Electrical and Computer Engineering

The Clemson University Electrical & Computer Engineering (ECE) Department occupies over 29,000 square feet of research space with approximately of that space within the Fluor Daniel Engineering Innovation Building, a 103,000 square foot ultramodern facility. ECE is also well-equipped with networked workstations and personal computers that serve as the foundation for course computing needs and as the backbone of computing support for research programs.

Offices

The main administrative office for the ECE Department is located in 105 Riggs Hall. Faculty and staff offices for the ECE Department are located in Riggs Hall and the nearby Fluor Daniel Building. Several faculty members also have second offices in off campus research facilities. Faculty offices in Riggs Hall have typically 250 sq. ft. of floor space, and offices in the Fluor Daniel Building have at least 150 sq. ft. of floor space. Except for two technical staff members who share a large shop area, all ECE staff members have their own office. Graduate Teaching Assistants and Graduate Research Assistants are assigned offices in either Riggs Hall or the Fluor Daniel Building.

Classrooms

The primary classrooms used for teaching ECE classes are Riggs 219 (37 seats), Riggs 223 (37 seats), Riggs 226 (51 seats), and Riggs 227 (51 seats). Some ECE classes are also taught in other buildings around campus. The University has an efficient campus-wide system for helping Departments locate and schedule available classrooms to meet their teaching needs.

Laboratory Facilities

<u>Room: Riggs 12</u>

Labs Supported: ECE 495, ECE 496 (Capstone Design)

No. of Lab Stations: 9, each with

- 5530 Linear amplifier
- Quanser Q4 Board
- Quanser Terminal Board
- Dell PC
- DC Power Supply (HP or Agilent)

- Tektronix TDS2002B 2-channel digital storage oscilloscope
- Con-Tech Multimeter

Availability: Open Lab (for ECE 495, 496 students)

Room: Riggs 19

Labs Supported: ECE 327 (Digital Computer Design) and ECE 468 (Embedded Computing)

No. of Lab Stations: 15, each with

- Dell Optiplex PC
- LCD monitor
- Altera DE2-115 FPGA development board
- Logitech C310 webcam

Availability: Open Lab (for ECE 327 students and ECE 468 students)

Room: Riggs 22A

Labs Supported: ECE 449 (Computer Network Security)

No. of Lab Stations: 12, each with

- 17 PC workstations on an isolated network segment, running VMware (virtual machines are used with malware without harming underlying systems);
- Three netbooks for demos; HD video display for demos and presentations;
- Fifteen thin clients which form an isolated privacy network for testing;
- Six network sensors and a wireless intrusion prevention system used for wireless security exercise;
- Two routers with openflow network software to support flexible network design;
- Two Net-FPGAs for low-level network instrumentation.

Availability: Open Lab (for ECE 449 students)

Rooms: Riggs 23/25

Labs Supported: ECE 495, ECE 496 (Capstone Design)

No. of Lab Stations: 4, each with

- 5530 Linear amplifier;
- Quanser Q4 Board;
- Quanser Terminal Board;

- Dell PC;
- DC Power Supply (HP or Agilent);
- Tektronix TDS2002B 2-channel digital storage oscilloscope;
- Con-Tech MultiMate.

Availability: Open Lab (for ECE 495, 496 students)

Room: Riggs 200A

Labs Supported: ECE 211 and ECE 312 (Circuits I and Electronics II)

No. of Lab Stations: 10, each with

- National Instruments Elvis II system
- Dell Optiplex 760 PC
- Breadboard kit (purchased by students)
- (Plus assorted accessories)

Room: Riggs 200C

Labs Supported: ECE 212 and ECE 311 (Circuits II and Electronics I)

No. of Lab Stations: 10, each equipped with

- Dell Optiplex 760 PC;
- Hameg Digital MultiMate HM811-3;
- Hameg Function Generator HM 8030-5;
- Triple Power Supply HM 8040-2;
- Hameg Analog/Digital Oscilloscope HM 507;
- Curve Tracer (4 Tektronix Type 576 Curve Tracers and 6 Hameg Curve Tracers HM 6042).

Availability: During weekly scheduled lab periods

Room: Riggs 204

Labs Supported: ECE 309 (Service lab for non-EE, Non-CPE majors)

No. of Lab Stations: 15, each with

- Hampden AC WM-100;
- Hampden 120/208 Variable Resistance Load;
- AC meters: ACVA-100 and AC3V-300;

- Tektronix 2-channel digital storage oscilloscope;
- Tenma 72-7245 Decade Resistor Box;
- DC Power Supply;
- BK Precision 4011A 5 MHZ Function Generator;
- Tektronix CFC250 Frequency Counter;
- Meterman BDM40 MultiMate.

