

# Center for Intelligent Systems at Vanderbilt University

## An Overview

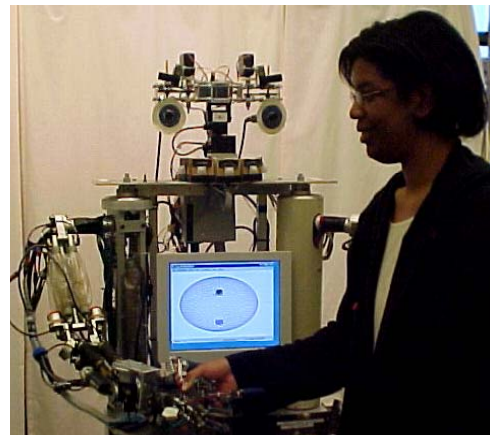
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### Introduction

The robotics field has evolved from industrial applications in the 1960s to nontraditional applications such as medical surgery and outdoor search and rescue missions. The Center for Intelligent Systems (CIS) at Vanderbilt University (See: <http://eecs.vanderbilt.edu/CIS>) was established in 1985 to advance the state of the art in intelligent systems through research and development of human-robot symbiotic systems. Currently research emphasis is on humanoid robots, collaborative teams of human and mobile robots and robust human-robot interface technologies. Other research areas include brain-machine and holonic manufacturing.

### Humanoid Research

Partnership between a person and a robot could be easier if the robot were intelligent enough to understand human intentions and perform accordingly. During the last decade, we have been developing such an intelligent robot called Intelligent Soft Arm Control (ISAC) in a form of a humanoid robot. Initially ISAC was designed to assist the physically disabled during meals [1], but gradually became a general-purpose humanoid test bed for human-robot teaming [2]. ISAC has been equipped with pneumatic actuators called McKibben Artificial Muscles and sensors such as cameras, microphones, and infrared sensors for capturing communication modes (See Table 1: ISAC system information). Unlike many humanoid research groups in the world who place more emphasis on human-like motion control and efficient walking pattern generation, our group places emphasis on the cognitive aspects of the humanoid. For example, we have developed short-term and long-term robot memory structures called the Sensory EgoSphere [3] and the Procedural Memory [4]. Another uniqueness of our humanoid is a multi-agent architecture called the Intelligent Machine Architecture (IMA) [5]. IMA allows us to integrate the robot itself and the human within a unified framework. ISAC also provides the ability to develop mix-initiative interaction between the robot and single or multiple human operators. ISAC's interaction capabilities include speech recognition and generation, visual displays, gesture creation, tactile interaction, and visual recognition. The appropriate combination of these capabilities provides a natural interaction between the robot and the human operators.



Our most recent research area is called cognitive robotics. In order for a humanoid robot to become a true human partner, we hypothesize that the humanoid robot must possess three abilities: *self-awareness*, *awareness of others*, and the *ability to reason its own abilities* [6]. We call such a robot a *cognitive robot*. One of the challenges here is how to represent self-awareness within a multi-agent cognitive architecture.

## Mobile Robotics

Research on mobile robotics is conducted within the Center's Intelligent Robotics Lab (IRL) (<http://eecs.vanderbilt.edu/CIS/IRL>). There are three main robots used in our research. *Scooter*, an ATRV-Jr, is equipped with sonar, laser rangefinder, compass and DGPS sensors, plus a pan-tilt vision system. The Pioneer2-AT, *Skeeter*, is equipped with sonar and a 360-degree camera array. *Rocky*, our newest one is a track-driven Matilda robot (right photo). Current research projects include human-robot teaming, PDA-based navigation, an adaptive Graphical User Interface [7], Egocentric Navigation, Sensory and Landmark EgoSpheres [8], an Egocentric user interface [9], and PDA-based supervisory control [10].



In mobile robot research, the human user is often located at a remote site. In such situations, there are multiple challenges. One challenge is that the robot must understand what the user is communicating, particularly the details of its task. Yet



another challenge is providing the remote operator with an accurate understanding of the remote environment, the current task status, and the robot's health. The human's ability to gain such an understanding requires that the robot communicate either raw sensory information or processed sensory information regarding the robot's status, perceptions, and understanding of the environment. The information obtained from the robot must be interpreted and presented to the human in a useful manner.

Simply presenting humans with raw data is not sufficient for the human to develop an accurate understanding of the remote environment. One task that the robot can become responsible for is determining when it requires assistance from the human and requests such assistance, thus creating a mixed-initiative interaction. Therefore, the development of intelligent adaptive interfaces is central to this research. Such interfaces may be provided via portable devices such as notebook computers, personal digital assistants (PDA's) (left photo), and the new tablet PC's. One constraint when employing such portable interaction devices is the

inability to present large amounts of information given the limited display real estate. This constraint requires the development of integrated information displays and the incorporation of multimodal interaction techniques or the development of new and unique interaction capabilities.

