Course Title: Robotics Intelligence (RI)

(A Program Elective for CSE students)

Objectives:

- To develop the student's understanding of the issues involved in trying to define and simulate perception.
- To introduce students to recent developments in the area of learning-based robotics.
- To familiarize the student with specific, sensors, applied robotics, well known computer vision methods, and machine learning algorithms
- Design approaches to learn policies for solving various robotic tasks.
- Design experiments or conduct analysis to validate approaches.
- Broad applications of AI in the field of Robotics and vision.

Overview:

This course introduces techniques related to robotics, including methods of computer programming, data acquisition methods for sensors (such as infrared and optical imagers), control methods for actuators and servo motors, computer vision, and machine learning. The subject of robotics is considered as an interdisciplinary engineering subject which includes mechanical engineering, electrical engineering, optical engineering, control theory, and computer science engineering. The course addresses advanced robotic topics including autonomous control, machine learning and applied artificial intelligence. Using a hands-on approach to applied robotics, the students in this course write their own controller programs and build their own robot prototypes based on standard microcontrollers (including the Arduino and the Raspberry pi). This course will build a foundation for understanding real-world problems in the field of robotics and will present adequate resources for the students to work on their own ideas.

Prerequisites:

This is an advanced level graduate course for students who are seeking industrial jobs and conducting research in related fields. The course will be structured around computer programming, signals and systems, robotics, computer vision, and machine learning. Students should be familiar with mathematics and linear algebra, and have a basic understanding of computer programming, machine learning, and concepts in signals and systems. Students must

have taken at least three of the following (or equivalent) courses: Computer Programming, Signals and Systems, Machine learning, and Artificial Intelligence.

Grading Scheme:

Tentative and subject to change.

1. Examination: 30%
    a. Mid Semester Exam: 15%
    b. End Semester Exam: 15%

2. Take-home lessons:20%

3. Final Project: 40%- The goal of your project is to work on some novel idea and, perhaps, contribute something to the field of robot learning. Projects should be done in groups of one to three students. We encourage you to discuss possible topics with us during office hours. Some ideas for getting started on projects are listed below:

    a. We encourage you to first do few literature surveys (selecting the latest paper) in the field of robot learning.
    b. Select a paper from recent literature and then try to understand the basic motivation of the paper. After that, try to implement it (encourage you to choose publicly available source code paper) and pursue extensions that can improve the paper.
    c. Explore the selected paper with various ideas and modifications.
    d. Design and implement a solution to the problem that you have discovered. Make sure to formulate a clear short-term goal and desired outcome for the class project
    e. According to my belief, you should use the class project as an opportunity to try some new approaches that you can apply in real life.

4. Participation:10%-Participation in in-class discussion

Policies:

1. You are encouraged to discuss the assignment with each other, but the coding and writing of the report must be done individually.
2. You are encouraged to use publicly available resources, but do not forget to acknowledge them in the report.

3. In a group, each member has equal contribution and if it is found that some student's contribution is not enough, he will be reflected upon his grades.
4. Make sure the work in the report is original and not plagiarized. If it is found that the work has been copied from other students and unintentional sources on the web, a grade of zero will be assigned to the student.
5. If you discover something new, the institute has full authority over it and you are not allowed to publish the work anywhere without the permission of the institute.

Syllabus:

UNIT I

INTRODUCTION

- Introduction of robotics
- History of robotics
- Present status and future trends
- Need for service and field robots
- General robotics
- Applications, examples and specifications

UNIT II

Locomotion and Manipulation

- Locomotion and Manipulation Examples
- Static and Dynamic Stability
- Degrees-of-Freedom

Sensors

- Robotic Sensors
- Proprioception of robot kinematics and internal Forces
- Sensors using light
    - Reflection
    - Phase shift
    - Time-of-light
- Sensors using sound
    - Ultra-sound distance sensors
    - Texture recognition
- Inertia-based sensors

    - Accelerometer
    - Gyroscopes
- Beacon-based sensors

UNIT III

Robotics Vision

- Images as two-dimensional signals
- From signals to information
- Basic image operations
    - Convolution-based filters
    - Threshold-based operations
    - Morphological Operations
- Feature detection as an information-reduction problem
- Features
- Line recognition
    - Line fitting using least squares
    - Split-and-merge algorithm
    - RANSAC: Random Sample and Consensus
    - The Hough Transform
- Scale-Invariant Feature Transforms
    - Overview
    - Object Recognition using scale-invariant features
- Lightweight convolutional neural network feature extraction

UNIT IV

Applied robotics

- Introduction to applied robotics
- Computer operating system, scientific programming and reporting
- System on a chip microcontrollers
    - Introduction to microcontrollers (32-bit ARM-based devices) in embedded applications used in automobiles and home appliances (such as washing machines, microwave ovens, telephones, and computer system peripherals)
    - Controlling GPIO pins (e.g. connected to LEDs) on the Raspberry Pi 3 using Python
    - Controlling motors
    - Collecting sensor data (such as light-color sensor, touch sensor, infrared proximity sensor and ultrasonic sensor)
    - Writing and uploading robotic control programs
- Robotic actions and autonomous control algorithms
    - Robotic motion and autonomous responses
- General-purpose computing on graphics processing units (GPU computing)
    - Quad Processing Units (QPUs) on the Raspberry Pi 3

    - Compute Unified Device Architecture (CUDA) parallel computing platform and application programming interface model created by Nvidia
- Deep Learning for robotics
    - Object detection, classification, segmentation, depth estimation, navigation, etc.

UNIT V

Robotics Applications / Case Studies

- Object detection and classification
- Semantic segmentation and depth estimation
- Robotic navigation and manipulation
- Collaborative robotics
- Industrial robotics
- Autonomous robotics
- Other relevant applications and case studies

References:

1. Deep learning for robotics, Ian Lenz, Ph.D. Cornell University 2016.
2. Introduction to Autonomous Robots, NikolausCorrell, 2015.
3. Robotics, Vision, and Control, Peter Croke, Springer, 2011
4. Mobile Robotics: A Practical Introduction, Ulrich Nehmzow, 2nd Ed., Springer
5. Artificial Intelligence for Robotics: Build intelligent robots that perform human tasks using AI techniques,Francis X. Govers.
6. Computer Vision: Algorithms and Applications, Richard Szeliski, Springer, 2010.
7. Modern Robotics: Mechanics, Planning, and Control. Frank C. Park, Kevin M. Lynch. Cambridge University Press. Available Online