Availability: During weekly scheduled lab periods

Room: Riggs 203 (Rockwell Teaching Lab)

Labs Supported: ECE 412 (Power lab elective)

No. of Lab Stations: 10

Six stations, each equipped with

- Reliance Electric Flex Pak 3000 D-CV S Drive;
- Reliance Electric GV 3000/CE Sensorless Enhanced AC Drive;
- Reliance Electric 3575 Breaker;
- Tektronix TDS 2014 4-channel, digital storage oscilloscope;
- AC/DC Motors;
- Torque Sensor;
- Dell Optiplex GX280 PC;
- Tenma Laboratory DC Power Supply 72-2010;
- Tenma Function Generator 72-5010;
- HiRel Systems Motor Controller Board P/N 75136.

Four lab-volt stations, equipped with

- Variable Resistance;
- Three-phase Transmission Line;
- Three-Phase Transformer Power Supply;
- Squirrel Cage Induction Motor;
- Electro-Dynamometer Power Supply.

Availability: During weekly scheduled lab periods

Room: Riggs 304/306

Labs Supported: ECE 459 (CAD elective)

No. of Lab Stations: 11, each equipped with a Dell Optiplex 320 PC

Availability: Open lab (for ECE 459 students)

Room: Riggs 322

Labs Supported: ECE 209 and ECE 372 (Digital Logic and Microcontroller Interfacing)

13 stations, each equipped with:

- National Instruments Elvis II with Freescale Board
- Axiom CSMB12-DT-256 Microcontroller board
- Dell 760 PC
- Stepper Motor
- Key Pads
- Rotary Encoders

Availability: During weekly scheduled lab periods

Computational Electromagnetics Laboratory

The Applied Electromagnetic Group's (AEG) research emphasis, on which the work of the Computational Electromagnetics Laboratory (CEL) is based involves solving actual problems encompassing i) electromagnetic theory, ii) sophisticated analytical and/or numerical techniques, and iii) parallel and distributed computers, to develop electromagnetic analysis and design tools to study electromagnetic phenomena. Research sponsors include the US Army Research Office, NSF, ONR, the Ballistic Missile Defense Organization, the US Air Force Phillips Laboratory, US Army MICOM/ARO/White Sands, Electric Power Research Institute, and Duke Energy.

Research

Current research underway includes

- Signal Coupling and Penetration – where integral equation techniques are used to solve aperture penetration in which penetration through apertures has yielded the development of tools to predict fields necessary for missile penetration.

- Innovative Communications Antennas - in which rugged and lightweight omnidirectional antennae are being developed that can radiate/receive spread spectrum signals and transmit radiated power in the tens of watts.
- Millimeter Wave Circuits and Systems - in which frequencies above 40 GHz (the millimeter wave frequencies) are being explored for use in communications and imaging applications, specifically in 77 GHz band range for automotive radar and imaging applications. Ongoing research also includes millimeter wave electromagnetic, micromachining of waveguiding structures, antennas, and synthetic crystal structures using anisotropic silicon etching technology, modeling of guiding structures for millimeter wave frequencies and spatial power combining to achieve high radiated powers.
- Low Frequency Fields – in which modeling techniques are being developed to assess the shielding effectiveness of steel pipe on 60 Hz fields, due to the possible health effects of low-frequency electromagnetic fields (ELF)
- Improved Method for Computing Zero-Sequence Impedance – in which applications are being developed to compute zero-sequence impedance of underground pipe-type cables in power transmission systems to protect such systems via accurate calculation of fault currents in the system. This NSF sponsored work involves developing an improved method for computing zero-sequence impedance of underground pipe-type cables. The zero-sequence impedance can be computed based on information of the non-uniform current distribution in the phase conductors as well as the electric field intensity and the total current in the steel pipe.
- Robust Finite Element Methods for Electromagnetic Modeling - in which the finite element method (FEM) is being used for numerical modeling of numerous physical regimes. Until the last few years, difficulties posed by practical electromagnetics problems precluded the use of the FEM for electromagnetic modeling. Though challenges remain in refining edge-based basis elements and in dealing with infinitesimally thin metallic protrusions, the methods for addressing both the elements and formulations for thin protrusions are near to fruition.

- Extending the Range of Real-World Problems – Many problems in electromagnetic compatibility (EMC) and electromagnetic interference (EMI), wireless communications, and coupling between radiators and biological organisms cannot be addressed with the leading electromagnetic analysis tools (such as integral equation and finite element methods) simply because the analysis is too time consuming and costly to conduct. Even with the advances made in parallel and distributed computing, the resource requirements of popular electromagnetic analysis techniques exceed the supply of necessary resources. New analytical techniques are being developed to extend the range of real-world problems currently addressed with current computer resources. The Clemson AEG group is focusing on investigating applications of spatial decomposition techniques for efficient electromagnetic analysis of electrically large complex structures, systems, and environments. Spatial decomposition is an analysis technique whereby a large complex structure is subdivided into several smaller structures such that the ultimate union of the smaller structures is equivalent to the original large structure. The smaller structures individually require much less memory and computer time for analysis than do the larger ones. The AEG group is applying spatial decomposition techniques to volumetric integral equation and partial differential equation based formulations to extend the analysis to larger, more complex structures and systems using the fixed computer resources available today.

