The Islamia University of Bahawalpur

**University College of Engineering & Technology**

Course Outline: Robotics

General Information:

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| **Course:** | Robotics |  | **Instructor** | Engr. Zulfiqar Ahmad |
| **Course Code** | ES-421 | **Office** | 062-9255236, Room # 31 |
| **Credit Hours** | 2 (Theory) + 1 (Lab) | **Email** | [zulfiqar.ahmed@iub.edu.pk](mailto:zulfiqar.ahmed@iub.edu.pk) |
| **Contact Hours** | 2 | **Contact No.** | +92-321-6828037 |
| **Pre-Requisite(s)** | Industrial Electronics | **Office Hours** | 08:30 – 16:30 |

Course Description:

This course introduces fundamental concepts in robotics. The objective of the course is to provide an introductory understanding of robotics, their applications, classifications, hardware and system integration. Students will be exposed to a broad range of topics in robotics with emphasis on basics of manipulators, coordinate transformation and kinematics and control techniques for robotic systems.

Course Learning Outcomes (CLOs):

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| --- | --- | --- | --- |
| **CLOs** | **Description** | **Domain** | **PLOs** |
| CLO1 | To demonstrate the automation and brief history of robots and their applications. | Cognitive-2 | PLO1 |
| CLO2 | To illustrate the relationship between mechanical structures of industrial robots and their operational workspace characteristics. | Cognitive-2 | PLO1 |
| CLO3 | To apply spatial transformation to obtain forward and inverse kinematics equation of robot manipulators. | Cognitive-3 | PLO2 |
| CLO4 | To compute the Jacobian matrix and use it to identify singularities of robot manipulators. | Cognitive-3 | PLO2 |
| CLO5 | Ability to design robot controllers to meet the desired configuration. | Cognitive-6 | PLO3 |

Relation of CLOs to the Program Learning Outcomes (PLOs):

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
|  | **Engineering Knowledge** | **Problem Analysis** | **Design & Development of Solutions** | **Investigation** | **Modern Tool Usage** | **The Engineer and Society** | **Environment and Sustainability** | **Ethics** | **Individual and Team Work** | **Communication** | **Project Management** | **Life Long Learning** |
| **CLO1** | √ |  |  |  |  |  |  |  |  |  |  |  |
| **CLO2** | √ |  |  |  |  |  |  |  |  |  |  |  |
| **CLO3** |  | √ |  |  |  |  |  |  |  |  |  |  |
| **CLO4** |  | √ |  |  |  |  |  |  |  |  |  |  |
| **CLO5** |  |  | √ |  |  |  |  |  |  |  |  |  |
| **Total** | 2 | 2 | 1 |  |  |  |  |  |  |  |  |  |
| **Impact** | Medium | Medium | Low |  |  |  |  |  |  |  |  |  |

**Justification of Program Learning Outcomes (PLO’s) Coverage:**

**PLO1 - Engineering Knowledge:**

The assignments, exams, and laboratory experiments require engineering knowledge to successfully complete the course. Students will have the knowledge of forward and inverse kinematics, end –effector design and control methods.  (relevance to course).

**PLO2 - Problem Analysis**

The course shows the value of theory, by making it possible for the students examine the different robotic designs, perform kinematic and dynamics analysis. (High relevance to course).

**PLO3 - Design & Development of Solutions**

  Through the theory and different problems( kinematics, dynamics and trajectory planning) analysis, student will design different controller architectures of robots.

This objective is not directly addressed in this course.

**PLO4-PLO5**

This objective is not directly addressed in this course.

Textbook(s)/Reference Books:

1. John J.Craig , Introduction to Robotics: Mechanics and Control, 3rd Edition, Prentice-Hall, 2005.
2. Saeed B.Niku , An Introduction to Robotics Analysis, Systems, Applications, Prentice-Hall, 2001
3. S.K Saha , Introduction to Robotics, McGraw-Hill, 2008.

