Transforming Students into System Designers with myRIO

Beejal Shah
Academic Field Engineer, NI

Agenda

- Introduction
  - What is myRIO?
  - The expanding myRIO Ecosystem

- myDraughts: Common Elements of Mecatronic Systems
  - myRIO for Control
  - myRIO for Robotics
  - myRIO for Machine Vision

- Real World Examples
  - myRIO for mechatronic student projects
  - Robotic Table Football Revolutionising Mechatronics Education

- Questions and Useful Links

NATIONAL INSTRUMENTS

NI myRIO Product Overview

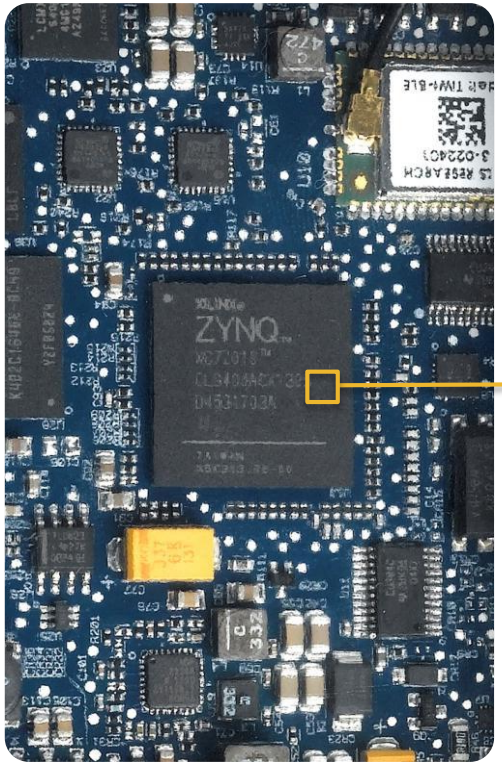
USB and Wi-Fi integration

10 Analog Input, 6 Analog Output

40 lines of digital I/O with SPI, I2C, UART, PWM,encoder, etc.

Xilinx Zync FPGA
and dual-core ARM Cortex-A9

NI myRIO Product Overview



ZYNQ™

Processor

AXI Bus

FPGA

Analogue Input

Analogue Output

Digital I/O

Custom I/O

Single System on Chip

NI Linux Real-Time

Unlock the vast Linux ecosystem

NATIONAL INSTRUMENTS

Why myRIO Matters in Education

Leading Industry Grade Technology

The same technology is used in the industry and research ready NI RIO platform

UNDERGROUND AIRBUS alliander THALES VolkerRail

FedEx Ford nationalgrid ASTON MARTIN HYUNDAI DUKE ENERGY

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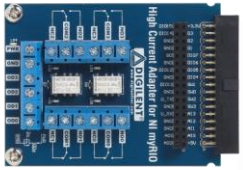
The Growing myRIO Ecosystem

myRIO Apps

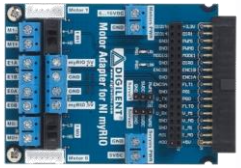
ni.com/labview-tools-network

Audio Analyzer
Lock-In Amplifier
Sprinkler Controller
Position Tracer
Programmable Switch
Oscilloscope
Function Generator
Web Messaging
Quiz Buzzer
Voice Remover
Lock-In Amplifier
Tilt Sensor
LED PWM API
Pedometer
Visual Edge Detector

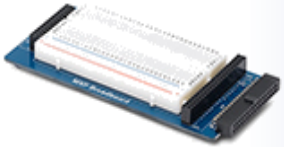
myRIO Hardware Ecosystem



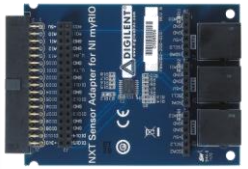
High Current



Motors



Breadboards



NXT Sensors

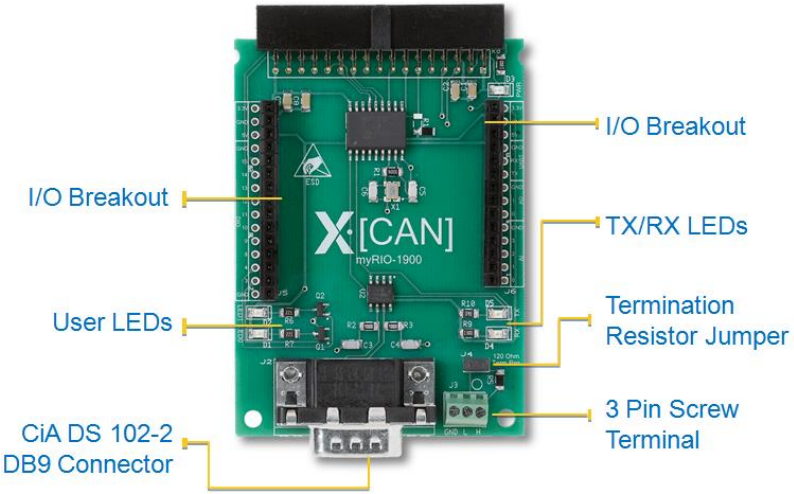
Shield Adapter

CAN

NATIONAL INSTRUMENTS

Stratom X-CAN Adapter for myRIO

Bringing Easy CAN Bus Connectivity to myRIO MXP Connector



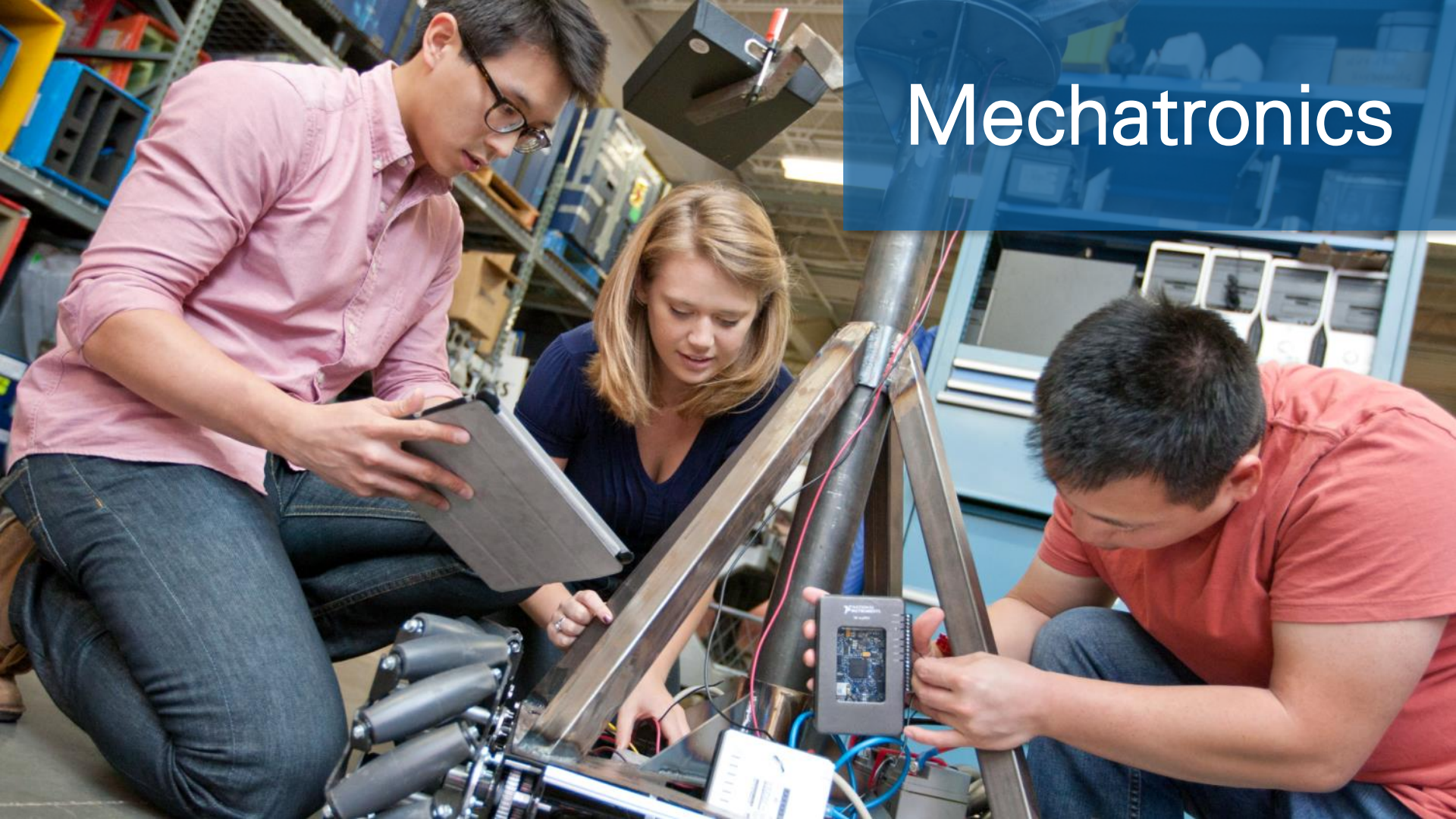
Widely adopted by European Formula Student teams, for test bench and in-vehicle systems

Stratom X-HUB

Seamlessly adds two extra USB ports and an Ethernet port to myRIO.

Example Use Cases

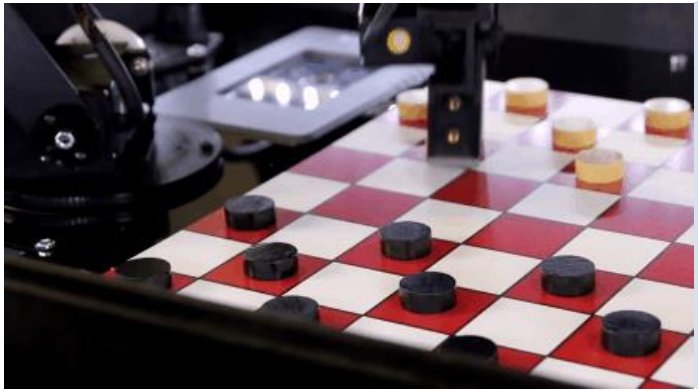
- Acquiring image data from a USB camera
- Saving information to a USB storage device
- Connecting to a network over Ethernet
- Communicating with devices over Ethernet-based communication protocols



Mechatronics

myDRAUGHTS

a robotic arm that can beat any human in a game of draughts/checkers

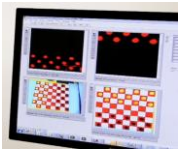


AI – Linux Community

- Draught engine found via Google
- Recompiled using Eclipse for myRIO

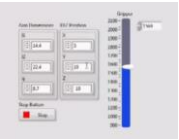
Vision – LabVIEW

- Webcam tracks the draughts pieces
- Threshold, spatial correction, binary analysis

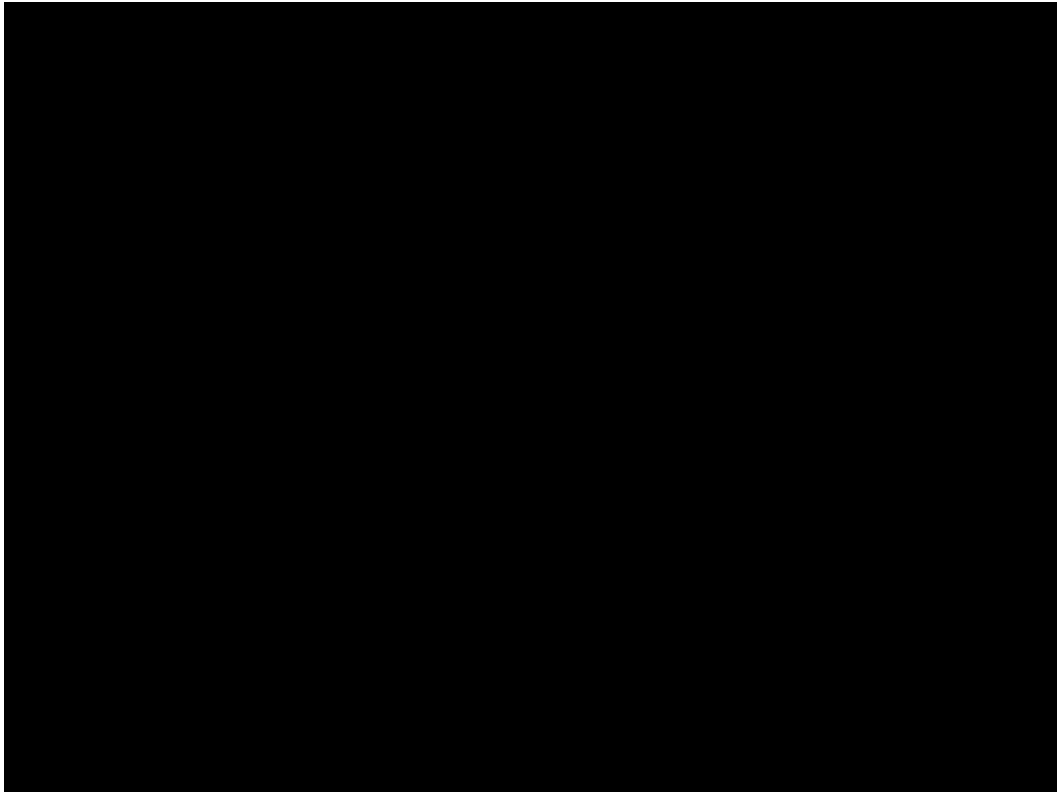


Robotics - LabVIEW

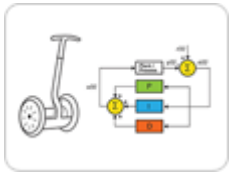
- Real time Inverse kinematics
- FPGA based motor control