Facilities

The CEL has several high-end PCs for developing codes to implement numerical theory-based formulations. A four-processor DEC Alpha system, for computationally intensive projects involving distributed processors, has 512 megabytes of memory available for each processor and a high-speed switched DEC GIGA switch for high-speed communication between processors. The laboratory also has six DEC Alpha 21064 processors running at 275 MHz, two DEC Alpha 21164 processors running at 300 MHz, eight DEC Alpha processors running at 500MHz, and four DEC Alpha processors running 667MHz. The measurement facility within the CE lab also has an antenna ground plane laboratory (AGPL), a roof-top antenna platform, a

70 ft telescoping antenna tower, a HF Yagi-Uda antenna designed for operation down to 7 MHz, an HP 8510B vector network analyzer, an HP 89441A vector signal analyzer, oscilloscopes and assorted multimeters. The lab also has an anechoic chamber for high frequency measurements, a micro-milling machine for building microwave circuits, two Kenwood HF Transceivers (a TS-950SDX, and a TS-850S), two Yaesu VHF/UHF Transceivers (FT-726R), a millimeter receiving system and a Cascade Probe station for performing nearfield scanning and holographic imaging of radiating apertures, a network analyzer capable of 10 Hz-150 MHz band with measurement capabilities for wireless communications systems in the HF band, and an arbitrary waveform generator to study spread-spectrum waveforms for use with antennas and electronic switching schemes.

AGPL

The AGPL is an 18 ft. high by 26 ft. wide by 12 ft. room with five of six walls lined with 12 inch microwave absorber and the remaining wall is 18 ft high by 21 ft wide by 0.5 inch thick aluminum sheet (group plane). The purpose of the microwave absorber is to reduce reflections from the walls and other objects to simulate a free-space environment. The large aluminum ground plane serves to isolate the operation region (the interior of the absorber-lined room) from the equipment region where the HP 8510B and the experimenter are located. Near the center of the aluminum ground plane is a tapered circular opening in which fixtures are mounted for conducting measurements on model antennas and other devices. The mounting fixtures also allow access for cables which connect to instrumentation. Using this facility, it is possible to perform accurate characterization of antenna driving-point admittance down to a low-frequency limit of around 300 MHz using full-scale antenna models. Hence, by use of 1/3-size scale models, it is feasible to simulate measurement at 100 MHz for all metal antennas types

Antenna Tower

The antenna tower located on the roof of the EIB allows point-to-point measurements to demonstrate the ability of the antennas designed at Clemson to link radios displaced from each other by several miles in hilly, mountainous, or moderately flat terrain. These antennas are

mounted on the boom of the HF Yagi-Uda antenna nearly 150 ft above ground level. Several members of the Clemson FRI team conduct transmit/receive experiments in the Clemson area. The close proximity of the Blue Ridge Mountains permit rigorous performance testing and the portable HF and UHF/VHF transceivers are also used.

Clemson University Electrical Power Research Association (CUEPRA)

The Clemson University Electrical Power Research Association (CUEPRA) provides visibility to electric power research to liaison between electric power companies and the academic community. Current research underway at CUEPRA involves

- Accelerating the contribution of University research to the power industry;
- Enhancing the ability of engineering graduates to contribute to US competitiveness in the power industry;
- Conducting research projects to the power industry, CUEPRA members and the University.

Additional areas of research include Digital Protection, Fault Location, Disturbance Identification and Fault Location, Power system Harmonics, Power Quality, Stability and Control, Wide Area Disturbance Identification, Distributed Generation, and Synchro-Phasor Application in Power System Operation & Control.

Microelectronics Research

Available equipment is housed in two rooms:

Rhodes 513

Thermal evaporator, Edwards model E12E3

Furnace for sintering aluminum, Thermcraft model 25-18-1ZH-ST

Profilometer, Dektak III

Microscope, Metallurgical

Microscope, Stereo zoom

Riggs 22H

Ellipsometer II, by Applied Materials

Furnace for Oxidation, Mini-Brute MB-80

Microelectronics Research Group

The primary research focus of the Clemson ECE department encompasses Solid State Nanoelectronics, and the creation of semiconductors. To produce such devices metals and insulators/dielectrics, and semiconductor materials must be used. Both fundamental and applied research focuses on materials, processing, devices, physical and electrical characterization, reliability, design, and applications to micro- and nanoelectronics. Participating ECE faculty are engaged in such diverse research as dc to high-frequency design, nanometer scale devices and materials, processing and characterization of thin film high-k dielectric materials (e.g. Hafnium oxide, organic electronic materials) based on polymers, carbon nanotubes, solar energy devices, low and high power electronics, bioelectronics, vehicular electronics, optoelectronics and display technologies.

