

# REU 2009 Projects

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## Video and Image Processing

### 1. Next-Generation Video

**Supervisor(s):** Dr. Ishfaq Ahmad (100%)

**Size:** 1 student

**Skills:** multimedia computing, computer vision, artificial intelligence

IRIS (Institute for Research in Security) is engaged in full-scale research on designing algorithms and systems for the next generation of video technologies that will have 3D or multi-view video. In addition, we are focusing on the detection, analysis and interpretation of human behavior, for example, surveillance and intrusion detection, movies, automatic analysis of sports videos, broadcasts, video conferencing applications, etc. This is a new area of computing in multimedia that requires the integration of various data modalities including video, audio, sensors, and a myriad methods from the area of machine learning and artificial intelligence. This project requires a survey of various surveillance techniques currently reported in the literature.

### 2. COPSE – Multimedia Communication over Wireless Media for Law Enforcement Support

**Supervisor(s):** Dr. Ishfaq Ahmad (100%)

**Size:** 1 student

**Skills:** video communication, multimedia computing, computer vision, surveillance

COPSE (Collaboration for Public Safety Enhancement) is an integrated platform of a set of software tools, such as mobile audio-visual communication, concealed weapon detection (CWD), surveillance, and video retrieval and mining, installed in police cars or attached to officers' uniforms. It provides police officers with powerful technological means to fight crime and to ensure their own safety as well as that of the environment and citizens. COPSE is also a distributed and networked system for providing and disseminating accurate, timely, and reliable information, in pervasive fashion, anywhere and anytime. One of its major components is ubiquitous and mobile audio-visual communication system tailored to police need using wearable devices attached to officers' uniform.

The multi-party video communication is a result of our on-going research in video compression, wireless communication, and video streaming. COPSE ensures interoperability of widely dispersed heterogeneous data streams, and uses an evolutionary approach, in which additional technologies, such as biometric solutions, can be included. Students are required to take our existing prototype and make it in a form that can be demonstrated.

### 3. Video Stitching

**Supervisor(s):** Dr. Ishfaq Ahmad

**Size:** 1 student

**Skills:** video surveillance, advanced sensor networks, computer vision

We are interested in mimicking a grid of airborne sensors delivering live videos. The sensors essentially would form a huge net over a large area. The video streams from these sensors are sent to a station at the ground where server integrates them to gather what I call video stitching. The view from each sensor provides a small rectangle of video, and when multiple such streams are stitched together (we assume the system will be completely scalable and include 100s or even 1000s of such sensors), they provide an extremely large view virtually providing an "eye in the sky" to see everything, everywhere and anytime. In this projects, students will build only the stitching modules of this systems. Basically, you will take multiple live video streams each covering a rectangular area and you will build a stitching tool to assemble these smaller views to construct a large view. The stitched video could be played back on a normal screen with an interactive control to see a smaller are or total area, with zooming capability, something similar to Google Earth (but with live video instead of static pre-computed images).

## Service Robotics and Control

### 4. Semi-Autonomy and Assistive Wheelchair Control

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

Devices in assistive environments provide inhabitants with services that improve the quality of life. One of the most apparent of these capabilities are provided through assistive devices such as computer assisted wheelchairs. This project is aimed at establishing a basic computer control and interaction interface for an assistive wheelchair. The goal here is to design and build basic sensor and control capabilities to enable the wheelchair to keep track of its position, to make it responsive to user commands and give it the ability to anticipate the intentions of the user. There are two connected sub-projects here:

- **Design and Integration of an wheelchair that is aware of its environment:**

**Skills:** hardware integration, low-level embedded coding, control

Integrate a wide range of sensors (optical encoders, laser range finders, cameras, etc.) with computing devices on a wheelchair base and develop interface and control software to allow the wheelchair to navigate autonomously given destinations specified by the user.

- **Semi-Autonomous, Assistive Control through a Haptic Interface:**

**Skills:** robot navigation, user interfacing

Research and Develop high-level intuitive interface technologies that integrates user instructions provided through multiple interfaces (touch, joystick, gaze tracking, etc) with an autonomous control component to allow for collaborative control of the wheelchair between a human user and an autonomous computer navigation controller (path planner code already exists).

