# MTECH 2022

**Discipline :** INTERDISCIPLINARY

**Stream:** ID4 (ROBOTICS & AUTOMATION, ROBOTICS)

## SEMESTER I

| SLOT | COURSE CODE | COURSE NAME | MARKS | | L-T-P | HOURS | CREDIT |
|---|---|---|---|---|---|---|---|
| | | | CIA | ESE | | | |
| A | 221TIA002 | MATHEMATICS FOR INTELLIGENT SYSTEMS | 40 | 60 | 3-0-0 | 3 | 3 |
| B | 221TIA003 | KINEMATICS, DYNAMICS AND CONTROL OF ROBOTS | 40 | 60 | 3-0-0 | 3 | 3 |
| C | 221TIA004 | INDUSTRIAL AUTOMATION | 40 | 60 | 3-0-0 | 3 | 3 |
| D | 221EIAXXX | PROGRAM ELECTIVE 1 | 40 | 60 | 3-0-0 | 3 | 3 |
| E | 221EIAXXX | PROGRAM ELECTIVE 2 | 40 | 60 | 3-0-0 | 3 | 3 |
| S | 221RGE100 | RESEARCH METHODOLOGY AND IPR | 40 | 60 | 2-0-0 | 2 | 2 |
| T | 221LIA001 | ROBOTICS LAB | 100 | -- | 0-0-2 | 2 | 1 |
| **Total** | | | **340** | **360** | | **19** | **18** |

Teaching Assistance: 6 hours

## PROGRAM ELECTIVE 1

| PROGRAM ELECTIVE 1 | | | | | | |
|---|---|---|---|---|---|---|
| SLOT | SL NO | COURSE CODE | COURSE NAME | L-T-P | HOURS | CREDIT |
| D | 1 | 221EIA012 | DESIGN OF ROBOTIC SYSTEMS | 3-0-0 | 3 | 3 |
| | 2 | 221EIA013 | EMBEDDED SYSTEMS | 3-0-0 | 3 | 3 |
| | 3 | 221EIA021 | MACHINE LEARNING | 3-0-0 | 3 | 3 |
| | 4 | 221EIA015 | ARTIFICIAL INTELLIGENCE FOR ROBOTICS | 3-0-0 | 3 | 3 |

## PROGRAM ELECTIVE 2

| PROGRAM ELECTIVE 2 | | | | | | |
|---|---|---|---|---|---|---|
| SLOT | SL NO | COURSE CODE | COURSE NAME | L-T-P | HOURS | CREDIT |
| E | 1 | 221EIA018 | INDUSTRY 4.0 AND INDUSTRIAL INTERNET OF THINGS (IIOT) | 3-0-0 | 3 | 3 |
| | 2 | 221EIA019 | COMPUTER VISION | 3-0-0 | 3 | 3 |
| | 3 | 221EIA020 | ROBOT MOTION PLANNING | 3-0-0 | 3 | 3 |
| | 4 | 221EIA014 | MOBILE ROBOTICS | 3-0-0 | 3 | 3 |

## SEMESTER II

| SLOT | COURSE CODE | COURSE NAME | MARKS | | L-T-P | HOURS | CREDIT |
|---|---|---|---|---|---|---|---|
| | | | CIA | ESE | | | |
| A | 222TIA001 | CONTROL OF DYNAMIC SYSTEMS | 40 | 60 | 3-0-0 | 3 | 3 |
| B | 222TIA002 | SENSORS AND ACTUATORS FOR ROBOTS | 40 | 60 | 3-0-0 | 3 | 3 |
| C | 222EIAXXX | PROGRAM ELECTIVE 3 | 40 | 60 | 3-0-0 | 3 | 3 |
| D | 222EIAXXX | PROGRAM ELECTIVE 4 | 40 | 60 | 3-0-0 | 3 | 3 |
| E | 222EEXXXX / 222EIAXXX | INDUSTRY/ INTERDISCIPLINARY ELECTIVE | 40 | 60 | 3-0-0 | 3 | 3 |
| S | 222PIA100 | MINI PROJECT | 100 | -- | 0-0-4 | 4 | 2 |
| T | 222LIA001 | AUTOMATION LAB 2 | 100 | -- | 0-0-2 | 2 | 1 |
| **Total** | | | **400** | **300** | | **21** | **18** |