CAD laboratory

The CAD lab is equipped with 11 PC's with PC spice (full version) and 8 Sun workstations running Mentor Graphics Cad tools and Berkeley 3f5 spice (within the Integrated Circuit Design Lab). This laboratory encompasses a 2000 square foot class 100 clean room with photolithography, mask making, metal deposition, and film thickness equipment. Scribing, bonding, and ovens are also available and UHV MOCVD and MBE equipment is housed in the rooms adjacent to the cleanroom.

Microelectronics Characterization Lab

Measurement equipment includes an I-V and C-V probe station, a 4-point probe resistivity station, and a DLTS system that are located in the metrology laboratory. The center also contains RPTP equipment for deposition of high and low K dielectric materials within a 1500 sq foot cleanroom in the Rhodes Engineering Research Center adjacent to Riggs Hall.

Electronics Systems Lab

Oscilloscopes, Curve Tracers, Radio Spectrum Analyzers, Arbitary Waveform Generator, PIC programmer and PCs running OrCAD Design Suite.

Electronics Research Labs

Various equipment and systems used for basic experiment such as ovens, work benches and fume hoods.

Semiconductor Process Lab (Clean Room in Rhodes Hall)

Rapid Photothermal Processing (RPTP) equipment for deposition of high and low-k dielectric materials is located in the 1500 sq foot cleanroom in Rhodes Hall.

Sub Fab - Houses the Spin coater, ovens, and CMP equipment.

Parallel Architecture Research Laboratory (PARL)

Directed by Dr. Melissa Smith, and Dr. Walt Ligon the continuously expanding PARL Computing Lab in Riggs 10 consists of an XtremeData XD1000 Development System (awarded by XtremeData systems), a Xilinx XUP VirtexIIPro Development System (donated by Xilinx) plus 10 more in use for ECE327 and my section of ECE893, a Reconfigurable Computing Cluster (2 nodes each equipped with: Two H101-PCIXM Application Accelerator cards from Nallatech and Dual Core 2.0GHz Intel Xeon processor systems), an SRC I-MAP station, a 4-node PS3 Cell-BE cluster, a ClearSpeed equipped workstation, 3 NVIDIA Tesla GPU-equipped workstations, 1 NVIDIA Fermi GPU-equipped Quad core workstation (GPUs donated by NVIDIA), 2 ATI Radeon HD 5870 GPU-equipped Quad core workstations (GPUs donated by AMD), a workstation with a GiDel 4-FPGA system for the Creative Inquiry team, and 4 GiDel 4-FPGA equipped nodes in Palmetto. Other additions to the Lab include the SRC SDK, CUDA, OpenCL, ClearSpeed SDK, ImpulseC SDK, Mitrion SDK (donated), DSPLogic RC Toolbox (donated), and the full suite of software from Xilinx (donated) and Altera (donated).

Current projects include developing

HECIOS - The High End Computing I/O Simulator

PVFS - The Parallel Virtual File System for Beowulf clusters

BeoSim - A Multi-cluster Computational Grid Simulator for Parallel Job Scheduling Research

SNR - Sensor Networked Robotics

STARE - STructured Analysis of the REtina

Real Time Power and Intelligent Systems Laboratory (312 Fluor Daniel EIB)

Directed by Dr. Kumar Venayagamoorthy, the Real Time Power and Intelligent Systems

Laboratory (RTPIS) Real-Time Power and Intelligent Systems (RTPIS) Laboratory is the platform for developing and applying various computational paradigms and technologies to develop methods for creating improved smart grids and power systems. Research areas include, but not limited to, adaptive devices, circuits and systems, cyber-physical power and energy systems, plug-in and hybrid vehicles, renewable energy systems, real-time simulation and hardware-in-the-loop (HIL) studies, intelligent sensor networks and signal processing, and wetware-in-the-loop (WIL) studies.

Current research in the lab involves the following research initiatives.

Adaptive devices – Developing algorithms and hardware for reconfiguring devices, circuits and systems under rapidly changing operating conditions to maintain system safety and security, and advance intelligent testing and fault detection algorithms, and circuit partitioning.

Computational intelligence – Developing Computation Intelligence (CI) techniques to solve real-world complex problems such as Adaptive Critic Designs, Evolutionary Computing, Fuzzy Logic, Immune Systems, Neural Networks, Swarm Intelligence, Hybrid systems .

Power and energy systems – Improving control and stability of the electric power grid, integrating alternative energy sources (wind energy, solar, fuel cells) to the conventional electric power network, creating strategies for optimal energy management and scheduling, and for reducing carbon emissions, and for the real-time simulation of power system and power system components.

