Complementary Simulation and Remote Laboratory Experiences to Hands-on Control Systems Curriculum

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Outline

- Background Florida's First Coast Manufacturing Innovation Partnership (MIP)
- Collaboration with Cologne University of Applied Sciences (CUAS), International Research and Education in Engineering (IREE) Grant, and ongoing collaboration
- RLab Overview, Implementation, Continuous Improvement, and Usage

Florida's First Coast

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Florida's First Coast MIP

Manufacturing Innovation Partnership

- Educate students through engineering practice
- Assist in the economic and technical development of the Northeast Florida Region through integrated engineering design and manufacture
- Over 20 Partnership Projects primarily with Regional Industry
- Expand from regional to national and international collaborations

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Laboratories

- Manufacturing and Machine Sciences Laboratory
  - Primarily Teaching Laboratory
- Robotics and Automation Laboratory
  - Primarily Applied R&D Laboratory

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Manufacturing and Machine Sciences Laboratory

- Computer-Controlled Machinery
- Dynamic Modeling and Analysis
- Advanced Controls
- Modal Analysis
- Metrology
- Mechanisms
- Machine Theory

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Robotics and Automation Laboratory

Robotics Research and Applications

- Dynamic Systems Modeling and Analysis
- Control Systems and Instrumentation
- Sensor Integration
- Dual-Arm and Multiple Manipulator Systems
- Simulation
- Application Development
- Biomedical and BCI-Robotics (Brain Computer Interface with Robotics) Project

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Project-Centered Module (PCM) Paradigm Machine Sciences Curriculum

- Develop and test new theories and knowledge about teaching and hands-on learning through development of the PCMs to engage students in processes and exploration of scientific and engineering principles
- Design and develop tools, materials, and methods through implementation of the PCMs to enhance learning through hands-on instructional technology
- Develop an innovative instructional model by distribution and application the PCMs across an array of courses and research projects in machine sciences

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Project-Centered Module (PCM)

- Level I - Curriculum
  - Motivational Demonstrations
- Level II - Curriculum
  - Laboratory Exercises
- Level III - Curriculum
  - Individual Projects
  - Group Projects
- Level III - Advanced
  - Graduate and Research Topics

UNF Hardware Resources

- ECP Systems
  - 205 Torsional Plant (x2)
  - 210 Rectilinear Plant (X2)
  - 220 Industrial Plant (X3)
  - 750 Gyroscope (1)
- Robots
  - Staubli TX40 Robots with CS8 controllers (X2)
  - Staubli RX60CR Robots (X2)
  - AdeptOne Robot

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Software Resources

- General use software
  - MatLab
  - MatLab Toolboxes
  - Simulink
  - LabView
  - ECP Software
  - C and C++
- Robotic software
  - RoboWorks
  - VAL 3

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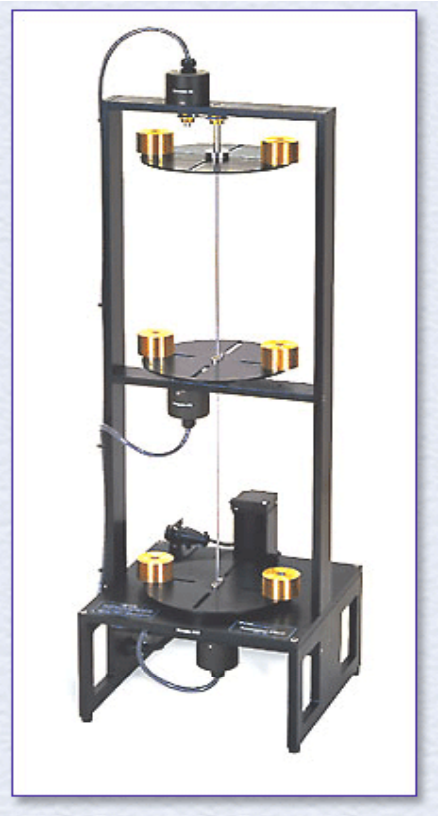
ECP 205 Torsional Plant



