LabVIEW control solutions on Mac

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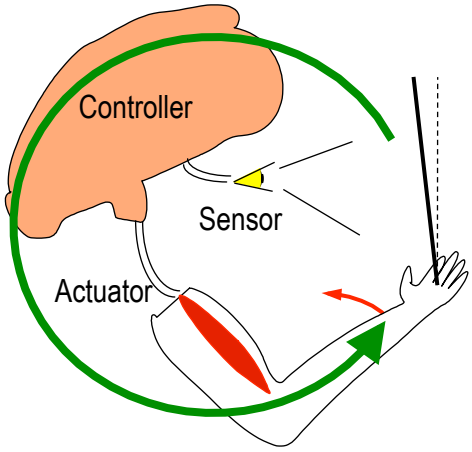
Outline

- Education & research context
- Control on the Mac (timeline)
- Current solutions
- Research example: spider crane
- Education example: inverted pendulum
- Conclusions

Context

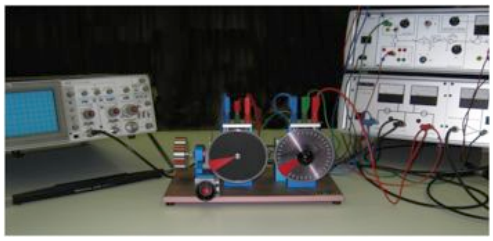
- Automatic Control Laboratory
  - Multidisciplinary lab
    - mechanical, electrical, bio, chemical
    - microtechnique, computer science, etc.
- Control theory
- Research on control and real-time information systems
- Industrial collaborations

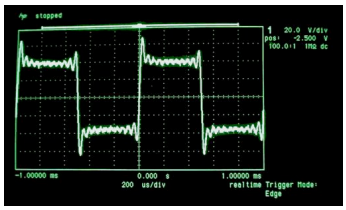
Control ?



Controller aims: to stabilise a system, to improuve the dynamic of a system

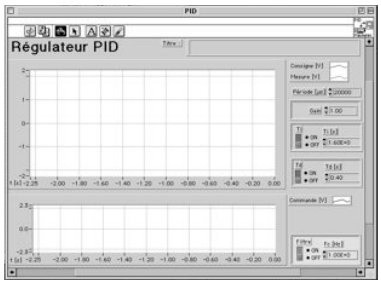
A long time ago (~1980-90)





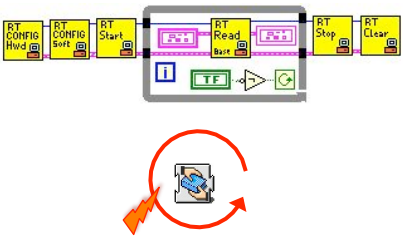
- Analog controller

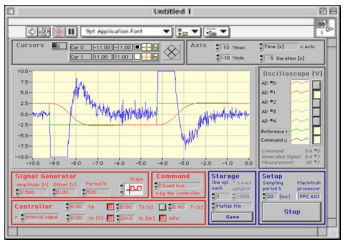
Computer based DAQ (~1990)



- DAQ board
- (no) Drivers -> Register level programming
- Visualization software -> LabVIEW ☺

Custom based RT Kernel (1992-2007)

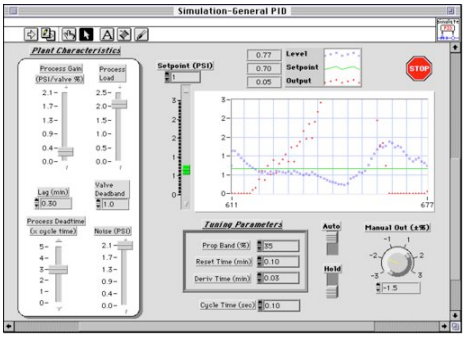




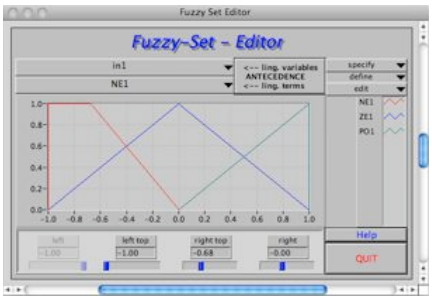
Sampling period ~0.5 ms with a PowerMac 8100 (80Mhz) using NB-MIO16x **hardware interrupt**