Sensor networks and robotics – Involves simulation and hardware studies to develop dynamic scheduling and minimizing energy consumption in sensor networks, smart topologies for sensor networks, and intelligent data fusion, and intelligent algorithms for collective robotic search.

Signal processing - Involves developing methods for facial expression recognition, speaker identification and verification, and speech and image quantization.

Power Quality and Industrial Applications Laboratory

The Power Quality and Industrial Applications Laboratory has the following equipment:

- Dedicated 500kVA, 480V, three-phase source
- Three-phase sag generator up to 25kVA, 480V
- Mobile three-phase sag generator to 18kVA, 480V
- Three-phase arbitrary waveform generator and linear power amplifiers
- Programmable dynamometer for testing ASD's and motors dynamically
- DC and AC motor drives of various types and capabilities
- Data acquisition systems and digital oscilloscopes
- Various Power Quality Monitors
- Assorted PT's and CT's up to 1300 V and 1200 A
- Assorted Power Transformers: < 1 kVA up to 37 kVA (1 and 3 phase)
- Power electronic load banks and switch mode power supplies

Robotics and Mechatronics Laboratories (Intelligent Systems)

The Robotics and Mechatronics Laboratory features over 2,000 sq. ft. of floor space for research into the development of mechatronic systems, robotics, and manufacturing automation. The Square-D Laboratory features a Barrett industrial robot hand/arm system and a Haptics testbed. The Biomimetics Laboratory has a non-anthropomorphic dexterous robot hand, an elephant trunk robot arm, and several "trunk/tentacle" continuum robots. The Robotics Laboratory includes several laboratory robots, PUMA 560 and 500 industrial robot manipulators, and a custom-built adaptable robotic wall system. These labs are supported by state of the art real-time computing hardware, numerous types of contact and non-contact sensors, and an in-house machine shop including a new drill press and bandsaw.

Haptics Laboratory

Directed by Dr. Timothy Burg, Associate Professor of Electrical and Computer Engineering at Clemson, The Haptic Interaction Laboratory at Clemson University involves the science of applying tactile (touch) feedback to users interacting with virtual environments using special Input/Output devices. Other departments involved with work at the lab are the Department of BioEngineering, and the Department of Psychology. This interdisciplinary laboratory involves research in medical and surgical applications of haptics, studies on the cognition of touch, and

kinesthesis, and teleoperation and human-machine systems. Also under active research is the development of an open source haptics API called H3D, a cross platform scene-graph API, written in C++ that uses openGL for the graphics rendering. X3D is the format used for 3D image display.

H3D and the Quanser 5 DOF haptic interface

Lab personnel have also developed a driver to work with the Quanser 5 Degree of Freedom Haptic Wand, making it fully functional with H3D.

Available Haptic Devices

The feeling of touch or force is transferred from the virtual world and sensed by the user using these special haptic devices, which have variations in degrees of freedom, workspace area and force capabilities. The following available haptic devices are available in the lab.

The Novint Falcon - The Falcon is a haptic interface aimed primarily at the gaming community. Priced substantially lower than other haptic devices, it is a 3 Degrees Of Freedom (DOF) device and is capable of rendering a higher range of forces. The Falcon is quite sturdy and most appropriate for testing new applications.

The Quanser 5-DOF Haptic Wand - The Quanser Haptic Wand is a 5-DOF haptic interface that may be used for high precision applications such as medical/surgical simulations and for commercial research. It allows for three translations and two rotations (roll and pitch).This is achieved by using a dual-pantograph arrangement driven by DC motors. This arrangement also allows it to render feedback in the form of torques. The workspace of the wand is large which makes it ideal for research in our lab dealing with kinesthetic haptic interaction.

The Phantom Omni - The Phantom Omni is a 6 Degrees of Freedom device that has a pen-like interface. Though it can sense the movement of the stylus in the x,y and z directions, and rotations - pitch, roll and yaw, it does not render any output torques. The range of forces it renders is smaller than the Falcon, but it has better force resolution capabilities. The Phantom Omni is medium priced and is good for applications requiring the higher freedom and larger workspace it provides, for example, in 3D sculpting and other applications involving the manipulation of virtual objects.

Biomimetics Laboratory

The Manipulation & Biomimetics Laboratory features several robotic workstations devoted to this task. The facility is equipped to carry out experimental investigation into robot kinematics, dynamics and control, path planning, and novel robotic device prototyping. Real-time computer interfacing is available either through Hyperkernel, a microkernel which runs concurrent with Windows NT, or through Matlab/Simulink on a real-time Linux platform.

The main focus of the biomimetics laboratory at Clemson is the study of hyper-redundant and continuum robotics, especially as it relates to manipulation. Both types of manipulators resemble trunks, tentacles, or snakes, in that they are highly maneuverable and have backbones consisting of either many small links or one continuous highly flexible material.