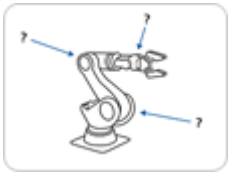
NATIONAL INSTRUMENTS



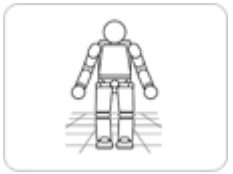
Control



Robotics



Vision



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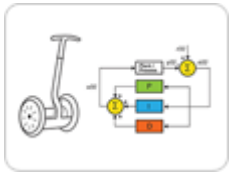
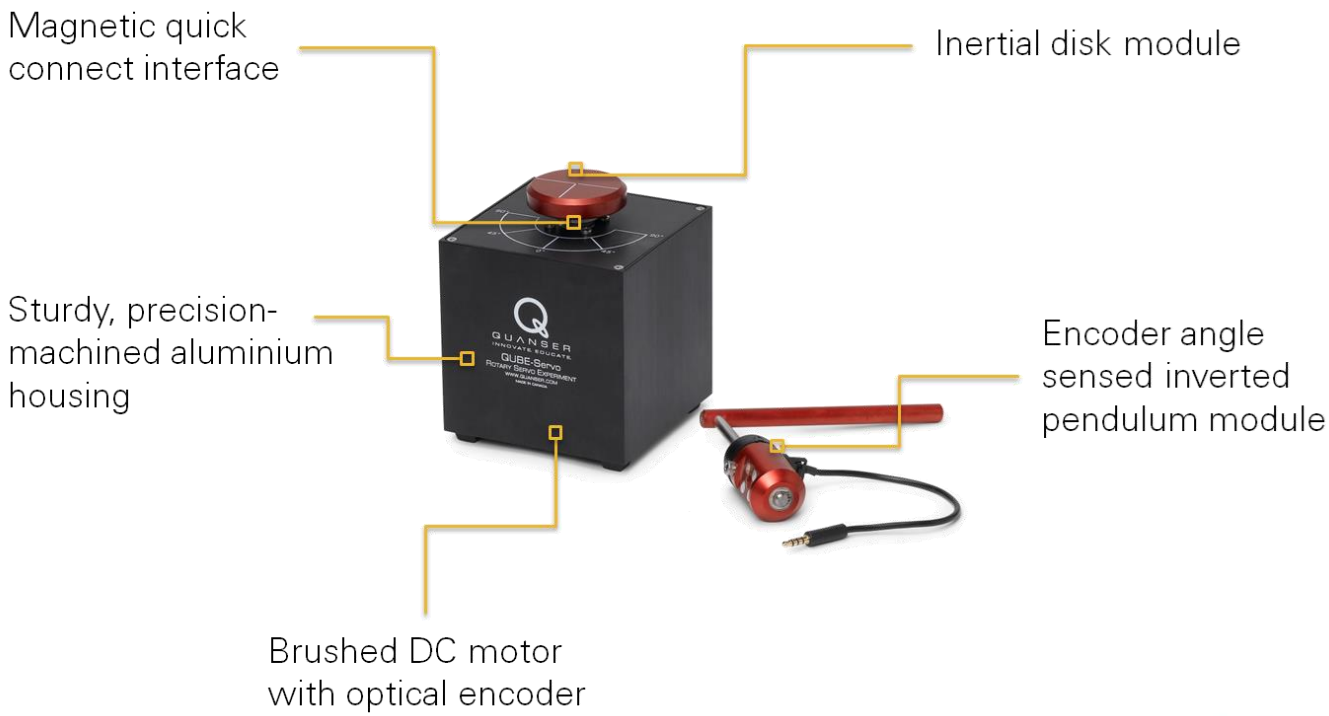


Robotics

Vision

NATIONAL INSTRUMENTS

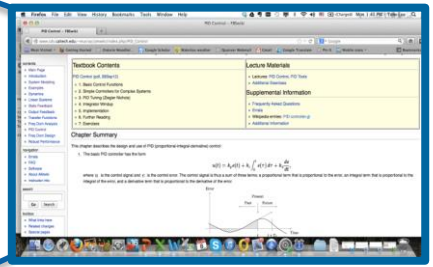
Control Quanser QUBE-Servo



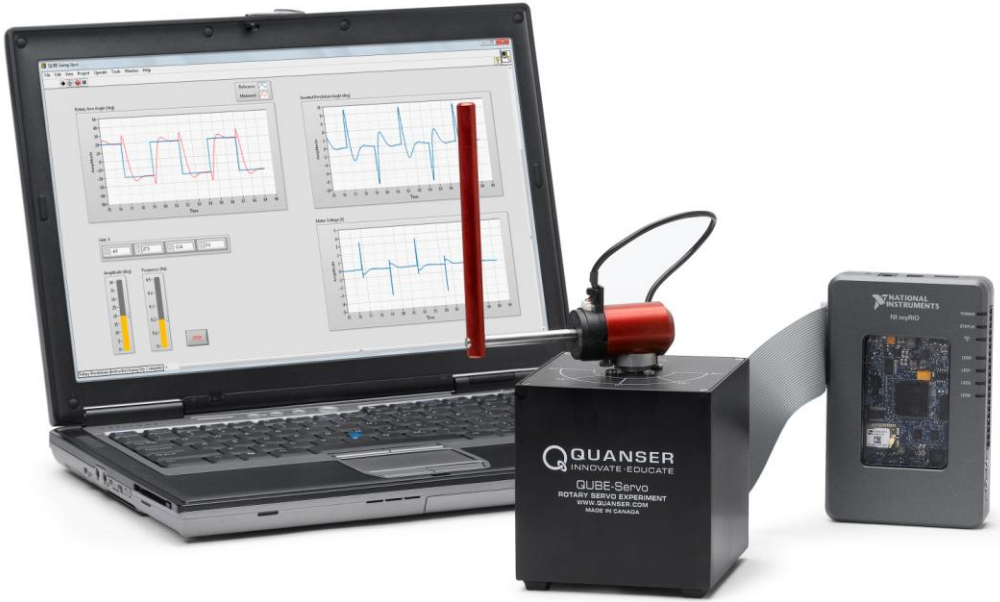
Textbook Mapping Guide

QUBE-Servo Curriculum Textbook Mapping	Norman S. Nise *Control Systems Engineering* 6th Edition Hoboken, NJ: John Wiley and Sons, Inc., 2011	Karl Johan Åström Richard M. Murray *Feedback Systems* Electronic Edition 2.11b Princeton, NJ: Princeton University Press, 2012	Gene F. Franklin J. David Powell Abbas Emami-Naeini *Feedback Control of Dynamic Systems* 6th Edition Upper Saddle River, NJ: Pearson Higher Education Inc., 2010	Richard C. Dorf Robert H. Bishop *Modern Control Systems* 12th Edition Upper Saddle River, NJ: Pearson Higher Education, 2011	Katsuhiko Ogata *Modern Control Engineering* 5th Edition Upper Saddle River, NJ: Pearson Education, 2010	Farid Golnaraghi Benjamin C. Kuo *Automatic Control Systems* 9th Edition Hoboken, NJ: John Wiley and Sons, Inc., 2010	I.J. Nagrath M. Gopal *Control Systems Engineering* 5th Edition Tunbridge Wells, UK: Anshan Ltd., and New Age International Ltd., 2008	W. Bolton *Mechatronics* 3rd Edition Essex, UK: Pearson Education Ltd., 2003
Integration Lab			p. 577 (Hardware Characteristics)			p. 195 (Incremental Encoders)	p. 146-148 (Optical Encoders)	p. 29-30 (Encoders) p. 110-112 (DAQs and LabVIEW) p. 254-261 (MATLAB/Simulink)
Filtering Lab		308 iltering the Derivative)	p. 371 (Design Considerations)	p. 246-247 (Measurement Noise Attenuation)		p. 411 (Frequency Response of Closed-Loop Systems) p. 497 (Summary of Effects of PD Control)		p. 66-67 (Filtering)
Bump Test Lab	p. 166-168 (First-Order Transfer Functions via Testing)	47-48 odeling from periments)			p. 161-162 (Unit-Step Response of First-Order Systems)	p. 63-64 (First-Order Prototype System)	p. 197-198 (Time Response of First-Order Systems)	p. 224-230 (First-Order Systems)
First Principles Modeling Lab	p. 79-84 (Electromechanical System Transfer Functions)	28-31 odeling Concepts)	p. 47-49 (Modeling a DC Motor)	p. 70-74 (Transfer Function of the DC motor)	p. 95-97 (A-3-9) (Mathematical Modeling of Mechanical Systems and Electrical Systems)	p. 198-205 (DC Motors in Control Systems)	p. 135-137 (DC Servomotors)	p. 214-217 (Electromechanical Systems – DC Motor)
Second Order Systems Lab	p. 173-186 (The General Second-Order System)	183-185 econd-Order Systems) 233-236 amped Oscillator)	p. 111-113 (Effect of Pole Locations)	p. 308-314 (Performance of Second-Order Systems)	p. 164-179 (Second-Order Systems)	p. 275-289 (Transient Response of a Prototype Second-Order System)	p. 199-210 (Time Response of Second-Order Systems)	p. 267-268 (Second-Order Systems) p. 230-239 (Frequency Response for a Second-Order System)
PD Control Lab	p. 470-477 (Ideal Derivative Compensation) p. 500-503 (Minor-Loop Feedback Compensation)	293-298 D Control)	p. 186-191 (The Three-Term Controller: PID Control) p. 184-185 (System Type for a DC Motor Position Control)	p. 480-488 (PID Controllers)	p. 567-569 (PID Control) p. 590-591 (PI-D Control)	p. 289-293 (Speed and Position Control of a DC Motor) p. 492 (Design with the PD Controller) p. 314-316 (Basic Control Systems Utilizing Addition of Pole and Zeros)	p. 216-219 (Derivative Error Compensation) p. 477-483 (Tuning of PID Controllers)	p. 289-296 erivative Control) p. 297-299 (Control System Performance) p. 301-302 (Velocity Control)
Stability Analysis Lab	p. 303-305 (Stability)	102-107 (Stability)	p. 108 (Effect of Pole Locations) p. 130-133 (Stability)	p. 387-390 (The Concept of Stability)	p. 182 (Stability Analysis in the Complex Plane)	p. 73 Bounded-Input, Bounded-Output (BIBO) Stability) p. 74 (Relationship Between Characteristic Equation Roots and Stability)	p. 270-275 (The Concept of Stability)	p. 278-279 (Stability)
Pendulum Modeling Lab	p. 142 (Simple Pendulum)	36 art-Pendulum System)	p. 32 (Pendulum) P.37 (Inverted Pendulum)		p. 69 (Inverted Pendulum System)	p. 227 (Inverted Pendulum on Cart)	p. 42-43 (Dynamics of Robot Mechanisms)	

