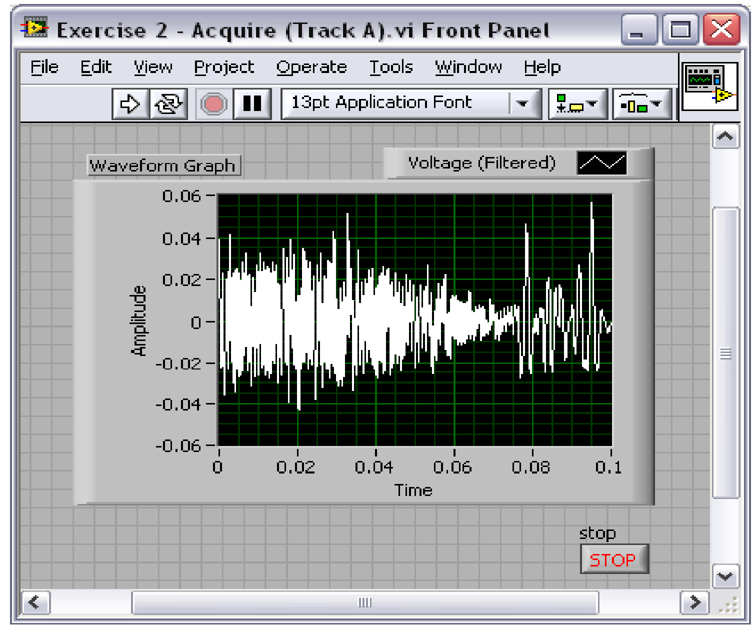


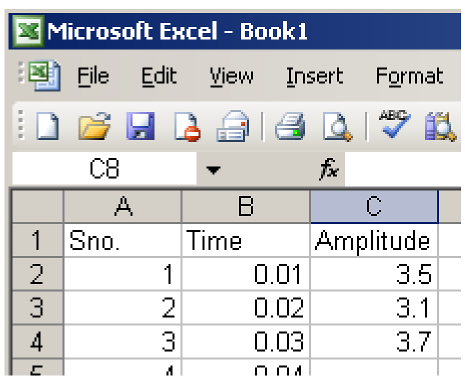
Features of LabVIEW

- **Design**
  - Signal and Image Processing
  - Embedded System Programming
    - (PC, DSP, FPGA, Microcontroller)
  - Simulation and Prototyping
  - And more…
- **Control**
  - Automatic Controls and Dynamic Systems
  - Mechatronics and Robotics
  - And more…
- **Measurements**
  - Circuits and Electronics
  - **Measurements and Instrumentation**
  - And more…

Example

Sound Signal Acquisition





This can help Design a Tuning Device for Musical Instruments.

LabVIEW Interface

Each Virtual Instrument (VI) has 2 Windows

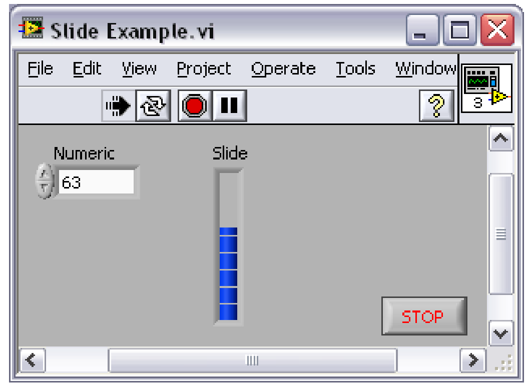
Front Panel

- User Interface (UI)
  - Controls = Inputs
  - Indicators = Outputs

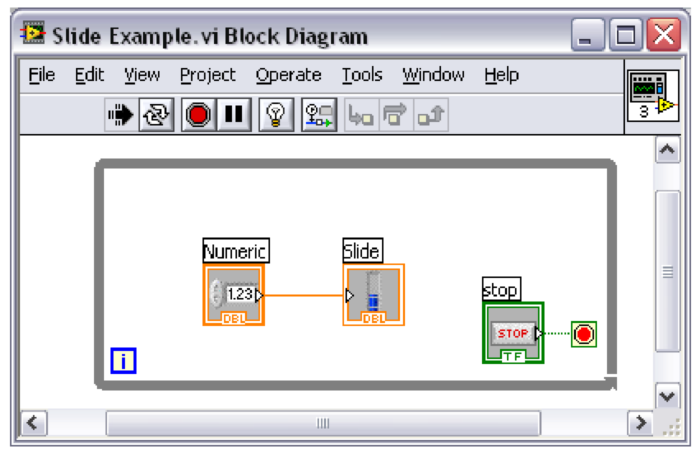
Block Diagram

- Graphical Code
  - Data travels on wires from controls through functions to indicators
  - Blocks execute by Dataflow