## 5. Localization and Mapping for Service Robots

**Supervisor(s):** Manfred Huber

**Size:** 1 student

**Skills:** uncertainty reasoning, odometry, Bluetooth interfacing

Using the Roomba robot with the Bluetooth interface. A number of robot tasks in the home are becoming available for robot assistants. Among them, cleaning has received significant attention. The Roomba is an example for this that uses a very primitive approach to navigate the robot. To achieve better results and to enable other capabilities (e.g. avoiding certain parts of the environment, etc), it would be preferable if the robot could use strategies that keep track of the location of the robot in the environment.

This project is aimed at providing the Roomba robot with the capability to keep track of its location in a known environment by using landmarks that it encounters with its bump and infrared proximity sensor to correct errors in its odometric location estimate over time. Research, design, and develop an approach that allows the robot to clean the environment without losing track of its location. The goal is to build a navigation scheme that minimizes the loss of precision in the robot's location estimate and that maximizes its ability to reacquire its location estimate based on known landmarks that it can acquire with its sensors.

## 6. Humanoid Robot Control

**Supervisor(s):** Manfred Huber

**Size:** 1 student

**Skills:** Zigbee interface, humanoid robotics, robot control

The Bioloid (you can google or youtube this fantasy name) is a small humanoid robot that come in a ready to assemble kit. It has on-board processing, sensors, and 18 actuators once it is assembled. Motion codes can be written in a user interface provided, which are compiled and uploaded onto the local processing board of the robot. Alternatively the robot can use a wireless interface to communicate with a powerful host (e.g., a PC) and transmit/receive sensory data and instructions. The same wireless interface can also be used to establish a “swarm” of communicating Bioloids.

The project itself involves setting up the Bioloid to communicate over its Zigbee (like) interface. After setting this up, odometry, kinematics, (maybe vision), and intuitive user interfaces (e.g., the Wii controller, or cyberglovkits) of Bioloids) can be used to control one or a swarm (depending on availability of other kits) of Bioloids.

## Intuitive User Interfaces

### 7. Human-Computer Interaction Using Muscle/Brain/Nerve Signals (EEG)

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

**Skills:** signal interpretation, biological data monitoring, machine learning

Making computer systems completely ubiquitous and transparent to the user, interfaces

should be in a way that does not require special attention by the user. Moreover, for users with severe disabilities, most existing interface technologies become unusable due to the physical challenges they pose for these users. The most direct (and least intrusive) interface technology would be to directly use signals from the brain or nerve cells of a user to drive the computer interface. This would effectively allow to interact with computer systems through “thought”. One of the most important challenges in making such interfaces possible is the interpretation of the signals produced to allow for the extraction of the intended actions. One application of this arises for example in the context of severely disabled users who no longer have full control of their arms or hands. In these individuals, smart prosthetic devices or assistive robotics could be driven directly off still existing nerves or muscles thus alleviating the need for non-intuitive, cumbersome commands to drive the assistive device.

The goal of this project is to research and study the use of direct muscle signals to drive an assistive robot arm. For this, a 12 channel EEG unit will be used to non-invasively read muscle activation signals at different locations on the arm. These signals have then to be interpreted and processed to extract corresponding movement commands for the robot arm. To achieve this, algorithms and training schemes have to be devised that allow to robustly interpret the biological signals in order to successfully command the robot arm such that it can pick up and manipulate objects.

## 8. Face and Facial Expression Recognition Using 3D Video

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

**Skills:** image processing, facial expression modeling

Being able to recognize and interpret the facial expressions of a person we interact with is a very important component in human to human interaction. This suggests that it provides essential clues that are of importance also to social computer systems that users interact with. While facial expression (and mood or emotion) detection from images has been studied, it is not very reliable. The goal of this project is to investigate how (and how well) emotional states can be predicted from 3D range and intensity images. For this, data from a Swiss Ranger ranging camera will be used which provides not only an image but also complete information about the distance between the object seen in each pixel and the camera (and thus information about the shape of the object – or face). On this data, algorithms for facial expression recognition will be developed and implemented which, in turn, allow to predict the current emotional state of the person that the system is interacting with.