- Electromechanical system
- One to three degree of rotational freedom

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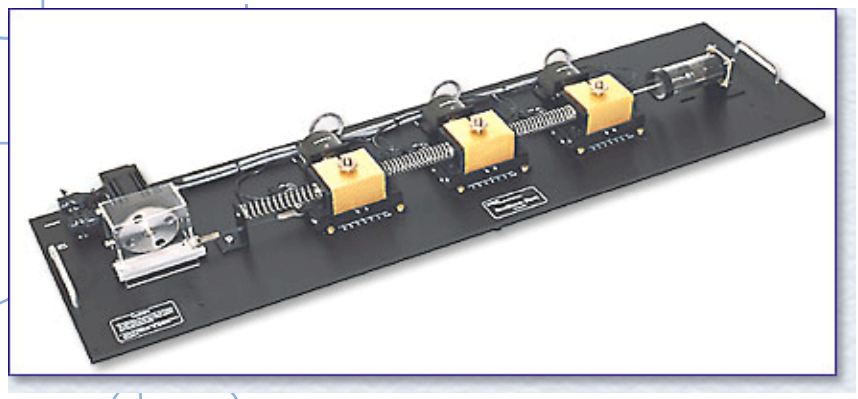
ECP 210 Rectilinear Plant



- Electromechanical system
- One to three degree of translational freedom

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ECP 205 and 210 Experiments

- Plant Identification & Dynamic Model Building
- Second-Order Systems
- Rigid Body PD and PID Control
- Fundamental Open & Closed Loop Properties (second-order systems, transient and frequency responses, rigid & flexible bodies, mode shapes & frequencies, time & frequency domain correlation)
- Phase & Gain Margin
- Nyquist Stability
- Root Locus Design
- Sensitivity to Parameter Changes
- Control Robustness
- Tracking Control
- Disturbance Rejection
- Tracking Control
- Flexible Structure Control
- Practical Control Issues (drive saturation, sensor quantization, discrete time sampling, custom control execution)
- …

ECP 220 Industrial Plant

- Most of experiments of 205 and 210, in addition…
- Gear Ratio & Inertia Changes
- Friction
- Backlash
- Drive Flexibility
- Drive Saturation
- Sensor Quantization
- Discrete Time Sampling

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ECP 750 Control Moment Gyroscope Plant

- Plant Identification & Dynamic Model Building
- Gyroscopic Dynamics: Nutation & Precession
- Reaction Torque Control
- Second Order System Fundamentals
- Gyroscopic Control
- Multi-variable Control
- Dynamic Tracking Control of SISO, SIMO, and MIMO systems

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Target ME Courses for PCMs

- EGN 3203 Modern Computational Methods
- EGN 3321 Dynamics
- EML 4312 Modeling and Analysis of Dynamic Systems
- EML 4313 Control of Machines and Processes
- EML 4301L Mechanical Systems Laboratory
- EML 4804 Mechatronics
- EML 4806 Robotics Engineering I
- EML 4990 Production Systems Engineering
- EGN 5991 Advanced Control Systems

Equipment and PCM by Course

PCM Equipment	EGN 3203	EGN 3321	EML 4301L	EML 4312	EML 4313	EML 4804	EML 4806	EML 4990	EGN 5991
Staubli Robots							II, III	III	
AdeptOne	I	I				II, III	II, III	III	
Modular Robotics	I	I	II		II, III	II, III	II, III	III	
Industrial Drives	I		II	II, III	II, III	II, III	II, III	II, III	II, III
ECP 205	I	I	II	II, III	II, III	II, III			II, III
ECP 210	I	I	II	II, III	II, III	II, III			II, III
ECP 220	I	I	II	II, III	II, III	II, III			II, III
ECP 750		I	II	II, III	II, III	II, III	II, III		II, III

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Laboratories and PCMs

- Manufacturing and Machine Sciences Laboratory
  - Primarily Teaching Laboratory
  - Levels I, II and III PCM activity
- Robotics and Automation Laboratory
  - Primarily Applied R&D Laboratory
  - Level III PCM activity
- Activity to expand global reach

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CUAS Collaboration

- Curriculum Development
  - Develop Level II and III PCMs for undergraduate curricula
    - Using CUAS plants
    - Using UNF ECP plants
- Advanced Control Topics for students in Master's Program
- Infrastructure Development (RLab)
  - Integrate RLab with ECP plants
  - RLab: LabView-based infrastructure for Remote Experiments
  - Control Plants with LabView and RLab
- Cultural Enhancement and Experience with German Culture

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Extending the PCM Concept through International Collaboration

- PCM Development
- Advanced Control Topics
- Infrastructure Development (RLab)
- Cultural Experience and Exchange

