The goal of these projects is to elucidate the mechanisms of human disease and develop promising new methods for cures and treatments.

The laboratory's facilities include more than 200 workstations, three Linux clusters, and access to the National Science Foundation (NSF) TeraGrid and other high performance computing facilities. Projects in the laboratory frequently involve cutting-edge genomic and proteomic instruments such as the Roche 454 next-generation sequencing platform and several high-throughput gene expression (microarray) measurement platforms.

## Computer Systems

High performance computing research involves development of collaborative and parallel computing environments and associated software tools, and use of these facilities and tools in varied application domains, including image processing and computational biology. Current work in networking focuses on protocols and layer-integration schemes that support high performance wireless networking, and on control and coordination of mobile ad hoc networks. Current research facilities in these areas include several large cluster computers and an experimental asynchronous transfer mode (ATM) network.

Departmental facilities that support this work include Linux and Windows workstations and server nodes that provide college-wide networked computer services. Advanced computing facilities also are available at national supercomputing centers and federal laboratories.

## Control Systems and Systems Theory

Control systems and systems theory use feedback to improve the predictability and efficiency of engineered systems ranging from electronic amplifiers to vehicle guidance systems, manufacturing processes, communication channels, and the internet. Work in control systems and systems theory draws heavily on results from mathematics, physics, and computer science to model the systems that are to be controlled and to implement feedback controllers.

Current research emphasizes optimal, adaptive, digital, robust, and stochastic control and the control of discrete event dynamical systems. Recent work has concerned the estimation, identification, and robust control of linear and nonlinear dynamical systems; set membership identification, control over wireless communication channels; coordinated fault tolerant control of unmanned vehicles; use of control theory to analyze distributed computing, communications, and manufacturing systems; Interplay between communications and control; design of fast digital controllers using subband coding; and multirate control systems.

Research in control systems and systems theory is supported by extensive computing resources and collaborations with local industry, the National Advanced Driving Simulator (NADS), the Iowa Technology Institute, and the Carver College of Medicine.

## Nanoscale Electronics and Spintronics

Nanotechnology is the branch of technology that deals with dimensions that are 10,000 times smaller than the width of the hair. Nanoscience and nanotechnology involve the ability to see and to control individual atoms and molecules.
Utilizing the nanofabrication and nanoimaging facilities available on campus, nanoscale transistors, optical circuits, biosensors, and solar cells are being developed. Departmental researchers are pursuing experimental, theoretical, and large-scale computational approaches.

**Optoelectronics**

Research in this area is carried out primarily in the new Iowa Center for Research, Exploration, and Advanced Technology in Engineering and Sciences (Iowa Creates) at the Iowa Advanced Technology Laboratories, a well-equipped, modern facility two blocks from the Seams Center for the Engineering Arts and Sciences. Current research topics are optical and electronic properties of semiconductors, semiconductor devices, electro-optics, nonlinear optics, nonlinear wave propagation in plasmas, nanotechnology, and medical devices. This research is at the interface of optical engineering, materials engineering, quantum physics, and electromagnetics.

Much work is done in collaboration with other University of Iowa departments, including the Departments of Physics and Astronomy, and Chemistry (College of Liberal Arts and Sciences), and the Departments of Internal Medicine and Neurosurgery (Carver College of Medicine). Facilities include two molecular beam epitaxy reactors (in physics and astronomy), a microfabrication laboratory with nanometer resolution capabilities, electrical characterization capability to 22 GHz, several Ti-sapphire lasers, a mid-infrared optical parametric oscillator, and plasma equipment for nonlinear wave plasma interaction studies.

Examples of current projects are the design and fabrication of diode lasers and light-emitting diodes based on the bandgap engineering of antimony and arsenic-based III-V compound semiconductors, phase control of laser arrays, development of an all-optical power equalizer, characterization of quantum well devices, nonlinear waveguide devices, development of a noncontact method to measure transport properties, plasma and optical soliton excitation and propagation, development of cellular probes, gas sensors, and a laser scalpel for medical research.

**Signal and Image Processing**

Research in image processing and basic and applied signal processing is supported by a digital signal processing laboratory and an image analysis laboratory. Collaborative research with faculty in the Departments of Radiology, Neurology, Psychiatry, Internal Medicine, Ophthalmology and Visual Sciences, Radiation Oncology (Carver College of Medicine), and the Roy J. Carver Department of Biomedical Engineering is directed at quantitative analysis of medical images.

In the area of signal processing, current projects include analysis and design of efficient adaptive algorithms for signal processing, efficient coding and transmission of speech, speech processing aids for the hearing impaired, robust equalization of uncertain channels, application of neural networks to communications systems, multirate signal processing, and subband coding and channel equalization.

Image processing and analysis projects include development of novel methods for image segmentation, image registration, computer-aided detection and diagnosis, early identification of disease patterns from medical image data, computer-aided surgical planning, augmented reality medicine, image visualization, building anatomic atlases, and a broad range of translational medicine projects focusing on research and clinical applications of the novel methods. The areas of interest span all scales, from molecules to cells to small animals to humans, and cover a broad range of organ systems and targeted diseases. The spectrum of medical imaging modalities used for research and applications in image processing and analysis is equally broad, encompassing all existing modalities, including X-ray, CT, MR, PET, SPECT, and OCT.

The Medical Image Analysis Labs consist of several specialized facilities for digital image processing. They are equipped with state-of-the-art devices for data storage, transfer, visualization, and analysis. High-capacity data storage devoted to image processing research offers more than 35 TB of online hard disk space. An augmented reality medical image visualization lab serves as a high performance collaborative resource for the Iowa Institute for Biomedical Imaging. The institute makes additional resources available to image processing research, including small and large animal as well as human research scanning facilities, and provides a backbone for interdisciplinary medical image analysis research to electrical and computer engineering graduate students and faculty.

**Wireless Communication Systems**

The department is engaged in research using wireless sensor networks (WSNs), which consist of spatially distributed autonomous devices that use sensors to cooperatively monitor physical or environmental conditions such as temperature, sound, vibration, pressure, motion, and pollutants at different locations. WSNs are used for environment and habitat monitoring, health care applications, home automation, and traffic control. Current research includes the application of WSNs, traditional telemetry, and commercial cellular communication infrastructure for geosciences data collection (e.g., rainfall, water quality, soil moisture).

Another important research interest involving distributed sensor networks is the distributed control of power systems, especially requirements of the next-generation electric grid with smart metering and distributed generation using small-scale wind and solar generators. Research on WSNs also includes the design of cooperative communication techniques for energy efficient WSNs and issues of localization, network organization, and control.

Research activities in communication systems focus on design and analysis of receivers for digital wireless communications, especially the development of effective and practical receivers for multiple-user wireless cellular systems in multipath channels. Topics of research include the design, analysis, and experimental demonstration of large-scale distributed multiple-input multiple-output (MIMO) arrays for communication sensing and electronic warfare; precision interference cancellation techniques using feedback control; and synchronization and channel estimation for massive MIMO Base Stations.