## 9. Focus of Attention Modeling and Interpretation using Gaze

### Tracking

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

**Skills:** machine learning, image processing, human gaze modeling, robot control

One of the essential skills humans have when interacting with complex situations is their ability to focus on only the important parts of the environment. In doing this, humans actively guide their perception (in particular their eyes) to concentrate on the aspects that are relevant to the task at the particular point in time.

The goal of this project is to investigate and model human focus of attention in terms of visual gaze and to translate this into a computational model for a robot system. For this, a gaze tracker in the lab will be used to analyze human gaze patterns in the context of a simple copying task where a stack of blocks has to be copied. The insight gained will then be translated into a model for computer attention (based on a previously developed model for learning of perceptual focus of attention and short term memory usage) to allow a robot system to efficiently perform the same types of tasks (block copying).

## 10. Intuitive Haptic and Gesture Interfaces for Intelligent Environments

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

In intelligent environments interaction with the computer should be noninvasive and intuitive. As a result other ways (besides keyboard and standard mouse entry) are needed to send commands to a computer interface and to manipulate objects. The goal of this project is to establish gesture and/or voice interface capabilities for either a computer desktop system where objects are to be manipulated on the desktop or to a robot system to indicate commands that should be performed. Gestures are intended here to be movements and configurations of fingers and hands that translate into commands (for example object magnification, movement, rotation, etc. for the computer desktop application, or directions and destinations for robot commands. Two sub-projects are envisioned here to study different I/O technologies:

- **Gesture Interface Using Wii Remote or Cyberglove:**

**Skills:** Bluetooth interface, gesture and interface design.

Design and develop a system that uses the infrared camera in the Wii remote to detect gestures off a glove equipped with a number of infrared LEDs (the Wii remote contains a medium resolution (~800,000 pixels) IR camera that can track up to 4 infrared blobs at 100Hz and transfer the information over Bluetooth to a computer). This part involves design of an appropriate prototype glove, a gesture set that can be used to control a user interface for an intelligent environment. The gesture set should be robust in terms of limiting the number of incorrect detections.

- **3D Haptic Interfaces for Intuitive Interaction:**

**Skills:** haptic feedback, performance evaluation

Using Novint Falcon 3D force-feedback joystick. Haptics is an important sense in everyday life, conveying information about surface characteristics, weight, etc. For blind people it provides even more important information about their environment. When interacting with the computer this sense has so far largely been ignored and its benefit has been evaluated only in limited applications. Recently, however, low cost devices have become available which can provide force feedback in multiple dimensions. This project is aimed at designing and evaluating the benefits of 3D force feedback on the interface for different applications. The application domain for the evaluation and design could here be either a simple learning and manipulation environment (either the infant game in which a torus has to be moved along a set of wires. Another application would be for a service robot in a security sensitive application - bomb disposal, nuclear facility, etc.- to use 3D feedback to assist in a manipulation task where objects have to be assembled - a

simulation similar to a block stacking task - to assist in the correct assembly by producing forces paralleling the interaction forces encountered.

## Health and Aging Technologies

### 11. Health Technology Integration

**Supervisor(s):** Manfred Huber

**Size:** 1 student

**Skills:** networking, multimedia formats

One of the big stumbling blocks in making medical data more easily sharable, thus reducing health care costs, is the wide diversity of data formats and medical data systems in use today. The goal of this project is to investigate and develop a system for distributed data access to diverse medical data formats (with a focus on medical imaging data). For this, current imaging and medical data formats will be studied and a system will be developed that can dynamically translate and integrate data items from a source system into the data formats used by the target system. This reflects the situation where one hospital requests medical data on a patient from a different hospital with different health records systems.

### 12. Sensing and Data Analysis for Fall Detection and Prevention

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

**Skills:** Machine learning, data mining, human behavior analysis

Falls are one of the largest risk factors for elderly persons living at home, producing up to 70% of all hospitalizations in the age group above 65. While a good number of falls are caused by tripping, many are due to fatigue or other deteriorations in the gait and muscle activity that occurs in the course of activity. If these could be detected, it might be possible to not only detect when a fall occurred (which in itself would already allow to reduce the time between a fall and the point when medical care can be provided) but even to predict the risk of a fall in the future, thus potentially facilitating its prevention.

