Object Recognition using Machine Learning Techniques

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Machine learning is a technique that allows computers to recognize complex patterns and make intelligent decisions based on knowledge extracted from empirical data, and it finds extensive use in a wide variety of applications, including homeland security, health care, surveillance, and game industry like Xbox Kinect. Object recognition is a key component in many such applications. In object recognition, a computer is usually given a set of example objects, the computer then analyzes their characteristics, learns how to distinguish different objects based on their characteristics and tries to recognize an unknown object using the knowledge learned from the examples.

A typical object recognition system usually consists of three components: feature extraction (extracting characteristics from objects, usually in the form of numbers), classifier learning (obtaining knowledge from those characteristics), and decision making (recognizing a new object using the knowledge). Figure 1 shows a toy image classification system to classify dogs and birds. Due to lighting, pose, or other variations, images taken from even the same dog are different. Therefore, working directly with the images shown in the figure is difficult for a computer. The feature extraction component converts those images into a set of points shown in the left. Coordinates of those points represent features computed from the images. The classifier learning component then draws a line (decision boundary) between different objects (birds and cats in the figure). After that, a new object can be recognized by its location relative to the decision boundary.

Objectives:
1. Learn basic machine learning techniques in the Matlab environment,
2. Study some basic feature extraction techniques and
3. Implement a simple prototype recognition system.

Prerequisite: Basic computer skills and some programming experience. Matlab experience is a plus but not required.
**Image Enhancement**
High School Summer Project @ Vision Lab (http://www.eng.odu.edu/visionlab/)
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**Image Enhancement:**
Image Enhancement is a preprocessing technique to improve the visibility and highlight the features and details of the image. The most common technique includes global histogram equalization and histogram specification which try to make the histogram of an image uniform over all intensity levels or follow a specific pattern. The goal of this project is to develop a robust and efficient image enhancement technique to improve the visual quality of digital images that exhibit dark shadows due to the limited dynamic ranges of imaging and display devices which are incapable of handling high dynamic range scenes. The proposed technique process images in two separate steps: dynamic range compression and local contrast enhancement. See below for an example.

To successfully finish the project, the team will analyze existing algorithm and software for image enhancement, design necessary modifications and work on new methods. The implementation, evaluation/test and report writing will happen during later part of summer term. The students must be prepared to work on computer simulation. Previous experience with programming in C/C++/Java/Matlab, is helpful. A basic knowledge of signals and systems would be helpful, but is not required. The The team will meet and work in the Vision laboratory ((http://www.eng.odu.edu/visionlab/) in IPR1 at ODU.
The Overlapping biphasic waveform (also referred to as OLBI) is now being tested in patients who have heart failure. The OLBI is an alternative to the bipolar stimulation method. There is evidence that the OLBI performs differently from the bipolar and has advantages sometimes in patients. However under certain theoretical conditions the OLBI is identical to the bipolar stimulation and they should perform the same. A question is why do they sometimes perform differently?

This project will model the bipolar and OLBI stimulation in a simplified 3 dimensional volume conductor. The goal is to create a program using the Matlab tool that computes and displays the electric fields that are produced by the different types of stimulation. A number of experiments with different electrode locations and current magnitudes can then be performed using this program.

Student(s) will need to know (or be prepared to learn), Matlab on a computer. The work will be carried out in the Kaufman building at ODU.
Ab initio Protein Folding

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This exciting research project targets the \textit{ab initio} protein folding problem, i.e., computationally modeling the protein 3D structure from its sequence. By taking advantage of the latest supercomputer, in this project, we plan to develop novel computer programs to understand the protein folding process and obtain protein structures in high resolution. \textit{Ab initio} protein folding is a grand challenge with broad scientific and economic impacts. Success in this project can likely lead to development of new drugs, bio-energy, and biotechnologies. This research is currently supported by the National Science Foundation (NSF).

1 or 2 students should be ideal for this project.

\textbf{Objectives:}

1. Understand fundamental concepts in bioinformatics and computational biology.
2. Learn skills in analyzing large-scale biological data.
3. Master programming techniques in large computer system.