Teaching Assistance: 6 hours

## PROGRAM ELECTIVE 3

| PROGRAM ELECTIVE 3 | | | | | | |
|---|---|---|---|---|---|---|
| **SLOT** | **SL NO** | **COURSE CODE** | **COURSE NAME** | **L-T-P** | **HOURS** | **CREDIT** |
| **C** | 1 | 222EIA012 | AUTONOMOUS VEHICLES | 3-0-0 | 3 | 3 |
| | 2 | 222EIA013 | PLC AND DISTRIBUTED CONTROL | 3-0-0 | 3 | 3 |
| | 3 | 222EIA014 | FIELD ROBOTICS | 3-0-0 | 3 | 3 |
| | 4 | 222EIA001 | DEEP LEARNING | 3-0-0 | 3 | 3 |

## PROGRAM ELECTIVE 4

| PROGRAM ELECTIVE 4 | | | | | | |
|---|---|---|---|---|---|---|
| **SLOT** | **SL NO** | **COURSE CODE** | **COURSE NAME** | **L-T-P** | **HOURS** | **CREDIT** |
| **D** | 1 | 222EIA017 | MECHANICS OF HUMAN MOVEMENT | 3-0-0 | 3 | 3 |
| | 2 | 222EIA018 | COOPERATIVE ROBOTICS | 3-0-0 | 3 | 3 |
| | 3 | 222EIA019 | MEDICAL ROBOTICS | 3-0-0 | 3 | 3 |
| | 4 | 222EIA020 | HUMAN COMPUTER INTERACTION | 3-0-0 | 3 | 3 |

## INTERDISCIPLINARY ELECTIVE

| INTERDISCIPLINARY ELECTIVE | | | | | | |
|---|---|---|---|---|---|---|
| **SLOT** | **SL NO** | **COURSE CODE** | **COURSE NAME** | **L-T-P** | **HOURS** | **CREDIT** |
| E | 1 | 222EIAXXX | INDUSTRIAL ROBOTICS | 3-0-0 | 3 | 3 |
| | 2 | 222EIAXXX | INDUSTRIAL AUTOMATION | 3-0-0 | 3 | 3 |
| | 3 | 222EIAXXX | AI FOR ROBOTICS | 3-0-0 | 3 | 3 |

## INDUSTRY ELECTIVE

## SEMESTER III

| SLOT | COURSE CODE | COURSE NAME | MARKS | | L-T-P | HOURS | CREDIT |
|---|---|---|---|---|---|---|---|
| | | | CIA | ESE | | | |
| **TRACK 1** | | | | | | | |
| A* | 223MIAXXX | MOOC | To be completed successfully | | -- | -- | 2 |
| B | 223AGEXXX | AUDIT COURSE | 40 | 60 | 3-0-0 | 3 | - |
| C | 223IIA100 | INTERNSHIP | 50 | 50 | -- | -- | 3 |
| D | 223PIA100 | DISSERTATION PHASE 1 | 100 | -- | 0-0-17 | 17 | 11 |
| **TRACK 2** | | | | | | | |
| A* | 223MIAXXX | MOOC | To be completed successfully | | -- | -- | 2 |
| B | 223AGEXXX | AUDIT COURSE | 40 | 60 | 3-0-0 | 3 | - |
| C | 223IIA100 | INTERNSHIP | 50 | 50 | --- | -- | 3 |
| D | 223PIA001 | RESEARCH PROJECT PHASE 1 | 100 | -- | 0-0-17 | 17 | 11 |
| **Total** | | | **190** | **110** | | **20** | **16** |

Teaching Assistance: 6 hours

*MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1).