Because of the abundance of links, HDOF robots such as the Elephant's Trunk may be modeled similarly to truly continuous-backbone devices like the Tentacle Robot. In our work, we often model these devices with infinite-dimensional kinematics. Because only a finite number of actuators deform the robot's shape, the infinite-dimensional kinematics admit an infinity of possible configurations for any given actuator input. Consequently, these robots exhibit a desirable side-effect, which we have termed "inherhent compliance" -- the tendency of a continuum manipulator to conform to environmental non-conservative forces in a compliant minimum-energy fashion.

Current devices include

- Goldfinger “thumbless" robot hand - This novel manipulator design is used to elucidate the possible uses of a non-anthropomorphic hand such as this one. With a solid understanding of the end effector's kinematics and actuation, Goldfinger serves as a testbed for work in dynamic and impulsive manipulation. Mounted to a Puma 560 or similar industrial robot, it has limited sensing abilities.
- Elephants Trunk Robotic Arm - The "Elephant's Trunk" robotic arm is comprised of 32 degrees of freedom in 16 small links. There are four sections with two controllable degrees of freedom each. Ongoing research using the elephant's trunk includes investigations into the robot's inverse kinematics and path planning.
- Tentacle Manipulator - This robotic arm has a continuous backbone encompassing two sections with two degrees of freedom each, and is remotely actuated. The primary

purpose of the Tentacle Manipulator is to study kinematic and dynamic modeling, especially as they relate to vibration control for hyper-redundant robots.

Robotics Laboratory

- The **TRC Pan-Tilt Unit** has custom control strategies for setpoint and tracking control and is controlled by a Pentium Pro 266 MHz running QNX Photon realtime operating system interfaced through a Quanser MultiQ board.
- The **IMI 2-Link Flexible Joint Robot** verifies torque-level control strategies. It has a base and elbow links actuated by NSK Megatorque motors RS1410 and RS0608, respectively, a Pentium Pro 266MHz running QNX real-time operating system, two NSK torque controlled amplifiers, and two IMI DS-2 encoder interface boards utilized in conjunction with two NSK resolver/encoders to measure actuator position.
- The Unimation 6 **Degree of Freedom PUMA 560 robot** has an RCCL/RCI system (Robot Control C Library) system controlled with 266 MHz Pentium computer running the QNX real-time operating system. The trajectory control task generates position and current setpoints for the individual joints of the robot(s) being controlled for this dual puma workcell.
- The **BH8-255 Barret Hand** multi-fingered programmable grasper can secure target objects of different sizes, shapes and orientations. The industry standard for serial communications, integration of the BH8-255 with any arm is fast and simple. The BH8-255 neatly houses a CPU, software, communications electronics, servo controllers, and all 4 brushless motors. Of its three multi-jointed fingers, two have an extra degree of freedom with 180 degree of synchronous lateral mobility supporting a large variety of grasp types.
- The Unimation Staubli RX130 manipulator is a six DOF robot with a payload capacity of up to 24 kgs. The rigid structure, totally enclosed arm, and patented gear reduction system to produce zero backlash, and is widely used in robotic assembly. It is controlled based upon feedback given by numerous cameras surrounding the workspace.
- Cybermation K2A Mobile Robot provides maneuverability to autonomous and tele-

operated systems in industrial environments. The synchro-drive locks all three wheels together in both steer and drive. When a turn is executed, all three wheels turn in unison and trace parallel paths to each other so that the platform itself does not rotate during turns. The K2A runs off a Pentium PC QNX real-time operating system.

- The 6 DOF High speed magnetic Bearing turbine can reach speeds of up to 10,000 rpm driven by 4 Techron Linear amplifiers. It is controlled by a Pentium Pro 333 MHz running QNX, with a special high speed D/A for data sampling up to 20,000 Hz.
- The Magnetic Levitation Apparatus Model (MAGLEV) 730 is used to create real-time algorithms via QNX for linear control of non-linear magnetic field created by the high flux coils. It has a a +/- 12V power supply and an operational amplifier circuit, laser sensors, and C code to O/P voltage to MLD. Unlike traditional mechanical bearings, the MAGLEV is subject to frictional loss, compensates for rotor unbalance, and eliminates associated lubricant and frictional wear contamination.
- The Auto-Balancing, Flexible Shaft Rotor System damps the vibration of a flexible at very high rotational speeds (3000rpm) to apply control force at the free end through a magnetic bearing assembly. Two linear CCD cameras measure the end point position and the shear force is measured by an XY shear sensor. A Pentium Pro 266MHz with QNX real time OS controls it through a Quanser MultiQ I/O board interface.
- The Barret technologies WAM Arm is a highly dexterous backdrivable manipulator with direct-drive capability supported by transparent dynamics between the motors and joints for unmatched joint-torque control. It has 4-degree-of-freedom and 7-degree-of-freedom with human like kinematics and internal for passing electric lines and fiber optics for custom end-effectors and sensors. The joints are highly backdrivable for high performance inherent force-control, hybrid control, and teleoperation.