\textbf{Prerequisite}: Basic computer skills and some programming experience.
Exposures from the hazards of severe space radiation in deep space/long duration missions for NASA are a problem that need to be solved. Typically for an interplanetary journey, the radiation hazards to space crews arise mainly from space radiation such as galactic cosmic rays (GCRs) and solar particle events (SPE). Current conventional radiation protection strategies based on material-based shielding alone will be inadequate. Since thicker shields have a weight and cost premium, attempting to go with thick passive-shielding is not an attractive or viable path. The feasibility of active methods, such as electrostatic or magnetic or plasmas for shielding spacecraft from hazardous space radiation have begun to be studied with the intention of reducing the mass penalties.

In this project numerical simulations will be carried out to predict the trajectories of incoming high-energy ions in the presence of charged structures meant to deflect the incident flux.

**Objectives:**

1. Learn the Matlab environment and develop proficiency to code,
2. Evaluate energy distributions, particle trajectories and angular profiles based on a 12-sphere configuration, and
3. Include some animation to provide a more visual analyses.

**Prerequisite:** Basic computer skills and some programming experience. Matlab experience is a plus but not required.
Brain-Computer Interfaces (BCIs) are systems that allow severely disabled individuals to communicate and interact with their environments using their brain activity. In this research the brain’s electrical activity is recorded using head-mounted sensors while the user performs specified tasks, such as moving a robotic arm or using a visual keyboard to type a message. The resulting brain activity is translated into the user’s intended device commands via specialized software and processing techniques.

For this project, students will become research assistants in ODU’s Advanced Signal Processing in Engineering and Neuroscience (ASPEN) Laboratory. Students will work on a selected BCI research project that will entail one or more of the following components:

- Literature reviews
- Experimental design
- Human subject data collection
- Software development using Matlab or C++
- Hardware development
- Data processing and analysis techniques
- Robotic interfaces
- Formal documentation of the methodology and results

The projects may be tailored to the student’s specific interests and capabilities. Students will work closely with other experienced undergraduate and graduate research assistants in the lab.
This project involves numerical simulation for obtaining the shortest path for a transportation network. Prof. Nguyen will provide (and explain) a simple step-by-step numerical algorithm (with sufficient details, including simple/small scale examples) so that a high school student can understand and write his/her computer code implementation on the internet. Emphasis will be placed on “internet computer animation” with extensive usage of color, voice, and graphics.

1 or 2 students should be ideal for this project.

**Estimated Duration:** Time for the Summer project ~8-10 weeks.

**Prerequisites:**

1. Programming Skills in “any language” that is related to (or connected with) INTERNET computer ANIMATION environment, such as C++, C-SHARP, FLASH, JAVA, etc…

2. Familiar with MS words, and power point presentation (typing skill with mathematical symbols, drawing figures, preparing tables)

3. Although it is “NOT” a requirement, however, a high school student that has a working knowledge about “camptasia” software, using in conjunction with “smart-board” for recording the “presentation materials” and uploaded to YouTube will be even more appreciated.
An intelligent machine system such as a factory robot or a military drone is multidisciplinary in nature. It involves circuit design, sensor technology, human-machine interface, power systems, dynamics and controls, software engineering, etc. As such, the system integration, system reliability, life cycle cost and maintenance should be addressed in the design of a mechatronics system and device.

The understanding of the microcontroller, hardware interface, software programming, communication protocols in wire and wireless, and mechanical operations and knowledge are the essential elements in this multidiscipline based project designs/implementations. This project covers theory, hands-on, and programming activities. There will be real implementations on the related controls and designs.

Objectives:
1. Learn basic machine/assembly and C language programming designs.
2. Study and implement the wire and wireless communication protocols.
3. Implement actuators in stepper and dc motor controls.
4. Learn the PIC microcontroller architectures.
5. Explore various mechanical modules in actuator designs.
6. Integrate different mechanical and electrical modules in an embedded system design.