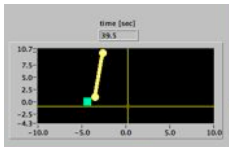
NI PID toolkit (~1994)

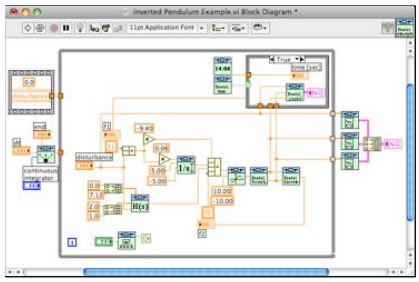
- Pure LabVIEW
- Interfaces the NB-MIO16
- Sampling period in the order of 100ms



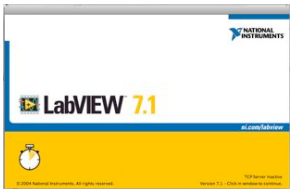
Fuzzy, G Sim toolkits (~1995)

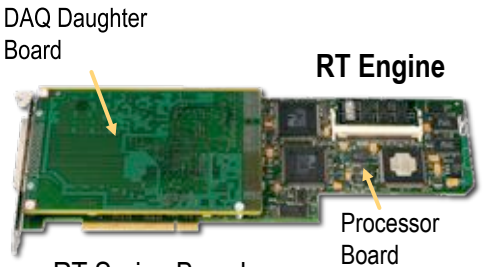






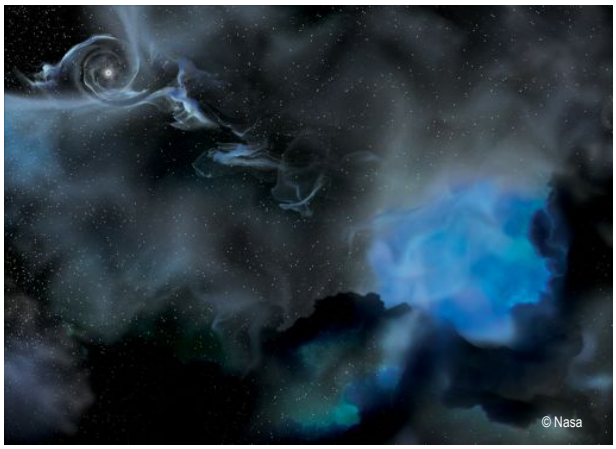
LabVIEW RT 2000 (1998)





PXI/PCI 7030-6030E
Intel 486/133 MHz
8M user DRAM

OS9 -> OSX = “DAQ transition black hole”

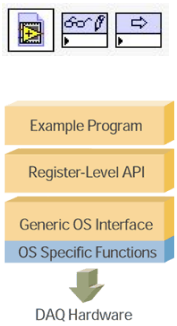


OSX DAQ solutions

- ~~Home brew DAQ/RT kernel~~
- ~~LabVIEW RT for OSX~~
- Measurement Hardware Driver Development Kit
- NI-DAQmx Base
- Emulation (PPC) / Virtualization (MacIntel)

MHDDK

- Provides register level access to DAQ boards
- DAQ acquisition using Register Level Programming is definitely not trivial!
- National Instruments provides a higher level on the top of the MHDDK, called DAQmx base