## AUDIT COURSE

| AUDIT COURSE | | | | | | |
|---|---|---|---|---|---|---|
| **SLOT** | **SL NO** | **COURSE CODE** | **COURSE NAME** | **L-T-P** | **HOURS** | **CREDIT** |
| B | 1 | 223AGE100 | ACADEMIC WRITING | 3-0-0 | 3 | - |
| | 2 | 223AGE001 | ADVANCED ENGINEERING MATERIALS | 3-0-0 | 3 | - |
| | 3 | 223AGE002 | FORENSIC ENGINEERING | 3-0-0 | 3 | - |
| | 4 | 223AGE003 | DATA SCIENCE FOR ENGINEERS | 3-0-0 | 3 | - |
| | 5 | 223AGE004 | DESIGN THINKING | 3-0-0 | 3 | - |
| | 6 | 223AGE005 | FUNCTIONAL PROGRAMMING IN HASKELL | 3-0-0 | 3 | - |
| | 7 | 223AGE006 | FRENCH LANGUAGE (A1 LEVEL) | 3-0-0 | 3 | - |
| | 8 | 223AGE007 | GERMAN LANGUAGE (A1 LEVEL) | 3-0-0 | 3 | - |
| | 9 | 223AGE008 | JAPANESE LANGUAGE (N5 LEVEL) | 3-0-0 | 3 | - |
| | 10 | 223AGE009 | PRINCIPLES OF AUTOMATION | 3-0-0 | 3 | - |
| | 11 | 223AGE010 | REUSE AND RECYCLE TECHNOLOGY | 3-0-0 | 3 | - |
| | 12 | 223AGE011 | SYSTEM MODELING | 3-0-0 | 3 | - |
| | 13 | 223AGE012 | EXPERT SYSTEMS | 3-0-0 | 3 | - |

## SEMESTER IV

| SLOT | COURSE CODE | COURSE NAME | MARKS | | L-T-P | HOURS | CREDIT |
|---|---|---|---|---|---|---|---|
| | | | CIA | ESE | | | |
| TRACK 1 | | | | | | | |
| A | 224PPE100 | DISSERTATION PHASE II | 100 | 100 | 0-0-24 | 24 | 16 |
| TRACK 2 | | | | | | | |
| A | 224PPE001 | RESEARCH PROJECT PHASE II | 100 | 100 | 0-0-24 | 24 | 16 |
| Total | | | **100** | **100** | | **24** | **16** |

Teaching Assistance: 5 hours

## ASSESSMENT PATTERN

### (i) CORE COURSES

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

**Continuous Internal Evaluation: 40 marks**

| | |
|---|---|
| Micro project/Course based project: | 20 marks |
| Course based task/Seminar/Quiz: | 10 marks |
| Test paper, 1 no: | 10 marks |

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

### (ii) ELECTIVE COURSES

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

**Continuous Internal Evaluation: 40 marks**

| | |
|---|---|
| Preparing a review article based on peer reviewed | |
| Original publications (minimum 10 | 15 marks |
| Publications shall be referred): | |
| Course based task/Seminar/Data | 15 marks |
| Collection and interpretation: | |
| Test paper, 1 no.: | 10 marks |

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

**Note:** The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

**(iii) RESEARCH METHODOLOGY & IPR/AUDIT COURSE**

**Continuous Internal Evaluation: 40 marks**

Course based task: 15 marks

Seminar/Quiz: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

**(iv) LABORATORY COURSES**

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final assessment shall be done by two examiners; one examiner will be a senior faculty from the same department.