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PCM Development

- Develop Project-Centered Modules (PCMs)
  - PID Control of Heater Fan, Twin Rotor, and Inverted Pendulum Using RLab
  - Student Instruction Guide
  - TA Manual
- Use CUAS Plants at UNF via RLab
- RLab Capability Ported to UNF
- Integrate ECP Plants at UNF with RLab

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RLab Infrastructure Development

- RLab uses LabVIEW as major component
  - Login Server
  - Database Server
  - Experiment Server
- Learn RLab Subsystems
- Upgrade RLab from LabVIEW 6.1 to 8.2
- Upgrade to LabVIEW 8.6 and beyond

Cultural Enhancement

- IREE Program 2008
- 3 month immersion
- Daily interaction with German students, faculty, and staff
- Six UNF students participated
- Live in Cologne
- Technology Transfer of RLab

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Cultural Enhancement for Students

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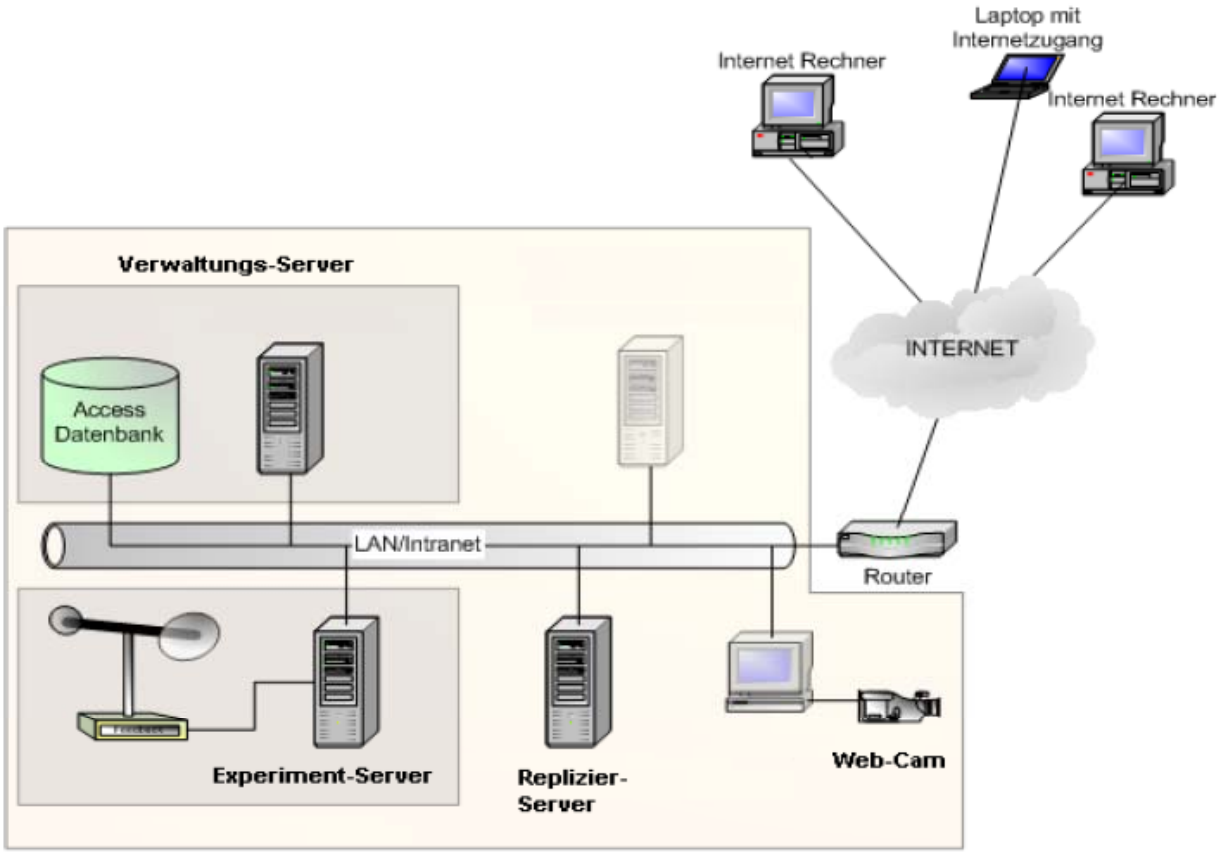
What is “Rlab”?