**Lecture Plan:**

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| --- | --- | --- |
| Topics | **Hours** | **CLOs** |
| **Introduction:**  History, Robot Usage, Laws of Robotics, Applications, Safety, Robot Subsystems. (Chapter No. 1 + Chapter 2 till 2.1) | **Week 1** | **CLO 1** |
| Robot Classification by: Application, Coordinate system, Actuation system, Control Method, Programming Method, Actuators, Pneumatic Actuators (Chapter No. 2 from 2.2 to Chapter No.3 till 3.1) | **Week 2** | **CLO 1** |
| Hydraulic Actuators, Electric Actuators, Stepper Motors, Types of Stepper Motors (Chapter No.3 from 3.2 till 3.3.1) | **Week 3** | **CLO 2** |
| DC Motors, Types of DC Motors used in Robots, AC Motors, Types of AC Motors used in Robots, construction and working, Selection Criteria of Robots (Chapter No. 3 from 3.3.2 till 3.4) | **Week 4** | **CLO 2** |
| Sensors used in Robots and their Classification, Position Sensors, Encoders (Linear, Absolute Linear, Rotary, Absolute Rotary), Potentiometers, LVDT, Synchros and Resolvers, Velocity Sensors, Tachometer, Hall Effect Sensors, Acceleration Sensors, Force Sensors, Stain Gauges and Piezoelectric switches (Chapter No. 4 – 4.1 and 4.2) | **Week 5** | **CLO 2** |
| External Sensors, Contact Type Sensors, Limit switches, pneumatic switches, Pressure transducers, Non-Contact type sensors, proximity sensors, hall effect sensors, microwave sensors, ultrasonic sensors, laser sensors, vision sensors, vision systems, levels of vision sensing, issues in vision sensing and their remedies, sensor selection criteria. (Chapter No. 4 from 4.3 to 4.5) | **Week 6** | **CLO 2** |
| **Transformations:**  Robotic Architecture: Links and Joints, Types of joints, Kinematic chains, Degree of Freedom, DOF calculations, Position of a rigid body and position description of a fixed frame. (chapter No. 5 from 5.1 to 5.2.1) | **Week 7** | **CLO 3** |
| Orientation of a rigid body, direction cosine representation, elementary rotations, properties of elementary rotation matrices, coordinate transformation, vector rotation, Euler Angles Representation, Coordinate transformation, Homogeneous transformation. (Chapter No. 5 from 5.2.1 to 5.3.1) | **Week 8** | **CLO 3** |
| Pure translation, Pure Rotation, General Motion, Transfer of a point, product of two homogeneous transformations, Denavit and Hartenberg (DH) Parameters description, DH parameters of a three link planar arm, DH parameters of a revolute prismatic arm, DH parameters of a prismatic revolute arm, DH parameters of a spherical arm, Transformation between DH frames. (Chapter No. 5 from 5.3.1 to 5.4.1) | **Week 9** | **CLO 3** |
| Homogeneous transformation of the: Three link planar arm, RP Planar arm, PR Planar arm, Spherical arm.  **Kinematics:**  Forward Position Analysis, Forward analysis of a: Two link planar arm, revolute prismatic arm, three link planar arm, SCARA Robot, Spherical arm, Anthropomorphic Articulated Arm, Wrist, Anthropomorphic articulated robot (Chapter No. 5 from 5.4.1 to Chapter No. 6 topic 6.1) | **Week 10** | **CLO 3** |
| Forward analysis of a: PUMA robot, Stanford arm, Wrist, Anthropomorphic articulated robot, PUMA robot, Stanford arm. Inverse Position Analysis, Inverse Position Analysis of a three link planar arm (Algebraic and geometric solutions) Inverse Kinematics of the Three link planar arm (Chapter No. 6 from 6.1 to 6.2.1) | **Week 11** | **CLO 3** |
| Inverse kinematics of the articulated arm & wrist, Velocity analysis, the jacobian matrix, Rotation matrix and angular velocity, Link velocities. (chapter No. 6 from 6.2.3 to 6.4) | **Week 12** | **CLO 3** |
| **Jacobian computation**:  jacobian of the two link arm, three link arm, anthropomorphic articulated arm, PUMA Robot, DeNOC, jacobian matrix using DeNOC,. (chapter No. 6 from 6.5 to 6.6) | **Week 13** | **CLO4** |
| **Singularities:** Singularity of Two Link Planer Arm and Anthropomorphic arm, Acceleration Analysis, Acceleration Analysis of the two link planar arm and anthropomorphic arm(chapter No. 6 from 6.7 to 6.8) | **Week 14** | **CLO4** |
| **Control:**  Control techniques, Second order linear systems, Feedback Control (Chapter No. 10 from 10.1 to 10.3) | **Week 15** | **CLO5** |
| Feedback control and Performance of Feedback control systems (Chapter No. 10 from 10.3 to 10.4) | **Week 16** | **CLO5** |

**Grading Policy vis-à-vis CLO Mapping**

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| Assignments, Quizzes, Projects/presentations etc | 20% | CLO1 to CLO5 |
| Midterm | 30% | CLO1 to CLO3 |
| Final | 50% | CLO1 to CLO5 |

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