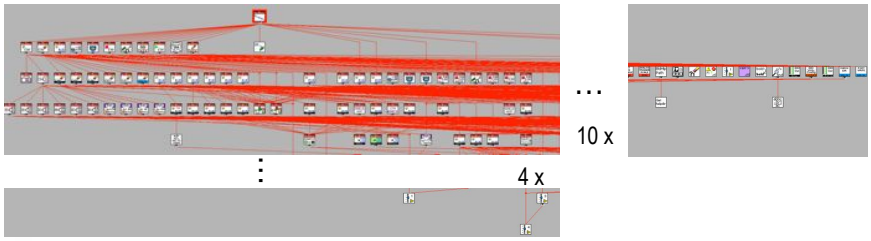


DAQmx base

- Lightweight subset of DAQmx
- Many NI hardware are supported

DAQmx base

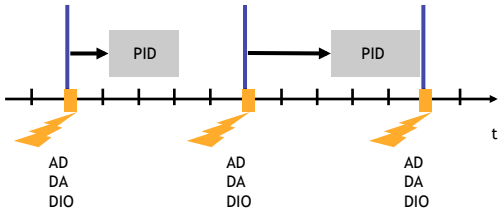
- Is mainly written in LabVIEW (expose the source code)
- Is therefore “easily” portable to other platforms/OS
- Is therefore modifiable by the user



Real-Time with DAQmx base

- Similar to DAQ occurrence
- Not hard real-time
- >5kHz for a PID controller (LV 8.5 MacPro)

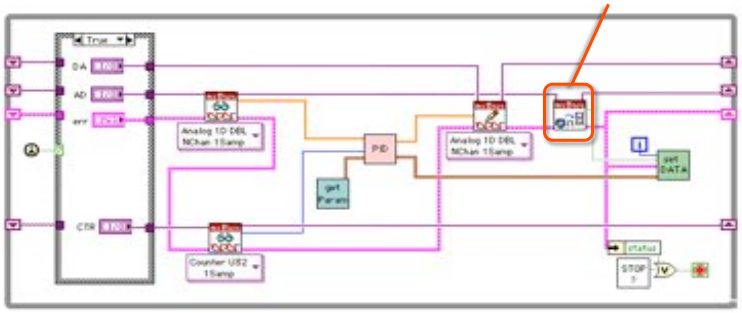
If all I/O operations are synchronized, the interrupt handling can be "floating" provided that the RT task is completed before the next interrupt ☺



Real-Time with DAQmx base

- Hardware IRQ goes from kernel space to user space via VISA

DAQmx base wait for next sampling clock.vi



Virtualization

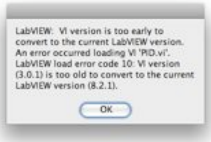
- Allows Mac and Windows environment to run at the same time
- Provides native performances (CPU)
- Main products Parallels & VMWare
  - Significantly improved over the last 2 years
  - Support some NI products (USB, Ethernet, PXI, cRIO)

- Boot Camp (built-in 10.5)
  - = Boot your macintel in Windows

Emulation

Microsoft VirtualPC (discontinued) for PPC machines

- LabVIEW run slowly on it, some usb support



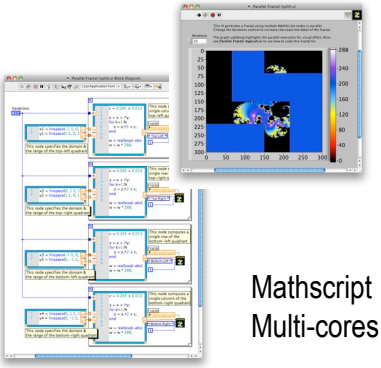
Emulation can be use to upgrade old Vis

- Mini v mac (MacPlus emulator)
  - for LV 1 and 2

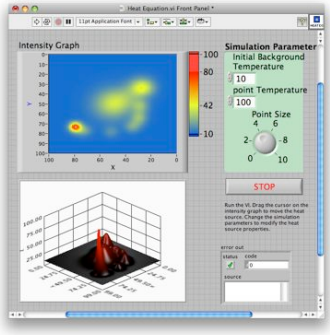
- SheepShaver (PowerMac emulator)
  - For LV 2 to 7.0