- Remote Laboratory
  - Allows a user from any location to access and perform a variety of experiments on electro-mechanical systems
  - This extends pool of PCMs for curricula
- LabVIEW
  - Uses Internet and Database Toolkits
  - Interacts with control systems

RLab Structure



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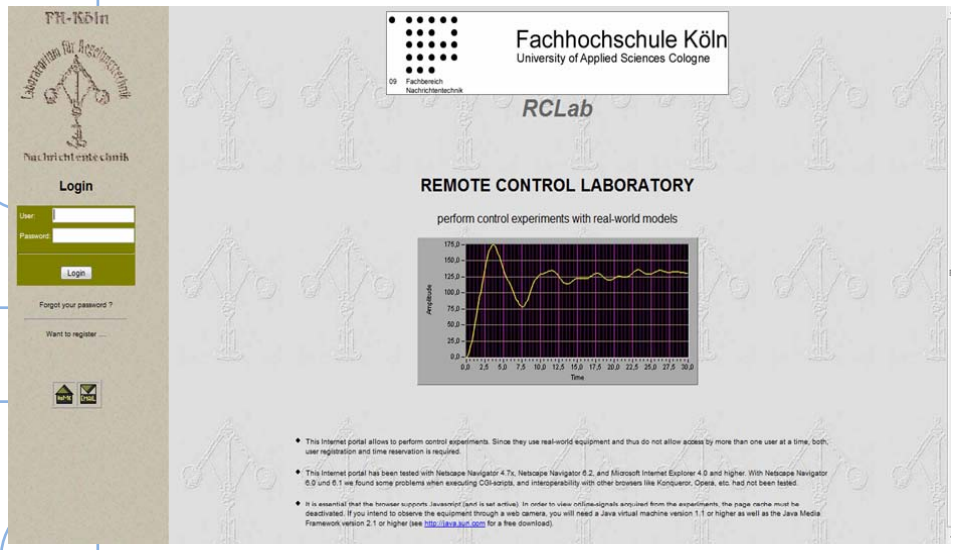
RLab Website Features

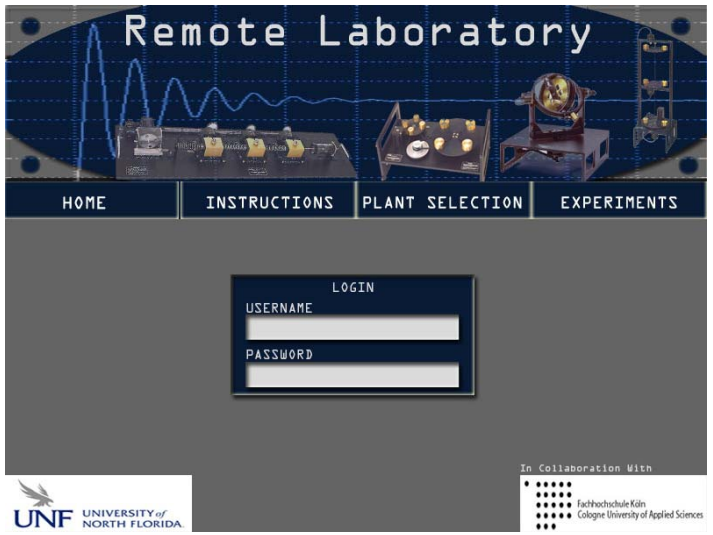
- Login process
  - Must register and be accepted by the admin
- Booking time
  - Reserve a checkout time for a plant
  - Ensures only one user per system
- Navigation of different systems and experiments
- Previous results
  - Revisit the output graphs from previous experiments

Login Server

- Contains the database
  - Login information
  - Booking times
  - Previous results
- Generates homepage
- Uses LabVIEW database toolkit
  - Checks passwords
  - Error checks booking times

Login Servers CUAS and UNF





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Experiment Server

- Contains the webcam for the experiment
- Generates the experiment webpages
- Reads input values from database
  - Places them into I/O hardware cards
- Obtains output from plants sensors
  - Creates response plots
- Multiple experiment servers
  - One for each plant

CUAS Control System Plants

- 3 Experiment Servers in Germany
- Twin Rotor
  - MIMO system
  - Vertical and Horizontal fans
- Heater Fan
  - MISO system
  - Control input current and fan speed
- Inverted Pendulum
  - SIMO system
  - Control cart position