**(v) INTERDISCIPLINARY ELECTIVE**

Engineering students frequently aspire to work in areas and domains that are key topics in the industry. There are concerns by recruiters that skill sets of engineering students did not match with the Industry requirements, especially in the field of latest topics. In response to their desires, the University has incorporated Industry/Interdisciplinary electives in the curriculum. Interdisciplinary knowledge is critical for connecting students with current industry trends, where multitasking is the norm. Interdisciplinary knowledge aids in the bridge- building process between academic institutions and industry. It aids pupils in expanding their knowledge and innovating by allowing them to create something new. While core engineering courses provide students with a strong foundation, evolving technology necessitates new methods and approaches to progress, prosperity, and the inculcation of problem-solving techniques. Other courses' knowledge, on the other hand, can assist them to deal with any scenario more effectively. Interdisciplinary courses may be one approach to address such needs, as they can aid in the enhancement of engineering education and the integration of desirable specialized subjects into the current engineering education system. This will enable students to fulfill the current industry demands. Students with multidisciplinary knowledge and projects are more likely to be placed in top industries, according to the placement trend. The future of developing engineers will be influenced by their understanding of emerging technology and interdisciplinary approaches such as bigdata, machine learning, and 3-D printing.

**Continuous Internal Evaluation: 40 marks**

| | |
|---|---|
| Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred): | 15 marks |
| Course based task/Seminar/Data collection and interpretation: | 15 marks |
| Test paper, 1 no: | 10 marks |

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

**(vi) MOOC COURSES**

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/NPTEL/SWAYAM or NITTTR. The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/offline end semester examination. The students can do the MOOC according to their convenience, but shall complete it by third semester. The list of MOOC courses will be provided by the concerned BoS if at least 70% of the course content match with the area/stream of study. The course shall not be considered if its content has more than 50% of overlap with a core/elective course in the concerned discipline or with an open elective.

MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1). A credit of 2 will be awarded to all students whoever successfully completes the MOOC course as per the evaluation pattern of the respective agency conducting the MOOC.

**(vii) MINIPROJECT**

**Total marks: 100, only CIA**

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem-solving skills. The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Interim evaluation: 40 (20 marks for each review), final evaluation by a Committee (will be evaluating the level of completion and demonstration of functionality/specifications, clarity of presentation, oral examination, work knowledge and involvement): 35, Report (the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level is not more than 25%): 15, Supervisor/Guide: 10

## TEACHING ASSISTANCESHIP (TA)

All M Tech students irrespective of their category of admission shall undertake TA duties for a minimum duration as per the curriculum. Being a TA, the student will get an excellent opportunity to improve their expertise in the technical content of the course, enhance communication skills, obtain a hands-on experience in handling the experiments in the laboratory and improve peer interactions.

The possible TA responsibilities include the following: facilitate a discussion section or tutorial for a theory/ course, facilitate to assist the students for a laboratory course, serve as a mentor for students, and act as the course web-master. TAs may be required to attend the instructor's lecture regularly. A TA shall not be employed as a substitute instructor, where the effect is to relieve the instructor of his or her teaching responsibilities (specifically prohibited by University Policy).

**For the tutorial session:**

(i) Meet the teacher and understand your responsibilities well in advance, attend the lectures of the course for which you are a tutor, work out the solutions for all the tutorial problems yourself, approach the teacher if you find any discrepancy or if you need help in solving the tutorial problems, use reference text books, be innovative and express everything in English only.

(ii) Try to lead the students to the correct solutions by providing appropriate hints rather than solving the entire problem yourself, encourage questions from the students, lead the group to a discussion based on their questions, plan to ask them some questions be friendly and open with the students, simultaneously being firm with them.

(iii) Keep track of the progress of each student in your group, give a periodic feedback to the student about his/her progress, issue warnings if the student is consistently under-performing, report to the faculty if you find that a particular student is consistently underperforming, pay special attention to slow-learners and be open to the feedback and comments from the students and faculty.

(iv) After the tutorial session you may be required to grade the tutorials/assignments/tests. Make sure that you work out the solutions to the questions yourself, and compare it with the answer key, think and work out possible alternate solutions to the same question, understand the marking scheme from the teacher. Consult the teacher if are and make sure that you are not partial to some student/students while grading. Follow basic ethics.