LabVIEW 8.6

New toolkits available on the Mac



Mathscript
Multi-cores



3D graph

+ Control and Simulation toolboxes

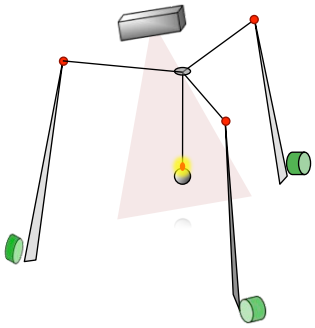
Research example: Spider crane

Specificities

- no moving parts beside cables
- flat system

Challenges

- control
- load position measurement

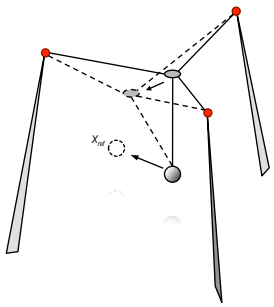


Control – flat systems

- Non-linear system
  - Un-modeled friction, etc.
- Flat system
  - Property that ensures **controllability** for non-linear systems
  - System inputs and states can be expressed in terms of the *flat* outputs and a finite number of its derivatives without integrating differential equations

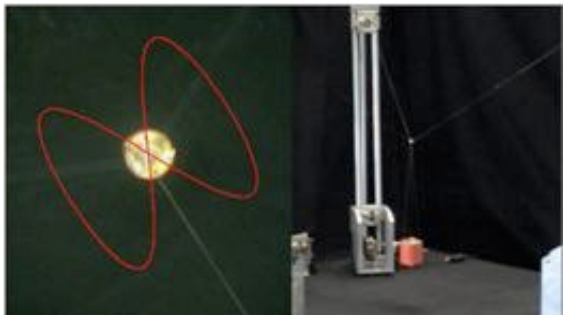
Control – jet scheduling

- measure the load position and its velocities and generate appropriate references for the three cable lengths
  - Compute load acceleration (jet) to reach desired position X_{ref}
  - Use flatness property to compute the new ring position and thus cable lengths
  - Track cable lengths with PD controllers



Spider crane – open loop* examples

Download the Spider crane movies from http://lawww.epfl.ch/page4506.html



*open loop: the load position is not measured

Measuring load position

The challenge:

- Get the load position in 3D, at 200Hz, with a millimetric resolution and no (read minimal) latency!

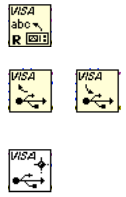
The accutrack has the need resolution and acquisition rate, but:

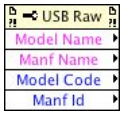
- return data via USB -> enormous latency for control
- no drivers for the Mac

LabVIEW came to the rescue!

USB drivers in LabVIEW

- "Easy", once you have vendor specifications
- OSX enforces USB norm (512kb bulk packet)
- 3 kind of USB pipes handled by LabVIEW
  - Bulk
  - Control
  - Interrupt





USB latency

USB (~ 15ms +/- 10ms)

fine for data acquisition

but for control represents ~2 sampling periods!

Solution: modify the 3D camera hardware

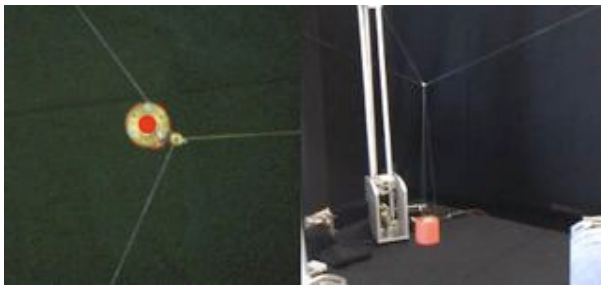
use the internal high speed serial interface

parallelize data

read parallel data using 24 x DIO inputs of a DAQ board

Spider crane – closed loop* examples

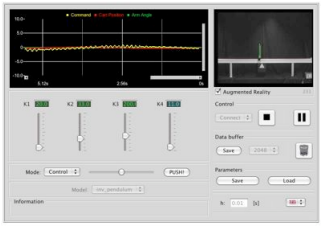
Download the Spider crane movies from http://lawww.epfl.ch/page4506.html