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UNF Control Systems

- Education Control Products (ECP)
  - ECP 205 Rotational Plant
  - ECP 210 Rectilinear Plant
  - ECP 220 Industrial Plant
  - ECP 750 Gyroscope

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Additional Servers

- 2 Remaining Servers
- Observer Server
  - Showed server status
    - Whether it is online or offline
    - If the control system was booked or not
- Real-Time Server
  - Generates response plots

Evaluation Methods

- Comparison to baseline of course without PCMs
- Student evaluation and survey feedback
- Feedback from industry and other academic and professional users

Curriculum Integration

- Existing Hands-on PCMs
  - In EML 4301L Mechanical Systems Laboratory
  - Make use of ECP Plants and Dynamic Systems and Control Experiments
- Add Simulation PCMs using MatLab and Simulink
- Add correlating PCMs with Simulation and CUAS Plants
- Add Remote Laboratory PCMs using RLab

Simulation PCMs

- Simulate using MatLab and Simulink
- Use plant parameters for CUAS Twin Rotor
- Simulate system off-line as a PCM exercise

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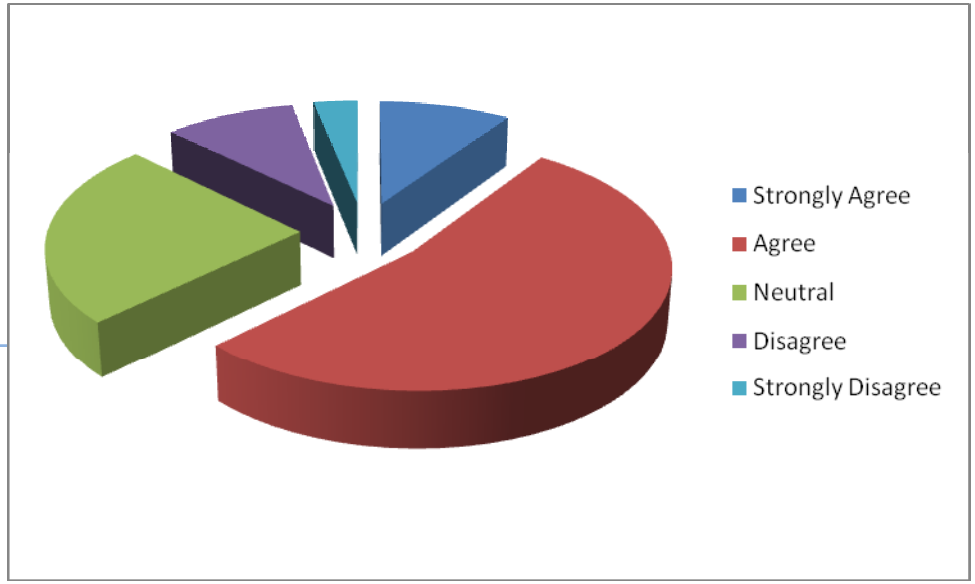
RLab PCMs

- Use Twin Rotor Plant located at CUAS in Germany
- Login during laboratory time at UNF in USA to use Plant in Germany
- Perform Remote Laboratory Experiments
- Student Surveys of Educational Experiences
- Continuous Improvement Process