Automotive and Mechatronic Research Laboratory

The Director of the Automotive and Mechatronics Research Laboratory is Dr. John Wagner, Professor of Mechanical Engineering at Clemson University. This laboratory conducts research

in Nonlinear & Intelligent Controls, Mechatronic System Design, and Diagnostic & Prognostic Strategies. A variety of automotive and mechatronic systems are the focus of real time control theory, intelligent system design concepts, and health monitoring research. The Automotive Research Laboratory has over 300 sq ft of floor space supporting vehicle thermal management, automotive steer-by-wire, and electro-hydraulic systems research. The automotive cells have the following equipment available to support mechatronics research: SuperFlow 901 engine dynamometer, International Dyno Corporation Model 500 dynamometer, Electro-Mechanical Micro-Dyn 35 dynamometer, Interro Systems emission gas analyzer, assorted gasoline and diesel engines, development and production automotive controllers, Omega temperature and fluid flow sensors, and assorted actuators and sensors. The hydraulics bench is equipped with a Bosch hydraulics pump, two Bosch servo-proportional valves, a Moog servo-valve, assorted sensors, and hydraulic cylinders and motors for chassis control investigations. The laboratory also has dSPACE based real-time workstations used for data acquisition and control, as well as Matlab/Simulink software packages with Real Time Workshop. The Mechatronics Laboratory has over 500 sq ft of floor space dedicated to real time hardware-in-the-loop automotive simulators supporting both human/machine interface haptic studies and steering system design research. The equipment includes a high fidelity motion based automotive simulator with dSPACE based data acquisition and control hardware, and open source video gaming mobile simulators for novice driver safety training. The laboratory has access to the machine shops in the Mechanical Engineering Department which has full time technicians to support research activities.

UAVs Laboratory

The Clemson University Unmanned Aerial Vehicle (UAV) Laboratory, housed in the Robotics and Mechatronics Laboratory in the Department of Electrical Engineering at Clemson University, fosters the design of aerial platforms through research on developing, simulating, and testing new systems built with a mechatronic approach in which issues regarded as separate, e.g., flight control, path planning, position sensing, image processing, are combined and solved together. The UAV platforms are targeted for applications requiring automated

launch and travel, precision hover and survey, and automated return. The laboratory includes electric actuators, encoders, tachometers, laser displacement transducers, torque meters, signal conditioners, oscilloscopes, multimeters, function generators, scaling amplifiers, Techron 2KW linear amplifiers, high speed vision systems for visual servoing, and QNX real-time workstations for data acquisition and control. The lab has the following aircraft:

- SR100 UAV Helicopter System−Gasoline power plant 7 kg / 18 lbs Payload Capacity WAAS differential Safety/Manual Aircraft Controller & Transmitter 802.11-based Telemetry System that can engage in stable hover.
- SR20 UAV Helicopter System with an electric propulsion motor, 10 lb. payload capacity, WAAS differential included, ready-to-fly autonomous, safety/manual aircraft Controller & transmitter, 802.11-based telemetry system with a Stable hover
- The Draganflyer X-Pro−Four rotor electric, radio controlled, electronically stabilized flying platform. Full pitch, roll, yaw, and altitude control using conventional helicopter inputs. Dimensions are 55.5" from rotor tip to rotor tip and 7" high. 4.8 volt 7800mAh Li-Poly rechargeable battery Professional Quality Pan and Tilt CCD Color Videocamera with 900Mhz Transmitter and Receiver 1lb payload capacity.
- Gohbee Stinger−Heli .50 radio controlled helicopter. 50 radio controlled helicopter600mm Carbon Fiber BladesMain Rotor Diameter: 1348mm (53.1") Fully Equipped Weight: 2850g (6.25lbs) Futaba controller and servosOS Engine.

Speech Process Laboratory (314 Fluor Daniel Engineering Innovation Building)

The Digital Speech and Audio Processing Laboratory, located in the Fluor Daniel EIB facility, involves research in the advanced processing of speech, audio and video signals as related to the use of visual cues in speech recognition. The laboratory has an array of cameras, microphones, a controlled acoustical booth, a controlled acoustical booth, Sun and Linux workstations. The Here's an overview of our ECE 846 Speech Tools Software is also available, used in a series of practical labs in conjunction with a speech processing course. In this Javagram used for remote homework submission, routines are included for visual phoneme segmentation, speech production modeling, coding, cepstrum, and zero-crossing. The software

runs under Linux or Solaris and possibly other Unix platforms. It is freely available with the Linux binary and all source code.