*open loop: the load position is not measured

Education example: Inverted pendulum

Test the remote experimentation via http://emersion.epfl.ch/



- Remotely accessible 24/7
- Server is written in LabVIEW, various client applications (LV, Java, web 2)

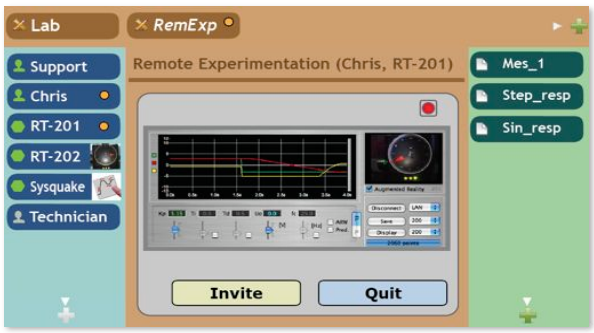
Remote Lab

3 x types of setups available 24/7

~40 x lab computers (G5/MacPro), remotely accessible

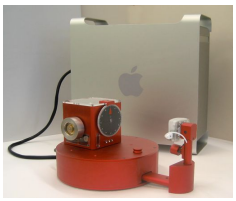
Open Collaborative Environment

Test elogbook via http://elogbook.epfl.ch/



Integration to ***open*** environments/clients/grid - Mashed-up environments

Smart devices



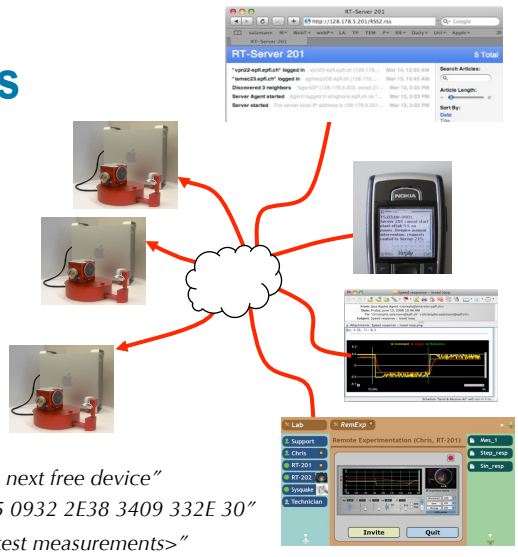
- No hardware change
- A way of implementing functionalities (paradigm shift)
- Transfer client functionalities to smart device (server)
- Can initiate information exchange (push)
- Ideally supports all formats/protocols or is ready to
- Can be seen as an agent (in collaborative environments)

Thomson's[1] definition:

A smart device has communication capabilities
A smart device has sensors and actuators
A smart device is capable of "reasoning" and "learning"
A smart device has identity and kind
A smart device has memory and status tracking

[1]Thompson, C. W. ***Smart devices and soft controllers,*** IEEE Internet Computing, 2005 vol. 9-1

Internet of Things



The internet of things is the interconnection of smart devices and other intelligent objects

"Where are my Pals ?"
"I'm busy at the moment,
I'll redirect your request to the next free device"
"3230 3435 3038 3030 3109 332E 3435 0932 2E38 3409 332E 30"
"<mailto:niweek@ni.com- status OK, latest measurements>"

Conclusion

Real-time control is possible on MacOSX 10.x
PID controller in plain LabVIEW can run at 5kHz
USB drivers can be written in plain LabVIEW
USB latency is generally too slow for mechatronic systems
LabVIEW is a very efficient tool for prototyping
LabVIEW + lab setup = smart device

Still missing

~~MathScript~~
~~3D graphs~~
~~Control and simulation~~
DAQmx
Timed loop
Shared variable
Vision
…

in LabVIEW 8.6

Links

- http://lawww.epfl.ch follow “research projects”
- christophe.salzmann@epfl.ch