**Handling a laboratory Session:**

(i) Meet the faculty – in- charge a few days in advance of the actual lab class and get the details of the experiment, get clarifications from him/her regarding all aspects of the experiment and the expectations, prepare by reading about the theoretical background of the experiment, know the physical concepts involved in the experiment, go to the laboratory and check out the condition of the equipment/instrumentation, perform the laboratory experiment at least once one or two days before the actual laboratory class, familiarize with safety/ security aspects of the experiment / equipment/laboratory, prepare an instruction sheet for the experiment in consultation with the faculty, and keep sufficient copies ready for distribution to students for their reference.

(ii) Verify condition of the equipment/set up about 30 minutes before the students arrive in the class and be ready with the hand outs, make brief introductory remarks about the experiment, its importance, its relevance to the theory they have studied in the class, ask the students suitable questions to know there level of preparation for the experiment, discuss how to interpret results, ask them comment on the results.

(iii) Correct/evaluate/grade the submitted reports after receiving suitable instructions from the faculty in charge, continue to interact with students if they have any clarifications regarding any aspect of the laboratory session, including of course grading, Carefully observe instrument and human safety in laboratory class, Preparing simple questions for short oral quizzing during explanation of experiments enables active participation of students, facilitate attention, provides feedback and formative assessment.

# SEMESTER I

**Discipline : INTERDISCIPLINARY**
**Stream : ID4**

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221TIA002 | MATHEMATICS FOR INTELLIGENT SYSTEMS | DISCIPLINE CORE | 3 | 0 | 0 | 3 |

**Preamble:** Mathematics for intelligent systems are indispensable for computing applications in robotic systems. This course is designed such that it will equip the students with mathematical framework for the numerical computation and optimization and techniques necessary for various computing applications in engineering and robotic systems.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Apply the basic ideas of linear algebra in determining spaces for intelligent systems |
| **CO 2** | Apply matrix algebra to represent the dimensions of intelligent systems. |
| **CO 3** | Apply probability in engineering |
| **CO 4** | Formulate optimization problems and identify a suitable method to solve the same |
| **CO 5** | Solve optimization problems in robotics using appropriate optimization techniques |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 2 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30% |
| Analyse | 30% |
| Evaluate | 20% |
| Create | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects are not permitted. The project may include the implementation of theoretical computation using software packages. The test papers hall include a minimum 80% of the syllabus.

**End Semester Examination Pattern:** 60 marks

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks*

**Model Question Paper**

**SLOT A**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**

**FIRST SEMESTER M.TECH DEGREE EXAMINATION**

**MONTH &YEAR**

Course code: **221TIA002**

Course Name: **Mathematics for Intelligent Systems**

**Max. Marks: 60** **Duration: 2.5 Hours**

**PART A**

**Answer all Questions. Each question carries 5 Marks**

| | |
|---|---|
| 1 | a) State whether the following vectors represent a vector space giving explanations<br>(i) V = a real polynomial of degree 5 or less<br>(ii) V = {f(x)/ f is continuous on $R$}<br>b) Explain an invariant subspace |
| 2 | Explain Lasso and Ridge regression models. While building a regression model using a data set, one of the feature is found to have relatively higher negative value. What does it indicate? |
| 3 | Prove that: If B ∈ F and P (B) > 0. Then, P (· \|B) : F −→ [0, 1] is a probability measure on (Ω, F). |
| 4 | Formulate an optimization problem to find a shortest path for a differential drive robot from start to goal location.<br><br> |
| 5 | In which context we can use optimization methods like genetic algorithms and simulated annealing? |

**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

| | |
|---|---|
| 6 | (i) Find the rank of the following matrix using<br>(ii) echelon form and (ii) canonical form<br><br>B = [−123 − 22 − 5123 − 8525 − 12 − 16] |