Front Panel



Block Diagram

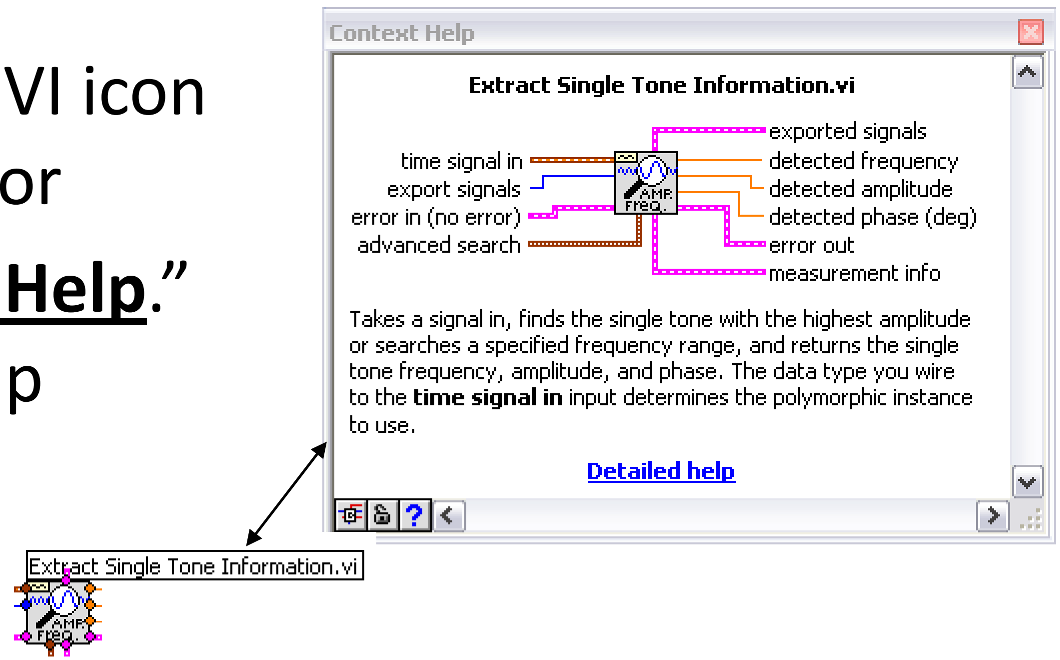


LabVIEW Interface (Contd)

- **Help»Show Context Help**, press the <Ctrl+H> keys
- Hover cursor over object to update window