Prerequisite:
Basic computer skills and some programming experience are required.
Understanding the basic logic/digital and analog circuits’ theory and operation is also required.
Conversion of Waste-oil into Valuable Products like Hydrogen and Activated-carbon

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Plasma is the fourth state of matter that can be defined as a partially ionized gas. One well-know plasma is the lightning bolt during the thunderstorm. Plasma can be created in a laboratory environment through electric discharges between electrodes in gases or in liquids. An example is shown in Figure 1. The power needed for the discharge is supplied through discharging a capacitor previously charged at high voltages.

Temperature in the plasma can reach several thousand Kelvin. If a plasma is generated in an organic compound like waste engine oil or vegetable oil, the organic molecules can dissociate into carbon, hydrogen and small organic molecules like acetylene and methane, a conversion process that is useful for waste material recycling.

The efficiency of the conversion process is to be determined. The electrical energy dissipated in generating plasma will be measured. The carbon particles in the liquid can be filtered out and weighed on a balance. The gaseous hydrogen, acetylene, methane, etc, will be collected for analysis. The gas mixture can be separated into pure components, e.g., by gas chromatography. The gas mixture is injected into the chromatography column and pushed forward by a carrier gas. The gas species can be identified by the time of arrival at the outlet.

The long-term goal of this project is to develop a method for converting waste oils into valuable products like carbon nano-particles, hydrogen—a reducing agent and fuel, and acetylene—a fuel and a raw material for chemical industry.

Objectives:
1. Learn basic pulsed power circuit with example of high voltage capacitive discharge.
2. Learn gravimetric analysis with the example of quantitative estimation of carbon particles.
3. Study gas chromatography with the example of separating hydrogen, acetylene and methane.

Prerequisite: Basic knowledge of chemistry and physics.
Software Development for CubeSat Satellites

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There is a possibility that the Virginia Space Grant Consortium (VSGC) will receive funds on an Office of Naval Research (ONR) STEM grant that is focused on high school girls who are interested in science and engineering. The general scope of this project involves using space-based ocean color measurements to study the influence of storm water and other effluents on the coastal ocean. I have agreed to serve as the engineering coordinator for that activity—should it be funded, and this activity would accommodate a few high-school students.

Regardless of the ONR STEM possibility, I would be interested in working with one or two high school students on developing software that can be used for CubeSat satellites. I have an Air Force-supplied CubeSat satellite development kit that can be used to simulate actual spacecraft system behavior, including a radio communication link between a laptop computer and a prototype satellite. Should students be interested, we would develop some type of satellite demonstration that could be taken around to different schools.
This exciting research project targets the context sensing problem, i.e., understanding the surrounding conditions and the behavior of the phone’s user. By taking advantage of the latest sensing capabilities in smart phones (e.g., Nexus S, iPhone), in this project, we plan to develop interesting programming modules to collect the sensors’ data, analyze the collected data, extract context information, and develop applications that utilize this information. iSense is a grand challenge with broad scientific and economic impacts. Success in this project could lead to development and deployment of real applications in the Android/iPhone market.

1 or 2 students should be ideal for this project.

**Objectives:**
1. Learn and have fun

**Prerequisite:** Basic computer skills and some programming experience.
Computer Science Projects

**Area: Bioinformatics/Computational Biology**

**Mentors:** Drs. Jing He, Shuiwang Ji  (Email: jhe@cs.odu.edu)

**Project Description:** This joint project will focus on developing artificial intelligence tools to analyze a variety of biological data, including the 3-dimensional protein structure and gene expression data generated by high-throughput experiments. In this project, students will get hands-on experiences in cutting-edge research by applying artificial intelligence tools to attack biological problems. (2 students)

**Mentor:** Dr. Yaohang Li  (Email: yaohang@cs.odu.edu)

**Project Description:** This exciting research project targets the *ab initio* protein folding problem, i.e., computationally modeling the protein 3D structure from its sequence. By taking advantage of the latest supercomputer, in this project, we plan to develop novel computer programs to understand the protein folding process and obtain protein structures in high resolution. *Ab initio* protein folding is a grand challenge with broad scientific and economic impacts. Success in this project can lead to development of new drugs, bio-energy, and biotechnologies. (1-2 students)