The downloadable package is available under the "Tools" page on this website. If you find the software useful, interesting, or have other comments, please send us an email. We have a series of labs in conjunction with the software that may be posted on the web in a future update.

It is recommended that the software be placed in /usr/local/ece846 and that "tcsh" is run as your command shell, with the lines in the file "addto.tcshrc" added to your .tcshrc file. We may be able to help if you have problems installing, but no official support is available, unfortunately.,

Vehicular Electronics Laboratory

The Clemson Vehicular Electronics Laboratory (CVEL) conducts targeted research related to automotive and aerospace vehicle electronics including electronic components, circuits, sensors, communications, power distribution and mechatronics with an emphasis on systems integration, electromagnetic compatibility and modeling. The lab is located in the Carroll A. Campbell Jr. Graduate Engineering Center on the campus of the Clemson University International Center for Automotive Research (CU-ICAR). It features a 28' x 20' x 18' RF semi-anechoic chamber and is equipped to make a wide range of electromagnetic emission and susceptibility measurements. It is also equipped to do real-time RF data collection and processing, as well as diagnostic testing and analysis. CVEL researchers specialize in the electromagnetic modeling and measurement of highly complex electronic components and systems.

Wireless Communications and Networks

The Clemson Wireless Communication and Network initiative encompasses several labs: the Holcombe Laboratory for Digital Communications, the Barnes Telecommunications Laboratory, and the ITT Laboratory for Spread Spectrum Communications.

Holcombe Laboratory

The Holcombe Laboratory has a high-speed Sun SPARC computational server with 20 processors for research on mobile spread-spectrum communication systems and networks. The workstations have communication system simulation packages that permit computer

simulation of key elements of radio communication systems and networks. The available Signal Processing Worksystem software enables the simulation of wireless communication links over many channels in conjunction with a highly detailed specification of the transmitter and receiver hardware. The Holcombe laboratory also contains OPNET for simulation of mobile, distributed, wireless communication networks. The workstations also have both C and FORTRAN compilers for more specialized analysis and simulations of wireless communication subsystems and systems. The Wireless Communications Program has a computer system for computation-intensive research that consists of twelve DEC Alpha processors operating at 667 MHz. Twelve older DEC Alpha processors are also part of the system. The processors use the Tru64 operating system (a variant of Unix) and include DEC's Load Sharing Facility (LSF), DEC FORTRAN, and Parallel Virtual Machine (PVM). DEC LSF permits the "load-balance" of large jobs across the cluster of processors, while PVM provides an easy-to-use message passing facility for writing coarse-grain parallel programs using all processors.

The processors are connected via a DEC Gigaswitch crossbar switch for transfer between any two processors at speeds up to 100 Mbits/sec. This allows sufficient communication throughput among the processors for efficient parallel processing. This Gigaswitch also enables sufficient throughput to the campus network backbone for data transfer to remote workstations for programming, visualization, and data analysis.

The Holcombe Laboratory also hosts research efforts in sequential and parallel computational electromagnetics research, simulation of wireless communication links and networks, parallel satellite data analysis programs, and experimental systems software for simplifying the task of scientific and engineering programming on a distributed cluster of computers. The ITT Laboratory and the Computational Electromagnetics Laboratory houses both Sun workstations and Alpha processors that are augmented by Macintosh and Pentium-based personal computers. These machines have FORTRAN software and can serve as additional terminals for the high-speed processors.

Center for Silicon Nanoelectronics Laboratory

The Center for Silicon Nanoelectronics at Clemson University conducts research in the

development of silicon nanoelectronic devices. Situated in the basement of Riggs hall, the 2000 square foot laboratory contains equipment for mask making metal deposition, wet etching, photolithography and packaging for semiconductor integrated circuits. The laboratory also has a 900 square foot clean room with class 100 areas. Measurement and surface characterization equipment includes surface roughness, wafer profilometers, resistivity and film thickness apparatus. Equipment can handle wafers up to 75 mm diameter and can be used to process small pieces for experimentation. Other research laboratories include the Rapid Isothermal Processing (RIP) and ultraviolet (UV) assisted Metal-Organic Chemical Vapor Deposition (MOCVD) facilities for the deposition of dielectrics, semiconductors and metal. . Additional equipment includes oxide growth, current-voltage measurement system, data acquisition and test systems, ovens, controlled humidity environments, mechanical stress equipment, probe stations, DLTS and C-V measurements. The department also has a laboratory equipped with four Apollo/HP and two Sun Sparc workstations with full Mentor Graphics Integrated Circuit Design software. A recent addition is the Silva co process modeling software. Over 100 SUN Sparc workstations are available in the College computer laboratories to access both the Mentor Graphics and Silvaco (process simulator) tools.

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