Åström and Murray Wikibook
Feedback Systems

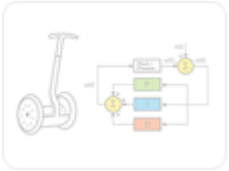


Demonstration

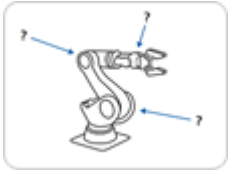


NATIONAL INSTRUMENTS

Control

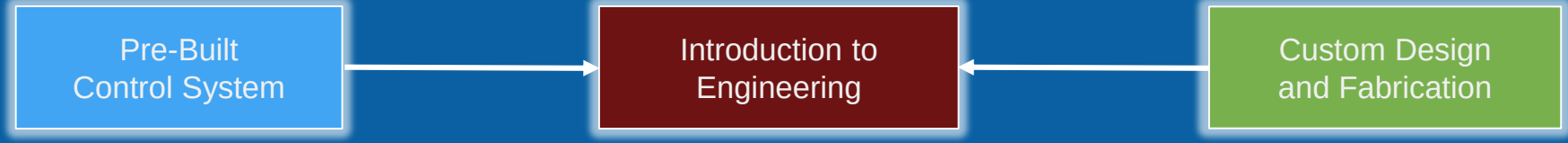


Robotics

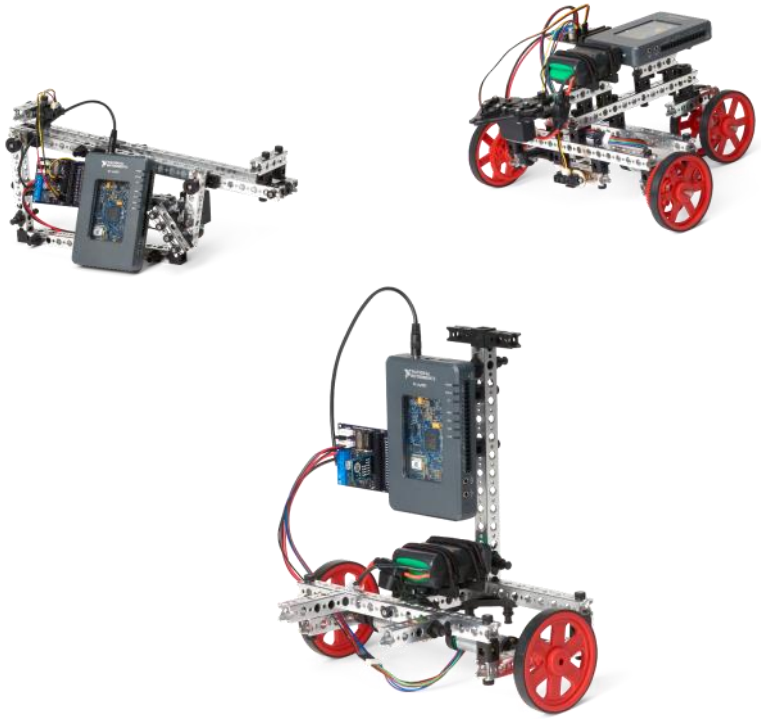


Vision

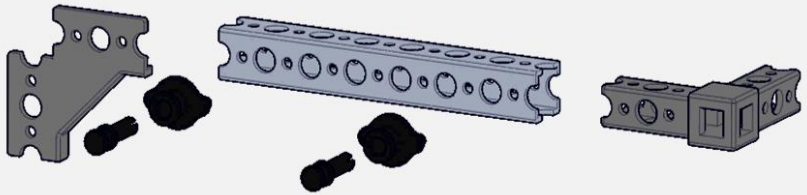
NATIONAL INSTRUMENTS


Pre-Built
Control System
Introduction to
Engineering
Custom Design
and Fabrication

NATIONAL INSTRUMENTS



Pitsco Tetrix Prime for myRIO

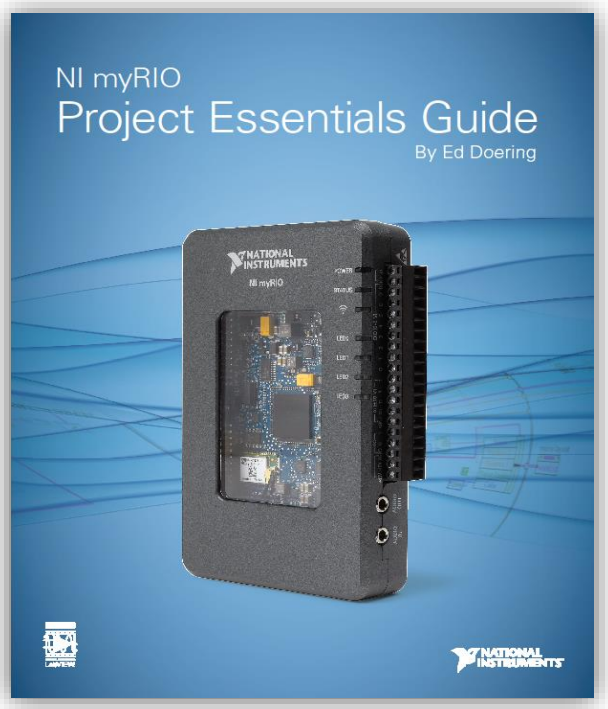


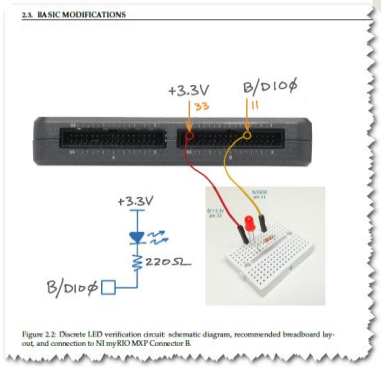
Simple Snap Design

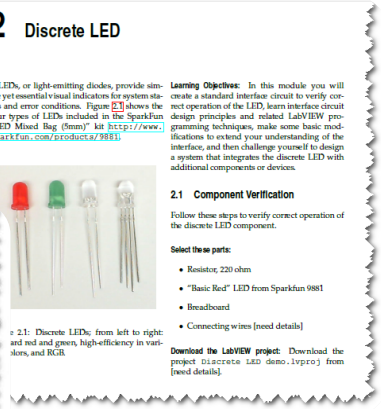
tetrixrobotics.com

NATIONAL INSTRUMENTS

myRIO Courseware



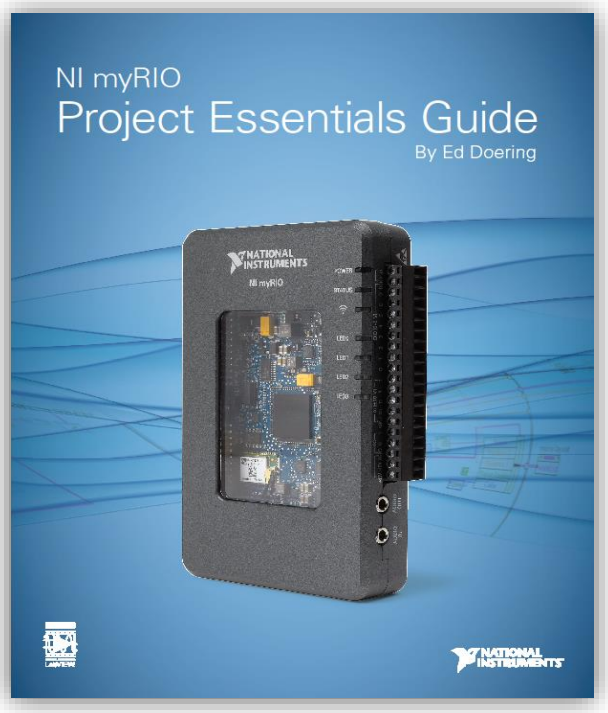




- Multimedia learning resource (text, diagrams, code, videos)
- Explains wiring, I/O requirements, device theory, and programming details

NATIONAL INSTRUMENTS

myRIO Courseware



Starter Projects

2. Discrete LED
3. Seven-Segment LED Display
4. Pushbutton Switch
5. DIP Switches
6. Relay
7. Potentiometer
8. Thermistor
9. Photocell
10. Electret Microphone
11. Buzzer/Speaker
12. Motor
13. Rotary Encoder
14. Photointerrupter
15. Hall-Effect Sensor
16. Piezoelectric-Effect Sensor

Mechatronic

17. Servo
18. 18 H-Bridge and Geared Motor
19. IR Range Finder
20. Sonic Range Finder
21. Accelerometer
22. Gyroscope
23. Compass
24. Ambient Light Sensor

Embedded

25. Keypad
26. LCD Character Display – UART Interface
27. LCD Character Display – SPI Interface
28. LCD Character Display – I2C-bus Interface
29. LED Matrix
30. Serial EEPROM
31. Bluetooth Module
32. Digital Potentiometer
33. Temperature Sensor
34. MEMS Microphone

Advanced Integrated Projects

39. HandheldMeter
40. Wireless Sensor
41. Data Logger
42. NTP Clock
43. Steer ByWire
44. Digital Thermometer
45. 3-D Color Controller
46. QR Code Scanner
47. RPN Calculator
48. Hotel RoomSafe Controller
49. Tachometer
50. Scanning Sensor
51. On-Off Control System
52. Security Camera
53. Compass with Tilt Correction
54. Guitar Tuner
55. MusicMaker
56. Digital Bubble Level
57. Weather Station
58. EEPROMProgrammer

NATIONAL INSTRUMENTS

myRIO Accessory Kits

Starter

LEDs & switches
7-segment display
Potentiometer
Thermistor
Photo resistor
Hall effect
Microphone/Speaker
DC motor

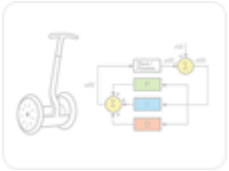
Mechatronics

DC gear motors/encoders
H-bridge driver
Accelerometer
Triple-axis gyro
Infrared proximity sensor
Ambient light sensor
Ultrasonic range finder
Compass
Hobby servo motors

Embedded

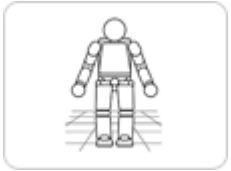
Numeric keypad
LED matrix
Digital potentiometer
Character LCD
Digital temp sensor
Bluetooth

Control



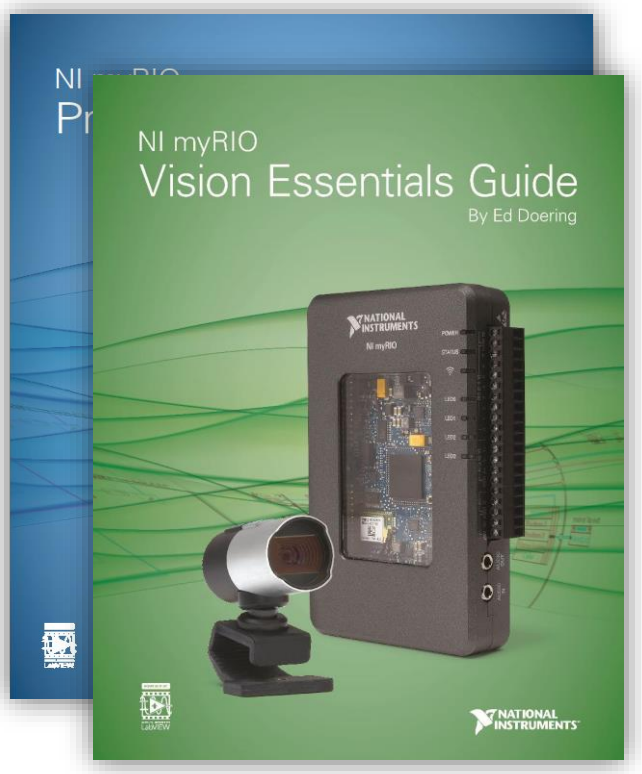
Robotics

Vision



NATIONAL INSTRUMENTS

myRIO Courseware



Vision Essentials Guide

Brings the exciting world of machine vision to myRIO projects

- Implement common vision algorithms
- Real world application context with systems approach
- Demonstrate value of myRIO seamless vision integration