Additional Help

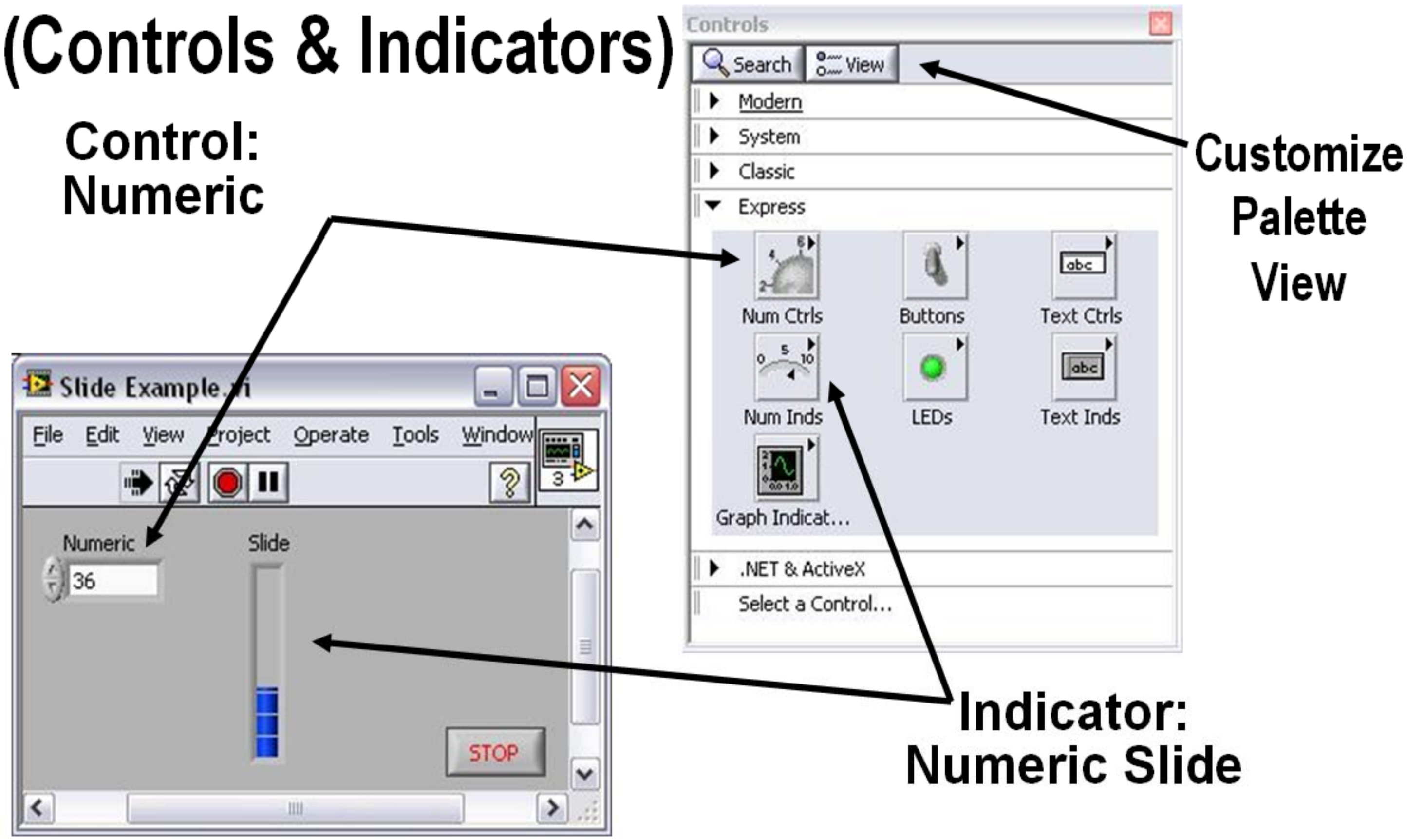
- – Right-Click on the VI icon and choose **Help**, or
- – Choose "**<u>Detailed Help</u>**." on the context help window



LabVIEW Interface (Contd)

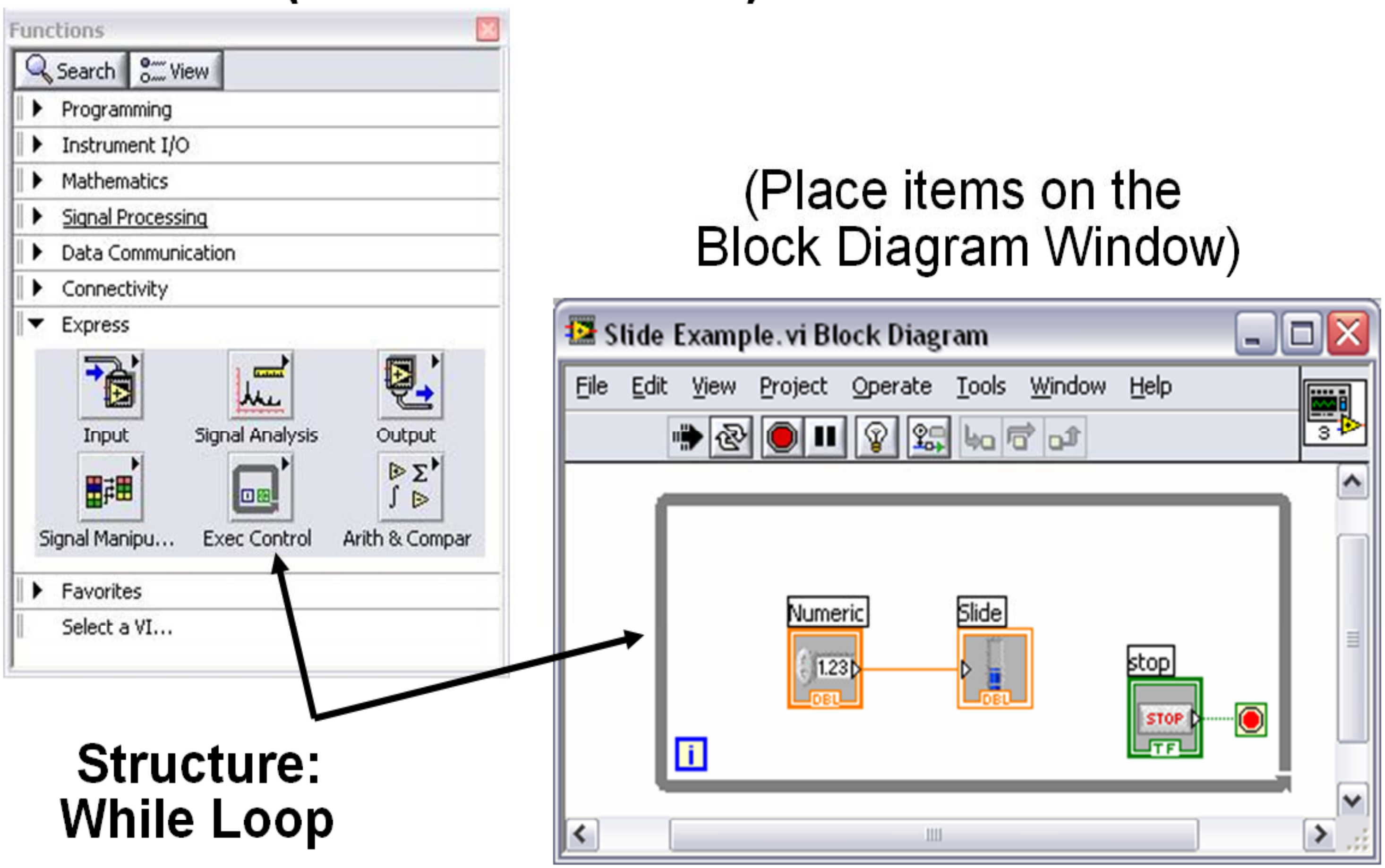
Controls Palette (Controls & Indicators)