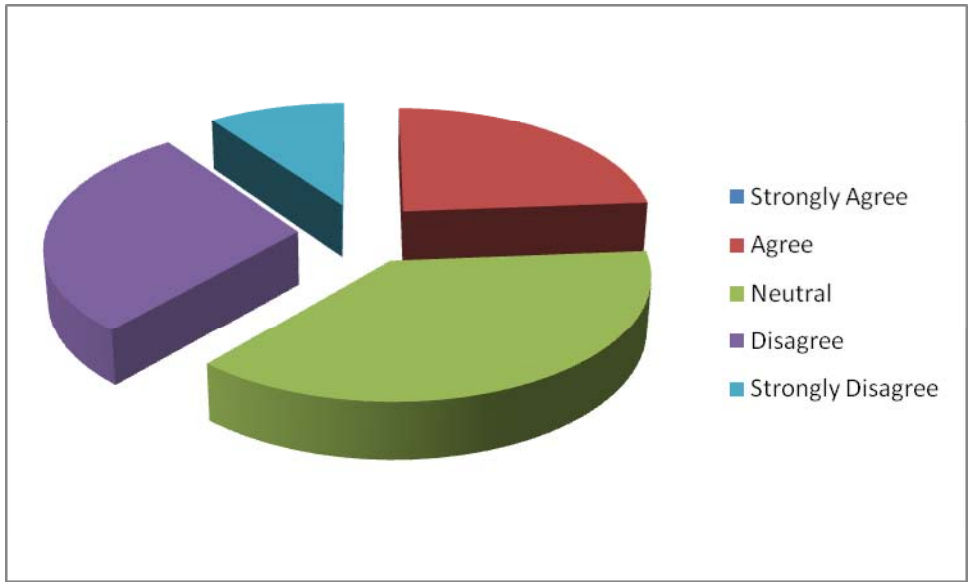
Response to Simulation

- Example question: “MatLab/Simulink is a great tool to use for understanding control systems”



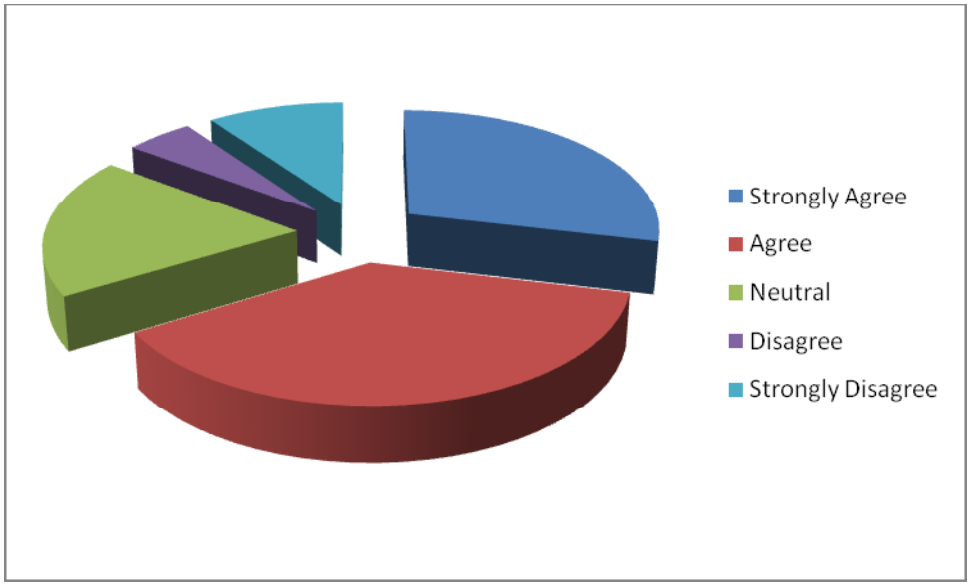
Response to Simulation

- Example question: “The results obtained from RLab experiment matched with the simulations done by using MatLab and/or Simulink”



Response to RLab

- Example question: “RLab is Very Interesting to Work With”



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Ongoing Activities with RLab

- Incorporate additional plants
  - ECP 205 and 210 integrated
  - Further integrate ECP 220 and 750
  - Add more experiments for each plant
- Use RLab for remote experiments
  - UNF students to use CUAS plants via RLab first used in Fall 2009 semester in EML 4301L
  - Use RLab subsequently in EML 4301L Fall Semester
  - CUAS students to use UNF CUAS plants via RLab planned
- Extend from electro-mechanical experiments to robotics

Summary

- MIP Program extended to International collaboration with CUAS
- RLab capability at CUAS ported to UNF and upgraded with latest versions of LabVIEW
- ECP plants at UNF accessible via RLab
- Gaining experience in using RLab in curriculum
- Ongoing expansion of experiments and capabilities
- Evaluation methods are included for continuous improvement
- Two CUAS exchange students to study and collaborate at UNF for 1 year beginning Fall 2010

Acknowledgements

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- Florida's First Coast MIP

  NSF Grant 0438582
- IREE - Computational Intelligence for Intelligent Control of Machinery and Manufacturing Processes

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- UNF School of Engineering and State of Florida Cortelius Equipment Funding
- UNF Transformational Learning Opportunity (TLO) Grant for Germany cultural excursions

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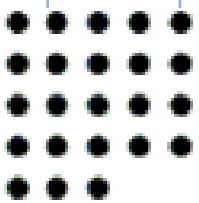
Questions?



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