Multimedia Resource with 115 Instructional Videos

NATIONAL INSTRUMENTS

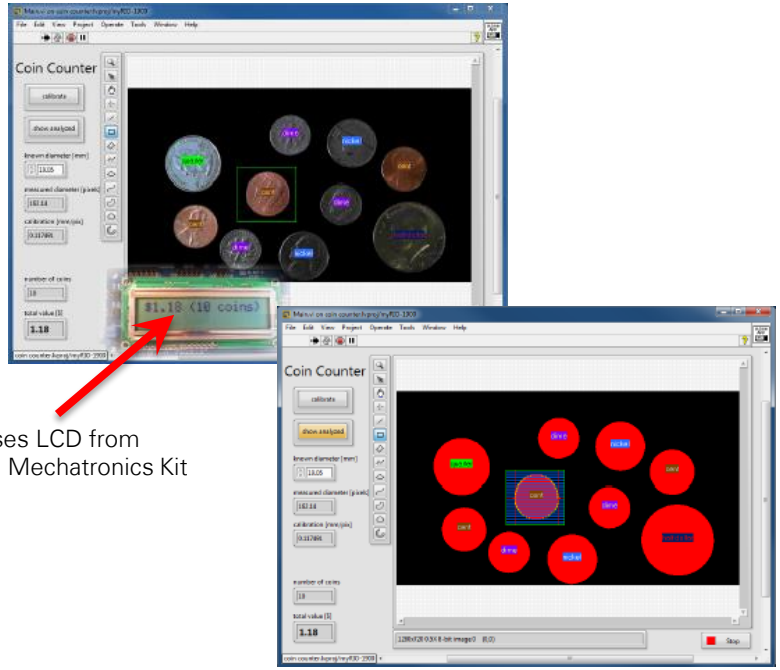
Vision Essentials Guide: Courseware Introduction

- Machine Vision Fundamentals
  - Introducing the Common Project Development Flow
  - Design Pattern for Machine Vision Applications
- Introductory Projects
  - Camera Setup
  - Coin Caliper I
  - Coin Caliper II
- Machine Vision Application Projects…

Vision Essentials Guide: Project Topics

Coin Counter

Point of Sale Terminal
Keyed Optical Lock
DMM Test Stand
Gauging Station
Product Label Inspector
Component Placement Inspector
Motion Detector
Auto-pan Camera
Marble Sorter



Uses LCD from
myRIO Mechatronics Kit

Vision Essentials Guide: Project Topics

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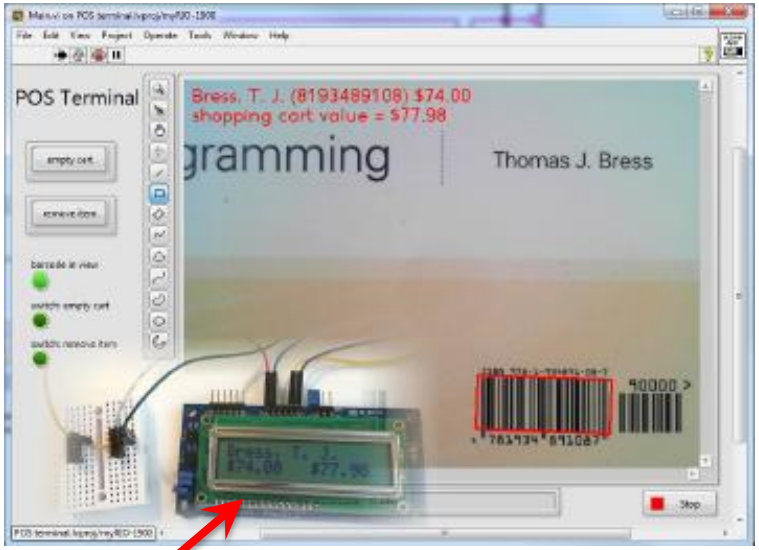

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NATIONAL INSTRUMENTS

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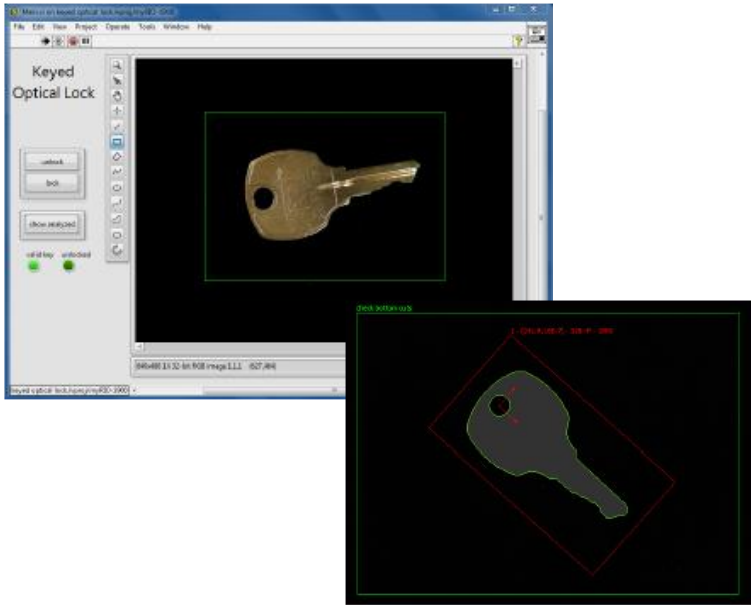

Vision Essentials Guide: Project Topics

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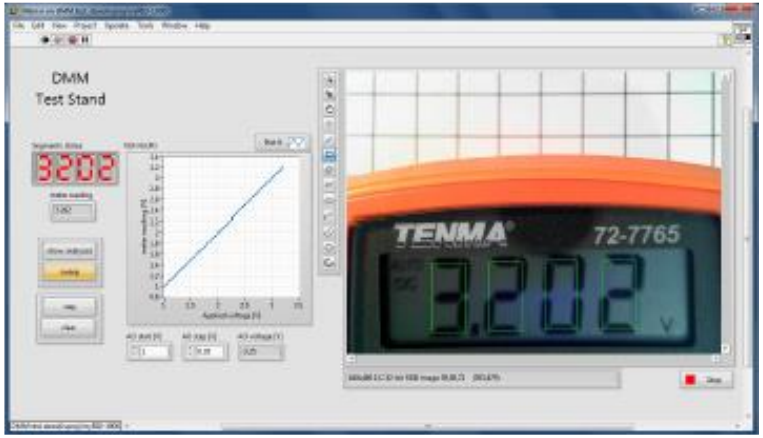

Vision Essentials Guide: Project Topics

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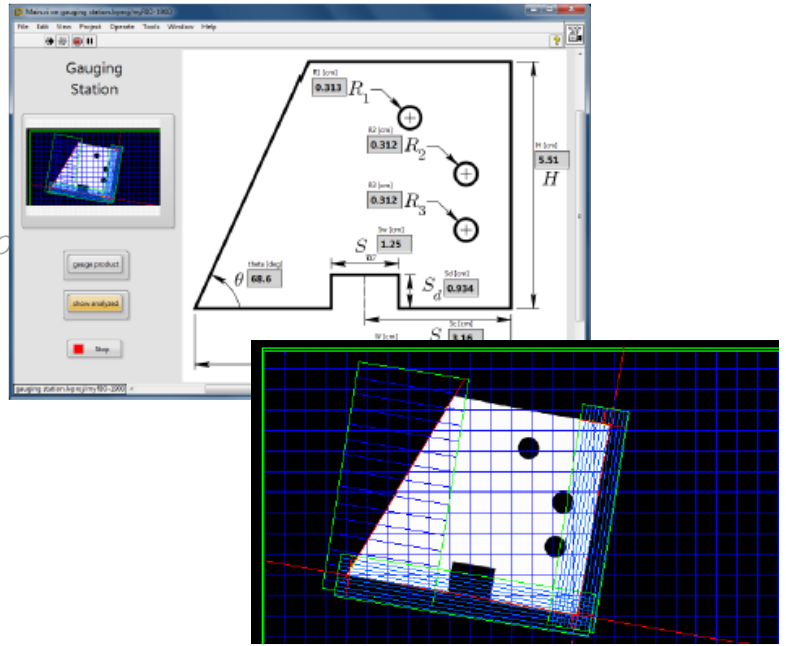

Vision Essentials Guide: Project Topics

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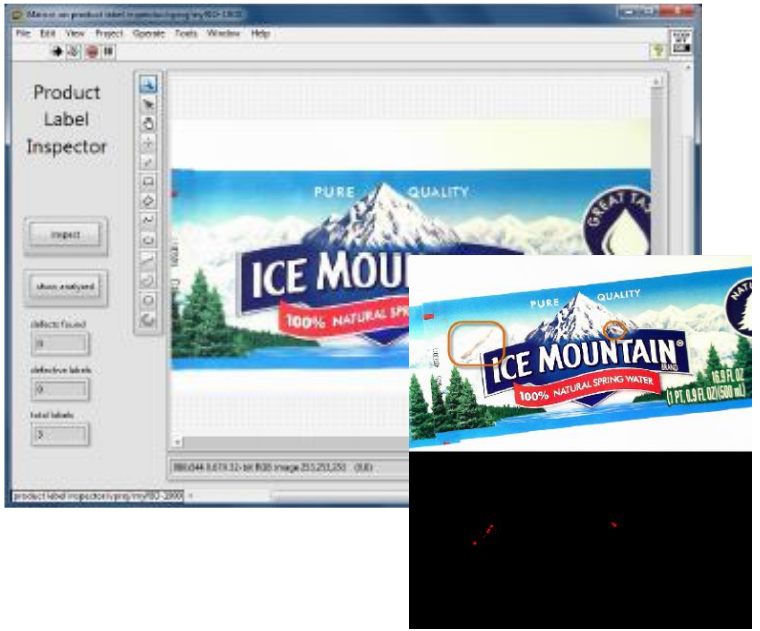
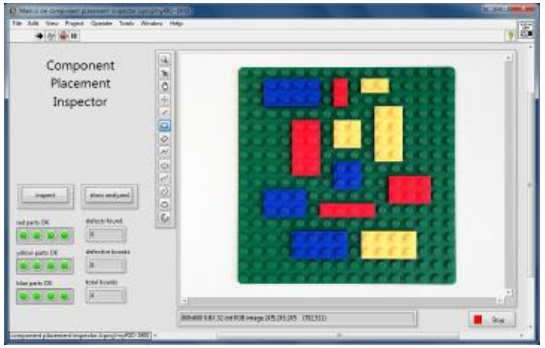
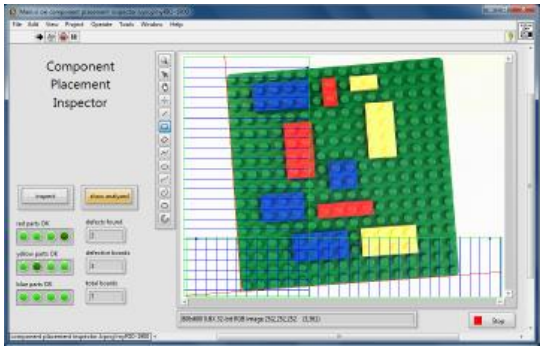


Vision Essentials Guide: Project Topics

Coin Counter
Point of Sale Terminal
Keyed Optical Lock
DMM Test Stand
Gauging Station
Product Label Inspector
Component Placement Inspector
Motion Detector
Auto-pan Camera
Marble Sorter