The goal of this project is to investigate and develop algorithms and models that permit to detect and predict the risk of falling from acceleration, foot pressure, and gait pattern data. These would allow the use of small sensor packages attached to a belt to be used to monitor gaits in a non-intrusive manner and subsequently to reduce the risk of falls and the injuries associated with it. Using the existing sensor systems in the lab and in the Kinesiology department, this project will collect data from different individuals, build models for standard gait patterns, and develop algorithms to detect deviations from these patterns that indicate risk factors for falling.

### 13. Behavior Modeling and Anomaly Detection

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

**Skills:** Machine learning, data mining, human behavior analysis

Using a person tracking system. Detecting unusual and unexpected occurrences of behaviors is an important capability in security sensitive environments. This applies to unusual behavior of devices (in order to detect or predict system failures) as well as of persons (to indicate security threats or to be able to predict the future behavior of the person - e.g. indicating disorientation in the case of elderly persons -), allowing to improve control. This project is aimed at investigating technologies to detect anomalies in inhabitant behavior and to classify the observed behavior. The goal is to develop a system that uses person tracking information to automatically form a model of the behavior of a person and subsequently utilizes this model to indicate significant changes in behavior of the person. Research and develop an algorithm that learns a model of the behavior of behavior data gathered by a tracking system and subsequently employ this model to detect if a sequence of observed behavior conforms with the model or represents an anomaly.

## Location-Aware Services

### 14. Location Aware Services for Mobile Devices

**Supervisor(s):** Manfred Huber

**Size:** 1 student

**Skills:** Web integration, mobile, embedded device programming

With the advent of mapping services on the Internet and the availability of large amounts of information on the world wide web, it has become possible for mobile devices (such as smartphones) to provide location-aware services to the user. The goal of this project is to investigate and develop such services that take advantage of sensors in the devices (GPS receiver and accelerometers) to determine the location of the user and then autonomously extract location-specific information from the Internet to provide valuable services to the user. In particular, the goal is to automatically provide floor plans for buildings a user enters as well as information about structures and available services an entertainment options that are available in those buildings.

Development will occur on a smartphone platform (iPhone, Google Android phone, or similar) and integrate the internal capabilities of the device with information sources such as restaurant web pages, Wikipedia, and google maps to autonomously extract relevant information.

### 15. Distributed Localization Using Wireless Signals

**Supervisor(s):** Manfred Huber

**Size:** 1 or 2 students

**Skills:** Localization technologies, networking, data filtering

Determining locations inside buildings is difficult due to the inability to use GPS signals. However, knowledge of the location would provide many potential benefits by enabling navigation aids inside buildings and other location-specific services. The goal of this project is to expand on existing localization technologies that use the wireless signals used for communication to determine the location of tags worn by the users. The specific scenario envisioned for this project is the situation where no wireless infrastructure is available in the

building. Instead, communication is established between the tags that are carried by a set of persons entering the building (e.g. in the case of firefighters entering a building, each might wear a tag and the goal is to be able to determine the location of every firefighter within the building from the wireless signals in order to be able to respond to problems in an efficient manner). Given that all tags can communicate, this project will develop the algorithms required to allow for the determination of location of all the tags through a process in which each of them estimates its position relative to the other tags.

## Energy-Aware Scheduling and Computing

### 16. Energy Efficient (“Green”) Job Scheduling on Multi-Core

#### Architectures

**Supervisor(s):** Dr. Ishfaq Ahmad (100%)

**Size:** 1 student

**Skills:** processor scheduling, simulations, high performance computing

More recently, industry and researchers are eyeing multi-core processors, which can attain higher performance by running multiple threads in parallel. By integrating multiple cores on a chip, designers hope to sustain performance growth while depending less on raw circuit speed and decreasing the power requirements per unit of performance. These workhorses of the next generation of supercomputers and wireless devices are poised to alter the horizon of high-performance computing. However, proper scheduling and allocation of applications on these architectures unfolds several new research challenges. We aim to develop novel scheduling algorithms for applications with and without precedence constraints that incorporate these essential issues. Using a simulation strategy, students will be given a code and simulator to develop new algorithms or improve existing ones.