**Area: Medical Image Computing**

**Mentor:** Dr. Andrey Chernikov  (Email: achernik@cs.odu.edu)

**Project Description:** Image-to-mesh conversion is the process of geometric discretization of the representation of biological structures for their modeling by numerical solution of partial differential equations. In this study the students will explore key requirements, recent progress, and open opportunities in real-time image-to-mesh conversion. (1 student)

**Area: Smart Devices**

**Mentor:** Dr. Tamer Nadeem  (Email: nadeem@cs.odu.edu)

**Project Description:** This project targets sensing and understanding the conditions of the mobile phone’s user. By taking advantage of the latest sensing capabilities in smart phones (e.g., Nexus
S, iPhone), we plan to develop interesting programming modules to collect the sensors’ data, analyze the collected data, extract context information, and develop applications that utilize this information. (1 student)

**Area: Real-Time Information Systems**

**Mentor:** Dr. Steve Olariu (Email: olariu@cs.odu.edu)

**Project Description:** The objective of our research is to design a real-time information system to improve emergency-response functions by bringing together information to respond to a terrorist attack, natural disaster or other small or large-scale emergency. (1 student)

**Area: Knowledge Based Systems**

**Mentor:** Dr. Kurt Maly (Email: maly@cs.odu.edu)

**Project Description:** The goal of this project is to develop an adaptive reasoning architecture and design an adaptive reasoning system whose scalability and efficiency are able to meet the interaction requirements of a question/answer system system when facing a large and evolving knowledge base. The system should be able to answer questions such as: Consider a potential computer science Ph.D. student who is trying to find out what the emerging areas are that have good academic job prospects. What are the schools and who are the professors doing groundbreaking research in this area? What are the good funded research projects in this area? (1 student)
Mentor: Prof. Dennis Darby (ddarby@odu.edu)

Project Description: I would be willing to supervise a project dealing with either the provenance of sediment archives from Denmark Strait during the Holocene using lithic counts to determine the history of ice calving from the east Greenland ice sheet. We would train a student or two to identify lithic grain compositions in the >250 micron size fraction from several sediment cores and then plot the data and interpret the provenance. This project would require one student to spend about 20 hours a week in our lab for about 2 months, but we could decrease the effort or expand it somewhat depending on the number of cores examined. This is part of an ongoing NSF project using Fe grain fingerprinting to determine the provenance of these same samples and the lithics would provide a nice comparison and hopefully add a different dimension to the research.

Mentor: Prof Dick Zimmerman (rzimmerm@odu.edu):

The Bio-optics research group will be working on a couple projects this summer that may be of interest to your Ocean Lakes HS students:

Project Description: 1) We are studying the impact of climate change (ocean acidification and temperature increase) on metabolism, growth and survival of eelgrass in the Chesapeake Bay. Eelgrass provide important ecosystem services for shallow water environments through the Bay (and throughout the world), but they are very sensitive to environmental conditions (temperature, light and pH/CO2). Projects this summer will involve laboratory experiments at ODU and the Va Aquarium, field work in the Chesapeake Bay and coastal lagoons of the DelMarVa Peninsula and, of course, data analysis.

Project Description: 2) We are also working with Charles Sukenik (Physics Dept.) to explore the ability of LIDAR (Light Detection and Ranging - radar with light) to measure the distribution and nature of particles (plankton, sediment & detritus) in the ocean. Activity this summer will involve some instrument development in the lab (electronics, optics & lab experiments) and at least one day-cruise offshore into the Atlantic to measure LIDAR signals in conjunction with more traditional measures of water optical properties.
Both projects require good problem-solving skills using algebra and some knowledge of Excel. Students interested in the eelgrass field work should also be good swimmers, preferably with some snorkeling experience.

More information is available at our website:

http://sci.odu.edu/oceanography/directory/faculty/zimmerman/researchpage/index.shtml
PROJECTS FROM THE DEPARTMENT OF PHYSICS

Mentor: Prof. Larry Weinstein (weinstein@odu.edu)

Project Description: Experimental Nuclear Physics can host two students to work on elementary particle detectors for Jefferson Lab, data analysis, and nuclear physics techniques.