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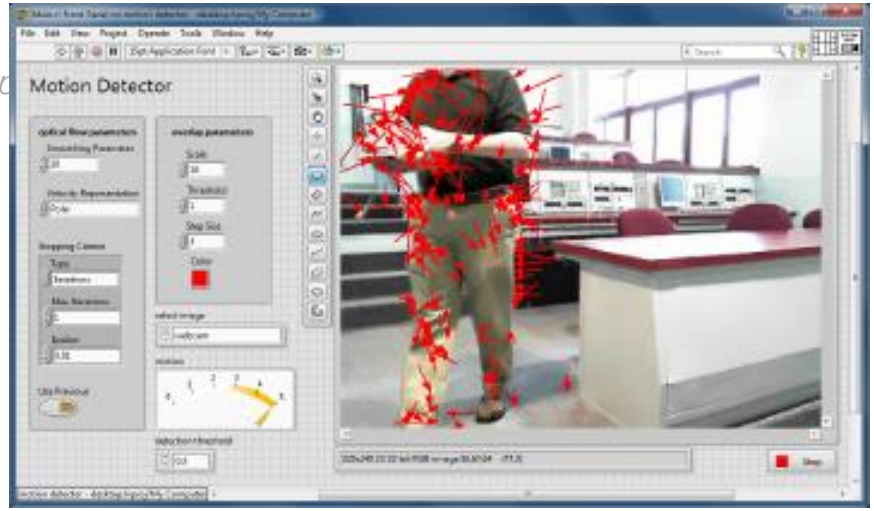
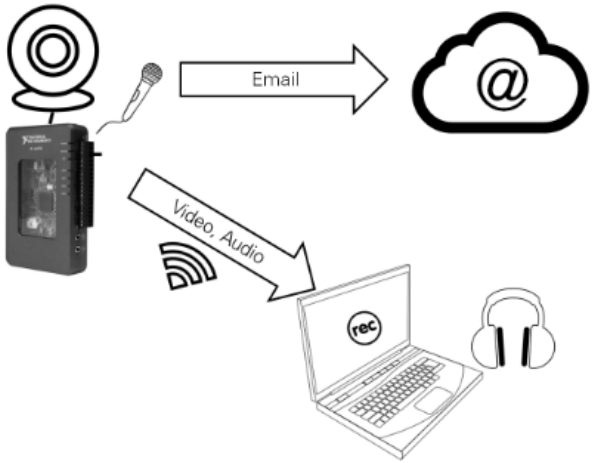
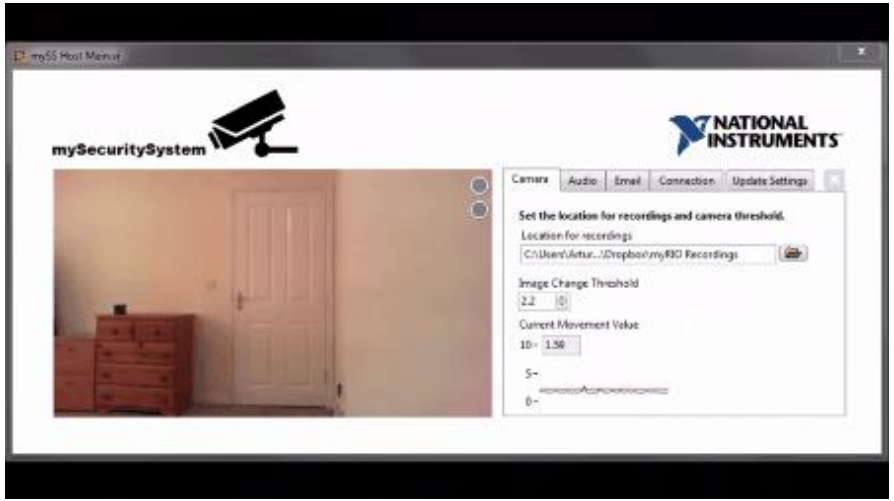


mySecuritySystem
Wireless Surveillance System

UNIVERSITY OF LEEDS





Replication Instructions
decibel.ni.com/content/docs/DOC-41252

NATIONAL INSTRUMENTS

Vision Essentials Guide: Project Topics

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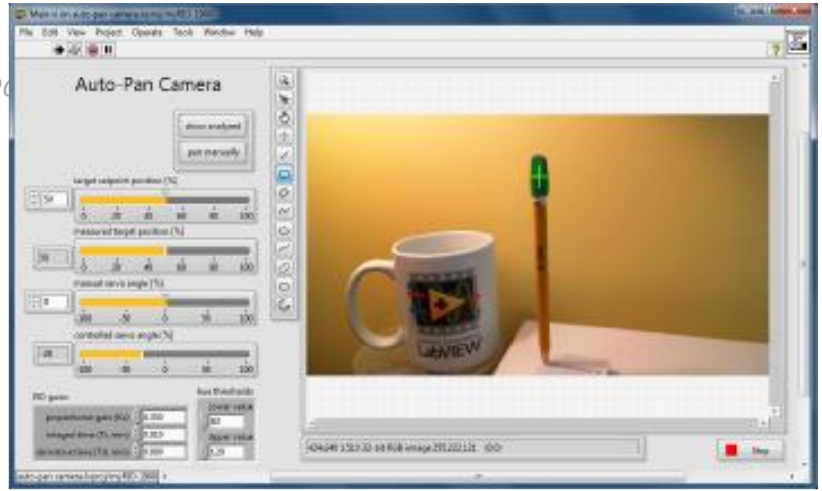
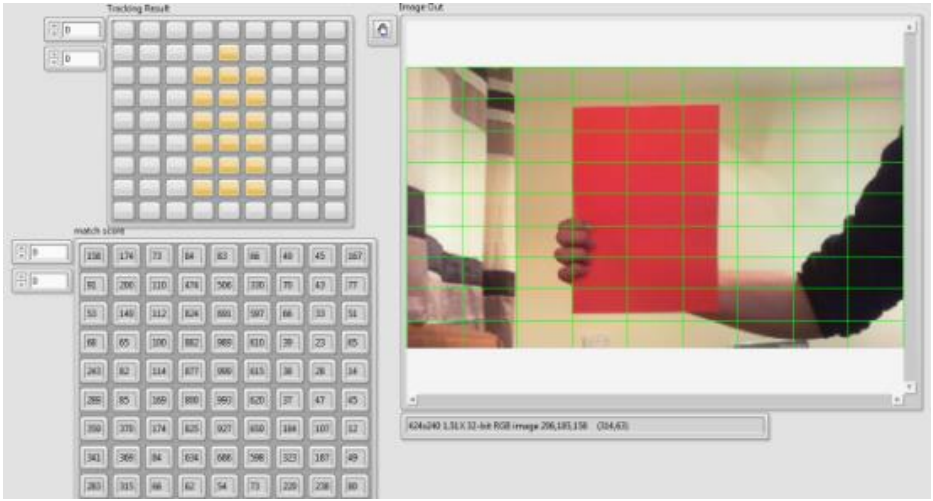
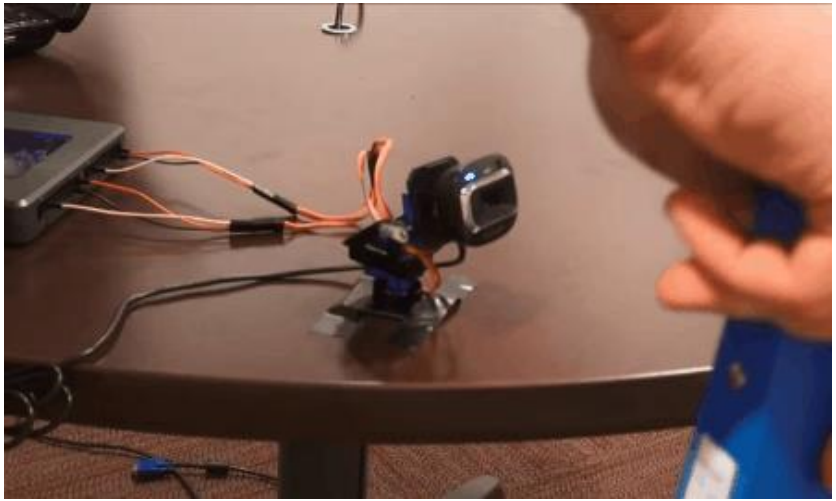


myTracker

autonomous colour tracking pan and tilt webcam

The University Of Sheffield.





Replication Instructions

decibel.ni.com/content/docs/DOC-41306

NATIONAL INSTRUMENTS

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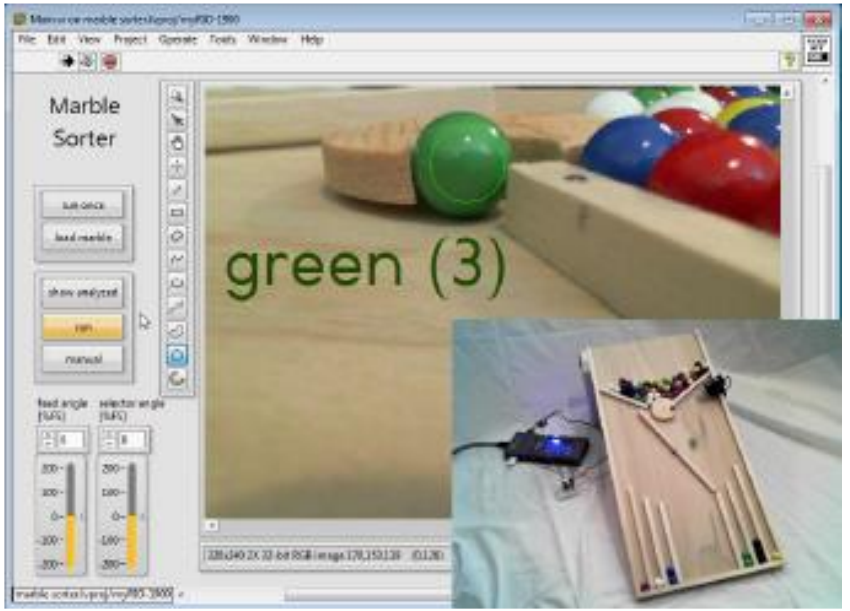
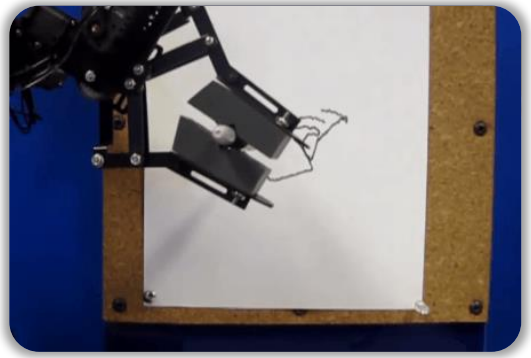


myRIO Student Projects: Control + Vision + Robotics



Robo-Caricaturist

Simplifies and physically draws what it sees

RICE

myExplorer

Remotely operated from anywhere on the network

The University Of Sheffield.

Sepios

Omnidirectional Biomimetic Robot Cuttlefish

ETH Zürich

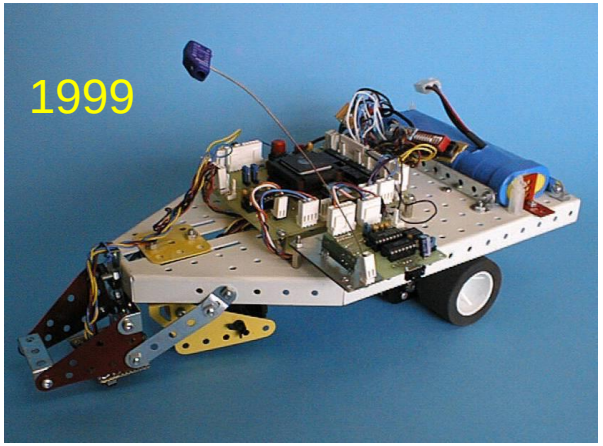
Robotic Table Football: Revolutionising Mechatronics Education using myRIO and LabVIEW

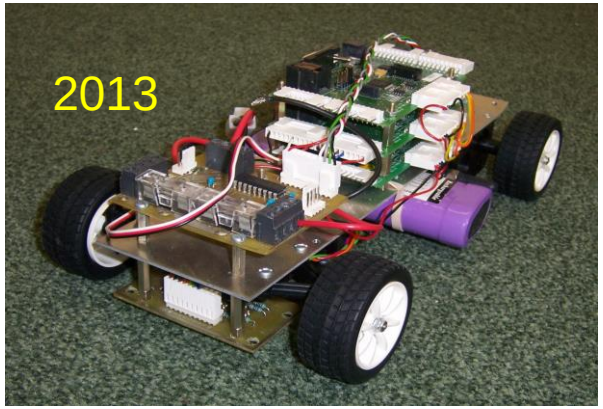
Module 14MMD901 Mechatronics

Tony Sutton

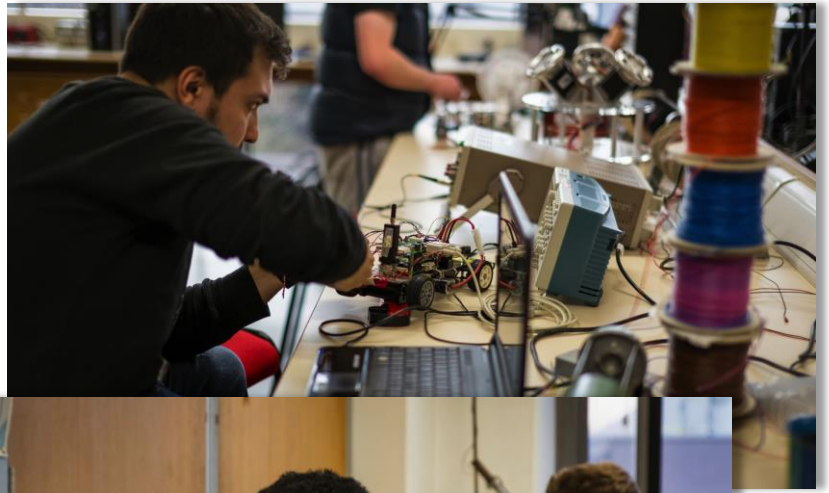
Motivation

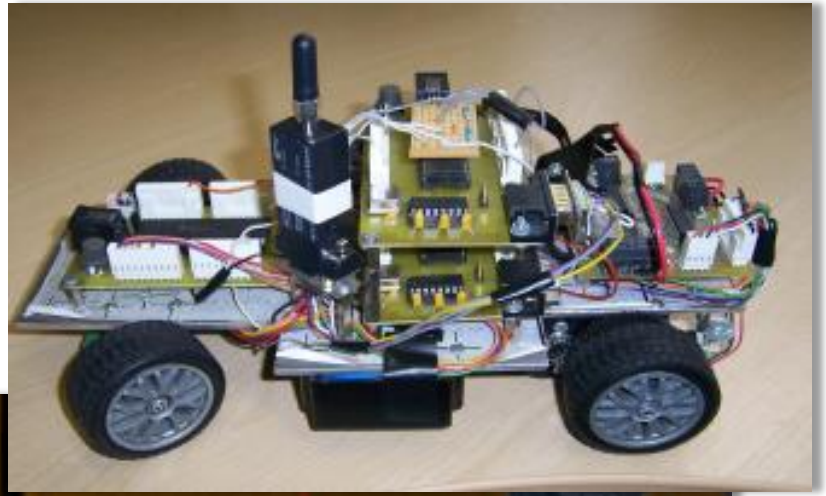
- Modern Mechanical Engineering students need a broad understanding of various other engineering disciplines
- Loughborough University has taught final year MEng mechatronics for 15+ years
- Typically an embedded control problem…..
- Various languages and processors used over the years
- Microchip PIC 16xxx, 17xxx, 18xxx PIC32
- Assembler, Visual Basic, Ansi C, C++…....