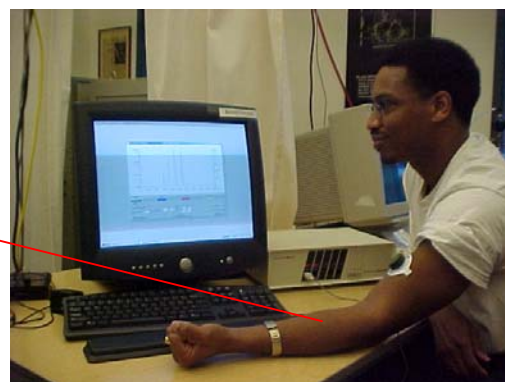
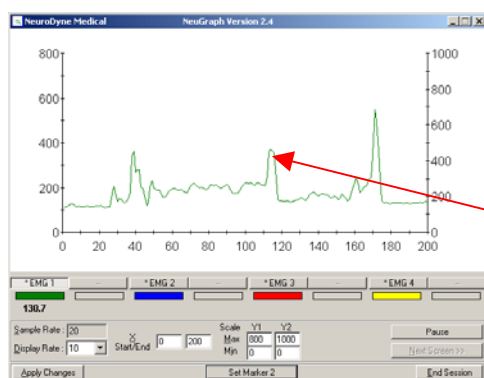
Recently, robots have begun to make their way into the field for military missions. Additionally, the DoD is supporting advanced research in robots as evidenced by the DARPA programs in Mobile Autonomous Robot Software (MARS) and Tactical Mobile Robots (TMR), as well as the DoD effort in Future Combat Systems (FCS). One thing that has become clear in such robotic applications is the importance of creating an effective team composed of potentially multiple humans and multiple robots. Some of the capabilities that are needed for effective teaming between man and robot are:

- Mixed initiative interaction that relies on the both the human and robotic capabilities when appropriate or necessary. For example, the human's superior perceptual or reasoning abilities may be employed to redirect a robot's activity that would otherwise lead to a problem situation and direct operator teleoperation.
- Novel Egocentric Navigation capability that incorporates a human's superior perception abilities with machine perception to achieve robust performance.
- Sharing knowledge between team members. For example, the sharing of the local tactical situation between the robots on the team or human team situational awareness.
- A practical, portable, and intuitive user interface that facilitates effective multi-way coordination and cooperation between human operators and machines. Such an interface may be based on hand-held computers or PDAs.

In the IRL we are developing enabling technologies for providing these capabilities. This work is supported by an ETEAMS Grant sponsored by AMCOM, SMDC, and NASA and previously by a grant from DARPA-MARS.

## Brain-Machine Interface

As part of human-machine interface research, we developed a tri-phasic robot arm control algorithm using simulated surface EMG signals as shown in the following figure. Current research seeks to extend this to surface EMG signals extracted from human muscles.



## References

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## Examples of Sponsored Research Projects

### Defense Advanced Research Projects Agency (DARPA)

- Acquisition of Autonomous Behaviors by Robotic Assistants (MARS2020)
- A Software Architecture and Tools for Autonomous Mobile Robots (MARS)
- Tools and Techniques for Agent based Adaptive Human-Robot Interaction
- Robotic Teams for Perimeter Surveillance and Reporting

## Industrial Sponsors

- Research and Development on Service Robots
- High Precision Robotic Manufacturing
- Pick-and-Place Robotic Handling System

## Facilities

There are two research labs within CIS. The *Intelligent Robotics Lab (IRL)* is equipped with a variety of mobile robots, including ATRV-Jr., Pioneer2-AT, Matilda, Helpmate and smaller robots such as Trilobots, Talriks and a Sony Aibo. The *Cognitive Robotics Lab (CRL)* conducts a variety of humanoid and cognitive robotics research using the ISAC Humanoid Robot.



The Center is located in the heart of Vanderbilt's campus in the new state-of-the-art engineering facility Featheringill Hall (left), completed in 2002.

## Faculty and Students

The faculty is comprised of professors and a post doc in the fields of EE, CS, ME and Psychology as follows:

- Kaz Kawamura**, EE, Director (Cognitive Robots; Intelligent Robotics/Manufacturing)
- Gautam Biswas**, CS, Associate Director (Hybrid systems, diagnosis and AI)
- Alan Peters**, EE, Assistant Director (Sensory EgoSphere, SMC-based skill learning)
- Mitch Wilkes**, EE, Assistant Director (Egocentric navigation)
- Bobby Bodenheimer**, CS, (Graphics and animation)
- David Noelle**, CS and Psych, (Computational cognitive neuroscience)
- Nilanjan Sarkar**, ME, (Human-robot collaboration, system health monitoring)
- Julie Adams**, CS, (Human-robot interfaces)
- Juyi Park**, EE (Real-time robot control)

More than 25 graduate and undergraduate students in EE, CS, BioMed and ME [Ph.D.(10), MS(11), BS(7)], currently conduct research plus we have one administrator.

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**Table 1: ISAC System Information**

<b>Interaction competencies for a personal robot</b>	<b>Hardware</b>	<b>Software</b>
<b>OBSERVATIONAL</b>		
Presence of Person: Infrared (IR)	Passive IR motion detector array	Digital I/O
Sound: Event Localization	Condenser Microphones	Matlab
Speech: Detection/Recognition	Handheld	Microsoft Speech Recognition Engine 4.0
Vision: Face and Gesture	Sony Color CCD Cameras	Visual C++ routines, some with Intel Libraries
<b>DEMONSTRATIVE / RESPONSIVE</b>		
Speech: Synthesis	PC Speakers	AT&T Natural Voices Engine
Motor behaviors: Head	Directed Perception PTU-46-70	IMA wrapper for serial port
Motor behaviors: Arms	Pneumatic Muscles	Visual C++ routines and control