(Place items on the Front Panel Window)



LabVIEW Interface (Contd)

Functions (and Structures) Palette



LabVIEW Interface (Contd)

Tools Palette

- Recommended: Automatic Selection Tool
- Tools to operate and modify both front panel and block diagram objects

Automatic Selection Tool

Automatically chooses among the following tools:

Operating Tool

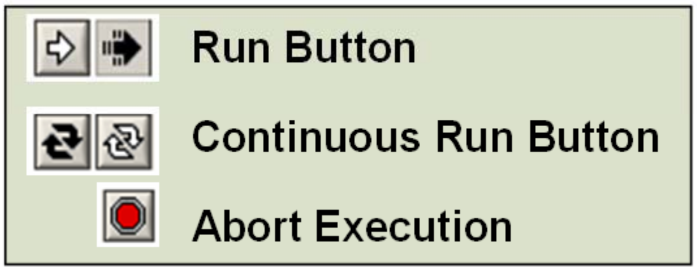
Positioning/Resizing Tool

Labeling Tool

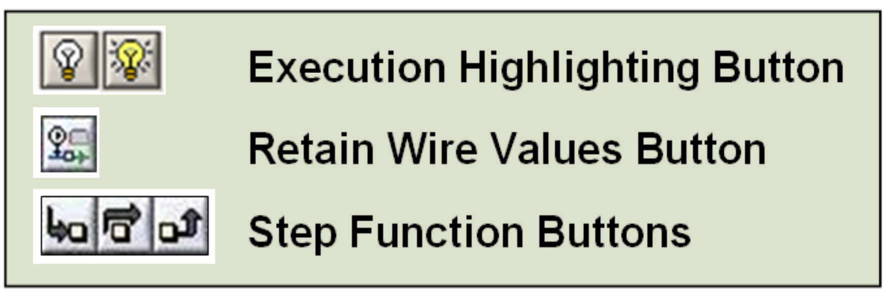
Wiring Tool

LabVIEW Interface (Contd)

Status Toolbar



Additional Buttons on the Diagram Toolbar



Lab. Equipment

- Oscilloscope

Universal Measuring Instruments

- Function Generator

Signal Generator

- Digital Voltmeter (DVM)

Goals of this week's Lab

- Introduce LabVIEW
- Experience DAQ
- Use of Electronic instruments:

  Oscilloscope, Function Generator

  Digital Volt-meter (DVM).

Measurement Examples

1. Instrumentation Overview.
2. Introduction to LabVIEW.
3. Data Sampling.
4. Time Constant.
5. Stress and Strain.
6. Transducer Sensitivity (Part 1)
7. Transducer Sensitivity (Part 2) and Linearity
8. Pressure Transducer Calibration and Jet Profile
9. Thermocouples: Calibration and Manufacturing

What you should know about LabVIEW being a physicist

- Selection of DAQ system for an application
- Communicating with instruments (drivers, GPIB, other)
- Modularity of programming approaches: making your .vi's flexible and adaptable

References

- www.ni.com
- Using the oscilloscope http://www.doctronics.co.uk/scope.htm