Previous challenge





Time for a change……..

- Needed new inspiration and challenges for students with an opportunity to increase complexity and sophistication of solutions + a design element
- 18 months begging and borrowing, (no stealing) £45k…
- Off-the shelf industrial components, C++, high-end 32-bit processors...
- Two months into design, myRIO released! Ordered 20 immediately!! (+ 20 NI myRIO Starter Accessory Kits)
- Exciting design/teaching possibilites……..
- **Introduce the first Wolfson School LabView module**

The Scenario and Assessment Points

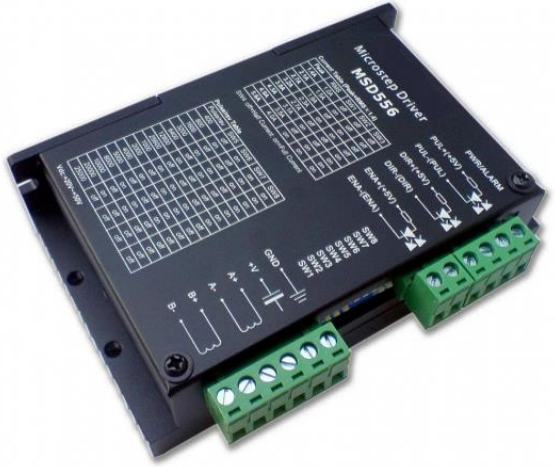
- "Competitive Tender" scenario
- 8 teams of 3 contracted to tender for development of control and design of a kicker for a "Table Football Rig"
- 'CAMs' – Vision, Kicker, Manipulator
- Camera, pitch, X-Y-Theta provided
- Design & manufacture a 'kicker'
- Score 5 'goals' in 5 minutes – no contact with rear of goal
- Adaptive shots, Dribble shots…
- All about "**Customer Confidence**"

Assessment points

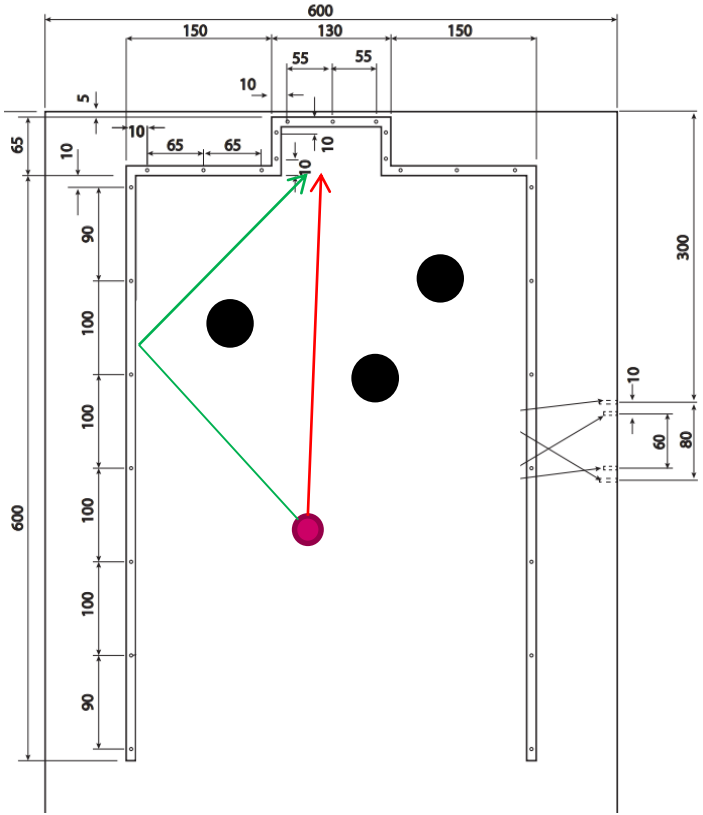
- **PDR** Preliminary Design Review
- **CDR** Critical Design Review
- **TRR** Test Readiness Review
- **CA** Customer Acceptance
- **Report**
- **55% team marks, 45%**

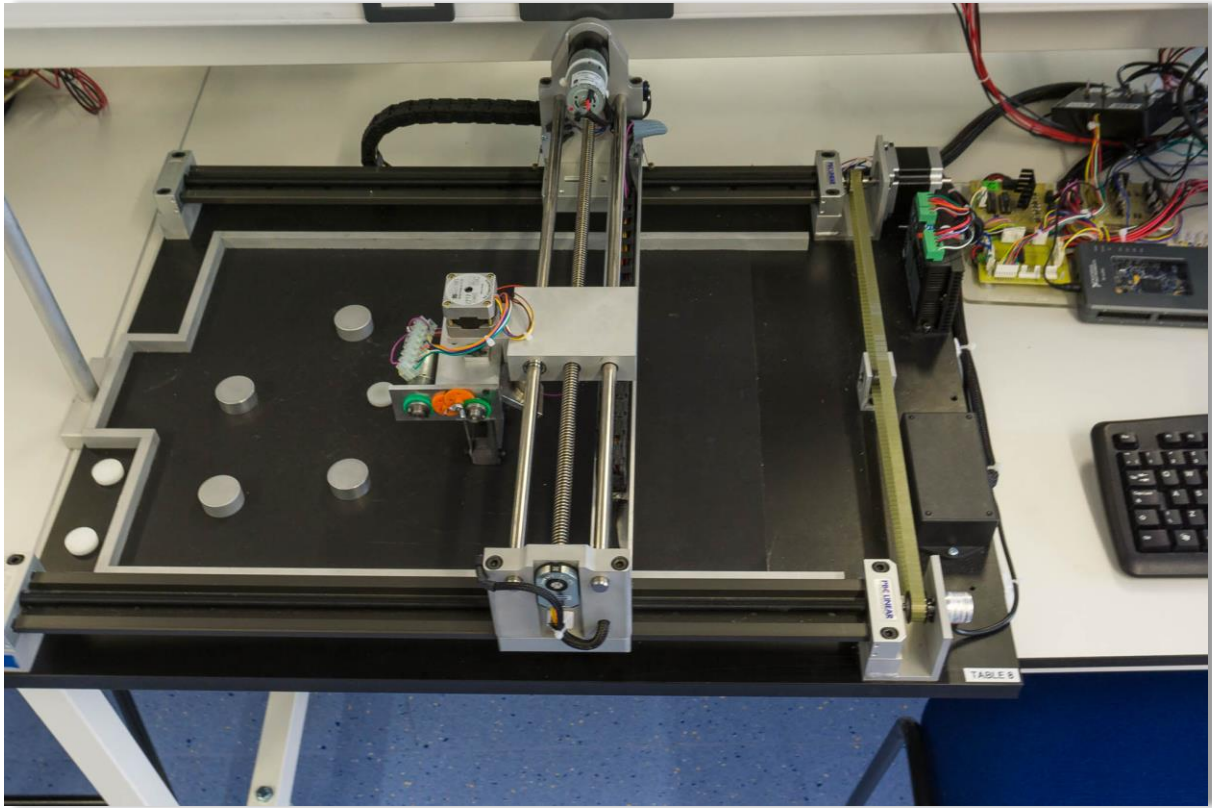
Components

- Previous module iterations were built entirely in house (no money!)
- The new module needed to reflect real industrial practice



Robotic Table Football





A new approach to software development

- Release of myRIO allowed adoption of LabView – strongly desired from the outset, but originally not possible within the budget
- Why LabView? Sophisticated solutions in short time-frame, complex VIs available – e.g. previously students would hard-code Sobel edge detector, now they just wire one in…....
- NI myRIO Starter Accessory Kit
- NI myRIO Vision Essentials guide
- NI Vision Builder

Support, training, and timing

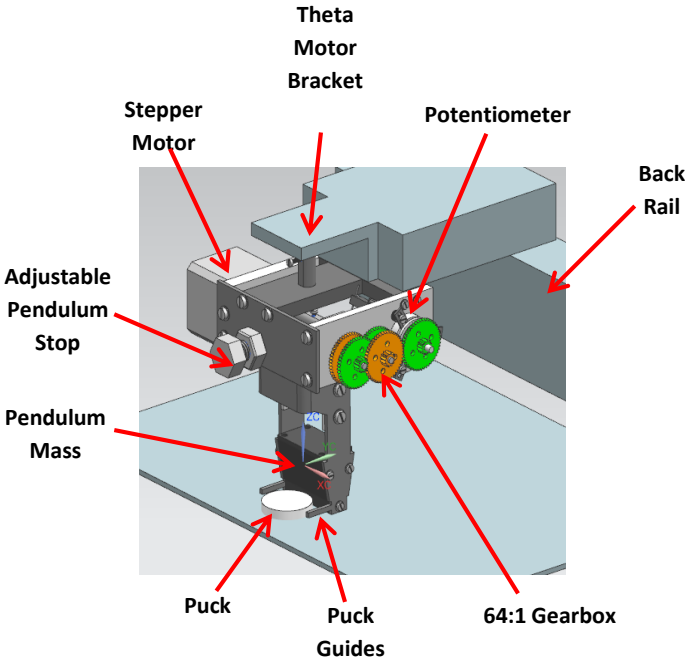
Wk	Task	CAM	Way point
	Initial delivery of task overview, assessment points, requirements, and Lab view introduction. Team selection and initial role allocation (Kicker/other) takes place (Machine vision and manipulator tasks will be allocated in week 4)	All	Kick-off meeting
	Lecture notes, some handouts, NI course documents		
	Work through Core 1 Online course outside of timetabled period through to week 2. Develop initial Schedule and Risk Register.	All Core 1 - Kicker CAM to develop planning documents	
	Develop initial Schedule and Risk Register.	Kicker CAM	
	Continue Core 1 online course with support from staff - includes a review of work completed outside the lab. Team photos taken.	Manipulator and Machine Vision	
	Start kicker design. Carry out experiments/tests and initial analysis. Monitor/update schedule and risk register.	Kicker	
	Electronics project worksheet will be handed out		
2	Complete Core 1 and work through Core 2 items (we are specifically interested in working towards producer/consumer design patterns): Design Patterns Timing Design patterns Notifier Queues	Manipulator and Machine Vision	
	Continue investigation/design of kicker unit. Carry out detailed design calculations and analysis. Identify various design ideas and actuators + sensors.	Kicker	
	Build demonstration myRIO project and then work on Electronics Project kit using myRIO units to develop familiarity with basic input output operations etc.	Manipulator and Machine Vision	
	Continue investigation/design of kicker unit. Carry out detailed design calculations and analysis. Identify various design ideas and actuators + sensors. Monitor/update schedule and risk register.	Kicker	
3	Machine vision worksheet will be handed out in readiness for week 4 lab. session. Further clarification provided on requirements for upcoming PDR.		
	Continue working through the electronics kit tasks outside of timetabled hours but working in the lab (attendance monitored). NOTE guidance as to which tasks should be completed from the sheet will be provided during week 2 session when the worksheet is handed out.	Manipulator and Machine Vision	
	Continue kicker design	Kicker	
	Introductory machine vision exercises with support from staff. Allocation of Machine Vision and Manipulator tasks.	Manipulator and Machine Vision	
4	Continue design and CAD of kicker unit plus generation of full parts list and report for week 6. Monitor/update schedule and risk register.	Kicker	
	Continue working on machine vision exercises outside of timetabled hours, but in the lab (attendance monitored). Finalise Kicker design and generate associated documentation. Monitor/update schedule and risk register.	Kicker	
5	Preliminary Design Review meetings plus commencement of work on actual project development.	All - Kicker CAM to discuss project planning and risk	PDR
	CDR guidance document handed out.		
6	Development of project solution in readiness for PDR	All	
	Submission of 5 page (maximum) bound report with FULLY designed kicker including overview of a minimum of 5 designs that were considered, analysis and calculations, full CAD of chosen solution, parts list and plan for manufacture. CAD will be included as an appendix. Monitor/update schedule and risk register.	Kicker	PDR submission - Kicker design completed
7	Development of project solution in readiness for PDR	All	
	Develop system towards TRY. Manufacture and integrate kicker unit.	All	
	Monitor/update schedule and risk register.	Kicker	
8	Handout of requirements for week 9 Critical Design Review (CDR).		
9	Critical Design Review consisting of a short viva type discussion and demonstration of performance requirements with customer present. Details provided in CDR guidance document. A short demonstration showing an integrated vision, manipulator and working kicker system is the core requirement for this review. Outside of allotted CDR timeslot, continue development work.	All - Kicker CAM to discuss build progress and show manufactured parts. Also kicker CAM to discuss project	CDR
	NOTE students to deliver 1-page confidence building flyer for CDR for customer to review by 5.00pm Tuesday week 9	All	
	Monitor/update schedule and risk register.	Kicker	
	Handout for finalised requirements for CA handed out - note that day 1 presentation containsan an initial overview of CA requirement details.		

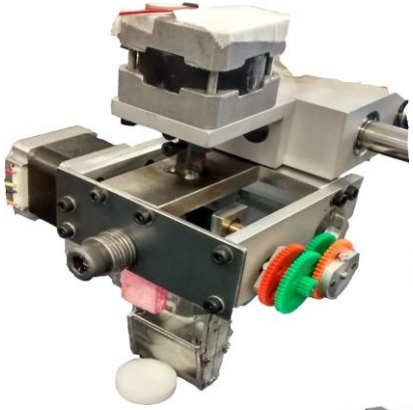
Project management and documentation

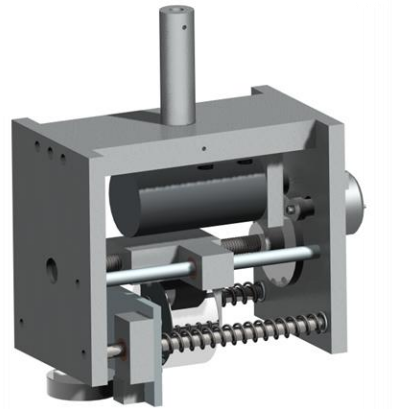
Risk ID	Risk (description)	Current Owner	Date Raised	Probability	Impact	Severity	Mitigation (Owner)	Target Date or Trigger	Current Status
1	Software failure on day of demonstration	Adam	09-Feb-2015	3	5	15	Revert to known last working version		Open
2	Team member can no longer contribute to the project	All	10-Feb-2015	2	5	10	Ensure all files are stored on shared drive. 2 minuted, progress meetings per week		Open
3	Delay in kicker manufacture	Ged	10-Feb-2015	2	4	8	Get files to workshop early	Week 4	Open
4	Software file(s) become corrupt	Anna	10-Feb-2015	4	4	16	Develop in small sections and save regularly to shared backup drive		Open
5	Lab is out of action during development or testing	All	12-Feb-2015	3	4	12	Ensure all resources available outside of lab		Open
6	Computer issue results in lost files	All	12-Feb-2015	2	3	6	Regular backups		Open
7	Behind schedule for review benchmarks	Adam	12-Feb-2015	3	4	12	Regular review of progress during meetings - manage resources appropriately		Open
8	Camera is dissloged or knocked out of position during demonstration	Anna	12-Feb-2015	2	4	8	Ensure valid calibration routine developed early in project lifecycle		Open
9	Kicker parts not manufactured to schedule	Ged	12-Feb-2015	3	3	9	Ensure drawings fully completed, toleranced, and checked	Week 4	Open
10	Electronic board failure	All	12-Feb-2015	4	3	12	Ensure spare boards available in the lab and technician avaialble		Open

Student-designed kickers

- Perform basic experiments, analyse requirements, draw up PDS, design, model (CAD), manufacture, test, calibrate…...







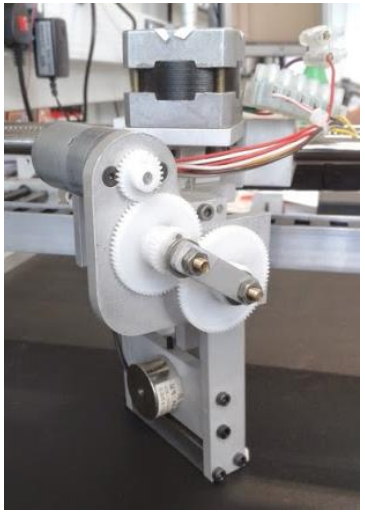
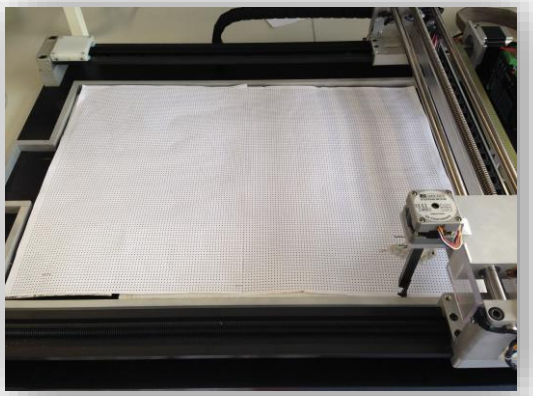
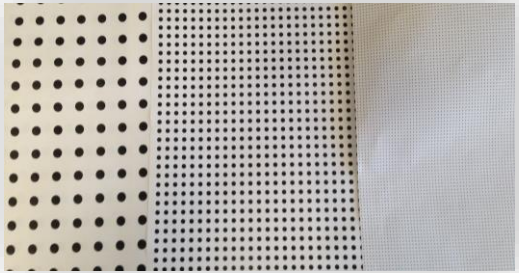
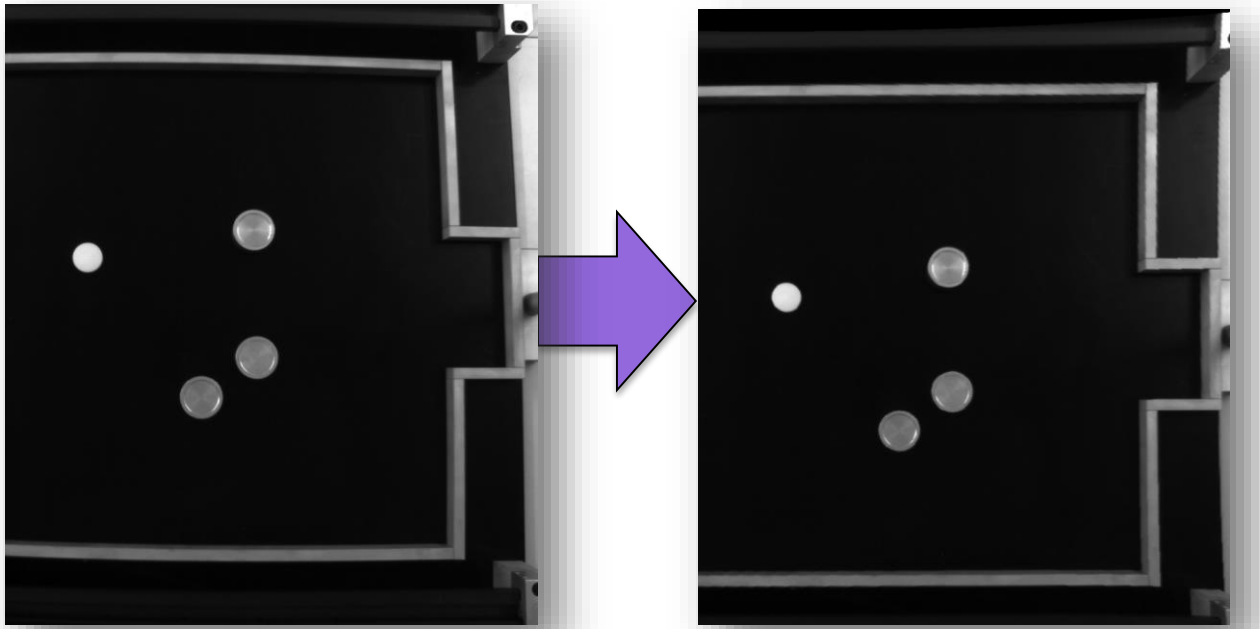


Image corrections

Image Calibration → Image Correction → Field Detection → Puck Detection

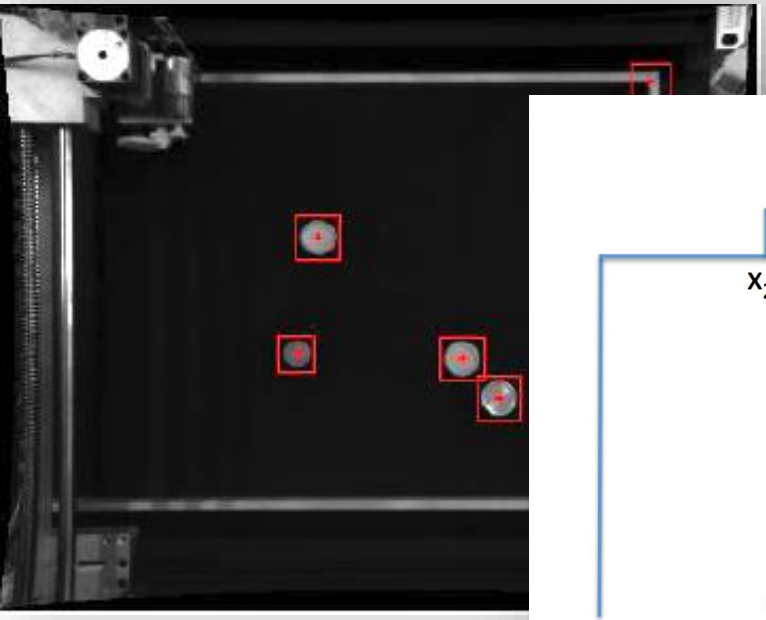


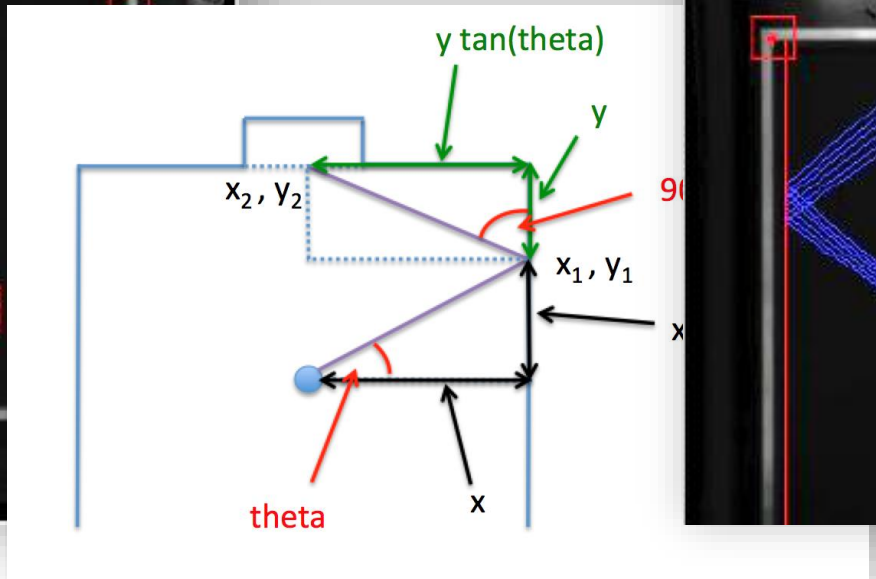


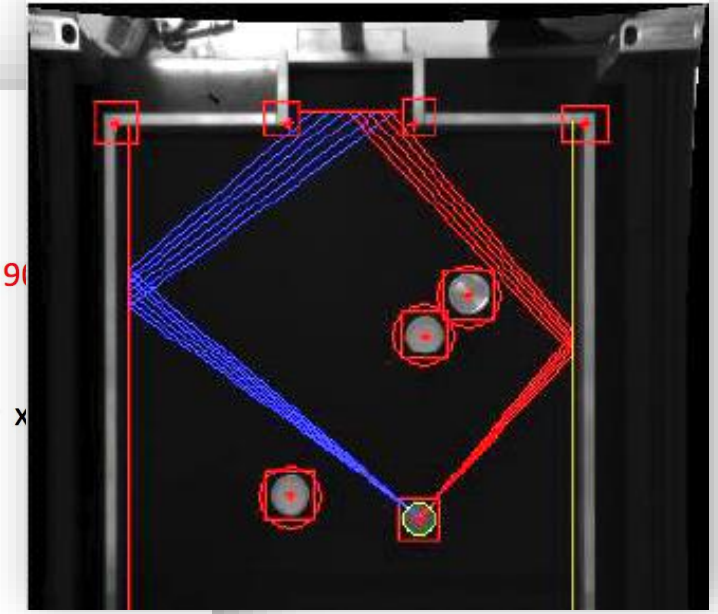


Shot identification and selection

- Great support in LabView for sophisticated image recognition/processing
- Programming maths using core LabView VIs, less so…..

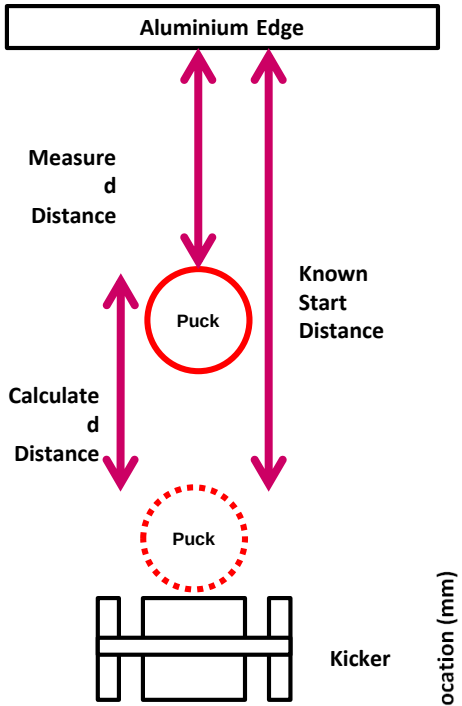


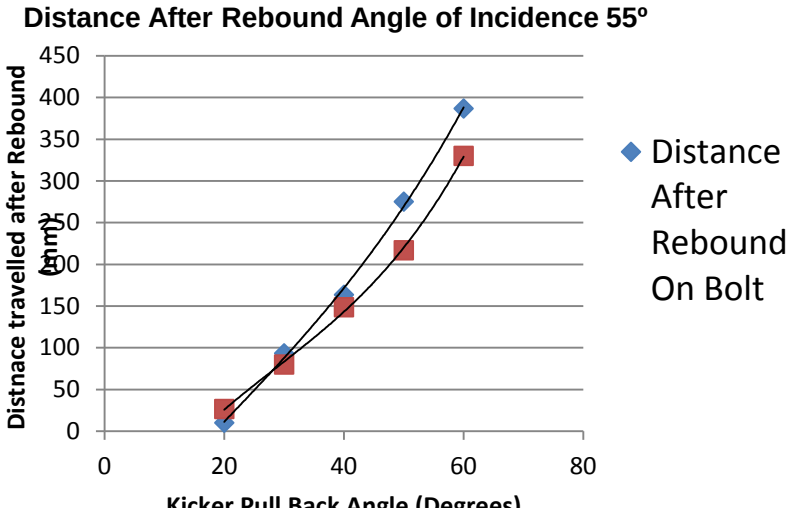


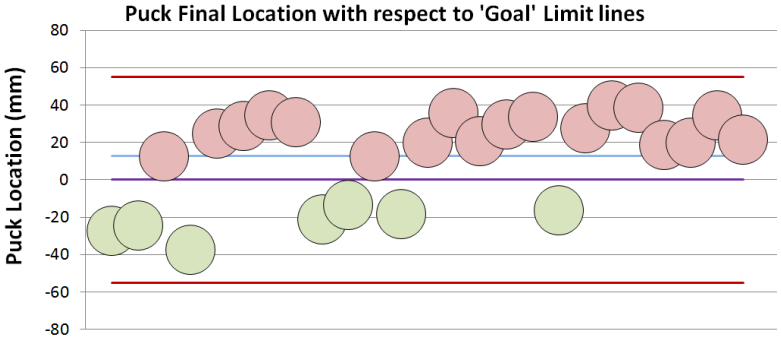


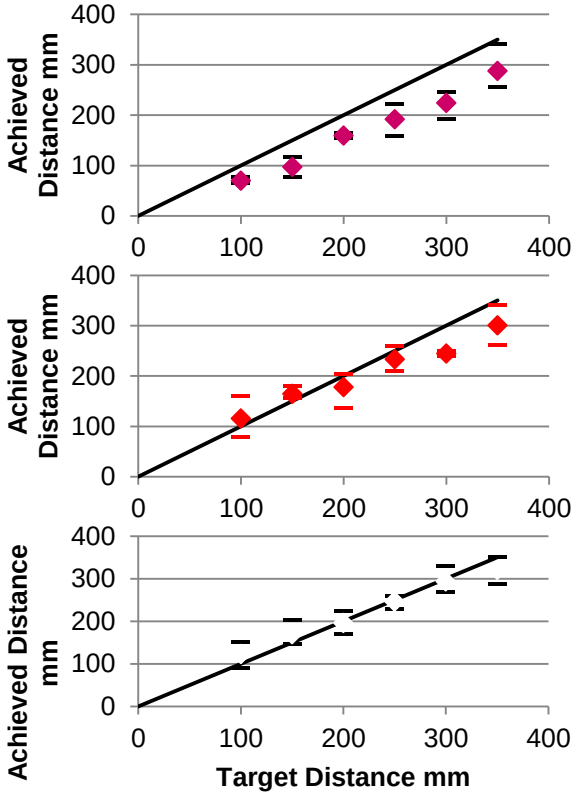
- Students created Matlab code for shot path generation and pasted into Mathscript!

Characterisation and performance testing

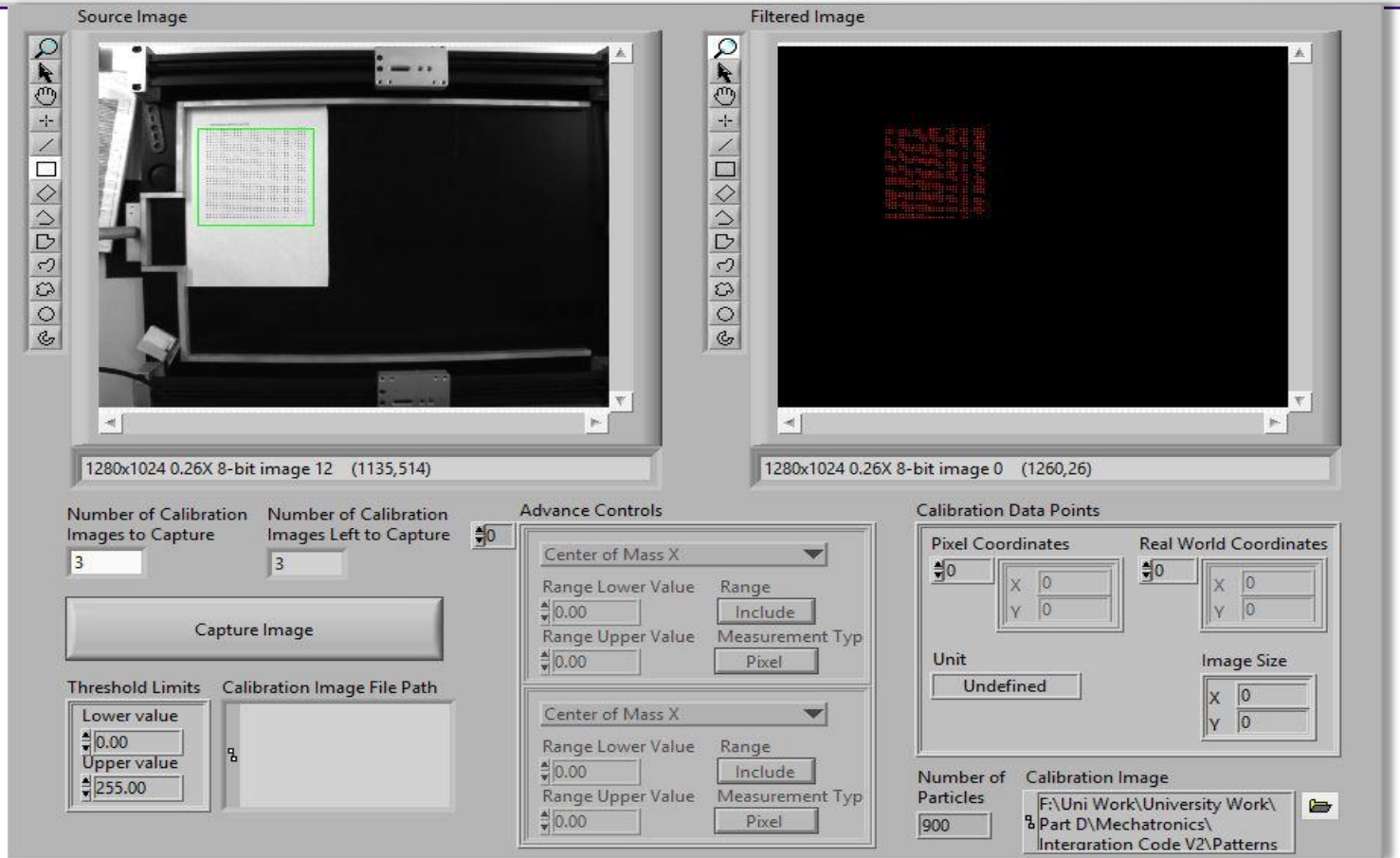








Student's development interface



Future developments?

- **Speed! Excitement! Control!**
- Both axes ran slower than desired
  - X axis developed at 24V, but existing H-Bridge failed above 12V
  - Currently testing new pulleys at 2.3:1 (1:1 originally) and new H-Bridge boards
  - Y-Axis developed and tested at 530kHz to stepper driver – myRIO PWM VI limited to 40kHz at present (developed a new approach running at 400kHz)
- Develop video tracking algorithms – currently static images
- More dynamic performance, learning algorithms?
- Goalkeeper?
- Add Pick and Place? CNC Cutting? Hardware design was flexible with these in mind…….

- Sincere thanks to National Instruments for the continuing support

  Especially **Beejal Shah** and **Hannah Wade**

Also thanks to two superb Wolfson School Technicians

Mick Ison and John Hales

Questions?

Comments or Questions?

myRIO Hardware Ecosystem

http://www.ni.com/white-paper/52419/en/

Introducing TETRIX PRIME for myRIO

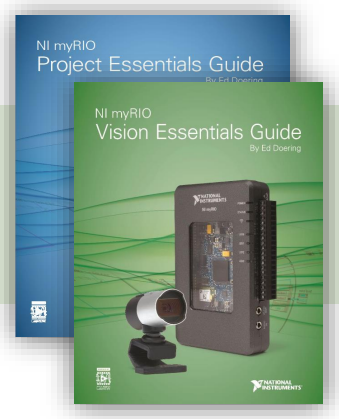
http://www.ni.com/white-paper/52707/en/

myRIO Courseware (including Project and Vision Essentials Guide)

http://www.ni.com/myrio/courseware/

Robotic Table Football: Revolutionising Mechatronics Education

http://sine.ni.com/cs/app/doc/p/id/cs-16755



NIDays

Recommended Next Sessions

13:00 – This Room
Wordsworth Room
5G Summit

Prototyping with Software Defined Radio for Industry, Academic, and Defence Applications
Jeremy Twaits, NI

13:00 – St James Room
Software and System Development Track

Building Basic Web Applications with LabVIEW
Charlotte Nicolaou, NI

13:00 –Wesley Room
Automated Test Track

Create Without Limits: 4 Ways to Customize Your Software-Designed Instrument
Sacha Emery, NI