| | |
|---|---|
| 7 | Find the Eigen values and Eigen vectors of the matrix A=[811280 − 72 − 1 − 3 − 7211124]. Show that the matrix A can be diagonalised using these Eigen vectors. |
| 8 | Given the following 3D input data.<br>1 1 9<br>2 4 6<br>3 7 4<br>4 11 4<br>5 9 2<br>a. identify the principal component and<br>b. the transformed input along the first two principal component. |
| 9 | A manufacturing firm is engaged in the production of steel pipes in its three plants $P_1$, $P_2$, $P_3$. It produces 30% steel pipes from $P_1$, 45% from $P_2$ and 25% s from $P_3$. From the historical data it is found that $P_1$, P2, P3 produce 2%, 3% and 2% defective products. If a product is randomly selected what is the probability that it is defective? Also determine the probability that the defective product is from plant $P_3$. |
| 10 | Is this a linear or nonlinear programming problem?<br>Maximize $Z = 3x_1^2 - 2x_2$<br>Subject to<br>$2x_1 + x_2 = 4$<br>$x_1^2 + x_2^2 \leq 40$<br>$x_1, x_2 \geq 0$ and are integers.<br>Solve this problem by a suitable classical method. |
| 11 | Minimize $f(x_1, x_2) = x_1 - x_2 + 2x_1^2 + 2x_1x_2 + x_2^2$ from the starting point $X_1 = \{00\}$ using Powell's method. |
| 12 | Minimize $f(X) = (x_1 - 1)^2 + (x_2 - 5)^2$ subject to<br>$-x_1^2 + x_2 \leq 4$<br>$-(x_1 - 2)^2 + x_2 \leq 3$<br>Starting from the point $X_1 = \{11\}$ and using Zoutendijk's method. Complete two one-dimensional minimization steps. |

## Syllabus and Course Plan

### Module 1

**Linear Algebra:** Introduction**:** Fields-System of Linear Equations Echelon matrices-invertible matrices. Vector Spaces and subspaces**:** bases and dimensions-summary of row equivalence-computations concerning subspaces. Linear transformations-isomorphism-double dual-transpose of linear transformations-pseudo inverse-application to regression.Orthogonality**:** Orthonormal subspaces-Gram Schmidt orthogonalisation-Projections onto sub-spaces -The Regression Least Square

### Module 2

**Matrix Algebra: Determinants**-commutative rings-modules-multi linear functions-The grass man ring. Elementary canonical forms- introduction-characteristic values-invariant subspaces-simultaneous triangulation and simultaneous diagonalization-direct sum decomposition. Principal Component Analysis-image processing Eigen Faces -Markov Matrices and the Google Matrix.

### Module 3

**Probability and Statistical Theory: Introduction**: Probability and counting-Conditional probability: Bayes' Rule and law of total probability -Random Variables and their distributions Expectation: Definition-Linearity of the expectation -Geometric and Negative Binomial- Indicator Random Variable and the Fundamental Bridge. Moments: Moment generating functions- generating moments-Transformations: convolutions-beta-gamma-beta gamma connections. Markov chains: Markov property and transition matrix-classification of states-stationary distribution-reversibility.Markov chain and Monte Carlo.

### Module 4

Optimisation problem, Formulation of optimisation problems and linear optimization - Review only.

**Classical Optimization Techniques** Single variable optimization, Multivariable optimization with equality constraints- Direct substitution, method of Lagrange multipliers, Multivariable optimization with equality constraints- Kuhn-Tucker conditions.

**Non-linear Programming: Unconstrained Optimization Techniques** Direct Search Methods: Random search methods, Grid search method, Univariate method, Hookes and Jeeves' method, Powell's method; Indirect Search Methods: Steepest descent method, Fletcher-Reeves method, Newton's method

### Module 5

**Nonlinear Programming: Constrained Optimization Techniques** Direct search methods: Random search methods, Basic approach in methods of feasible directions, Zoutendijk's

method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming.
Recent developments in optimization techniques: Genetic Algorithm, Simulated Annealing, Neural Network based optimization, Particle Swarm Optimization, Ant colony Optimization.

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Module 1 Linear Algebra** | |
| 1.1 | **Introduction:** Fields-System of Linear Equations Echelon matrices-invertible matrices. | 2 |
| 1.2 | **Vector Spaces and subspaces:** bases and dimensions-summary of row equivalence-computations concerning subspaces. Linear transformations-isomorphism-double dual-transpose of linear transformations-pseudo inverse-application to regression | 3 |
| 1.3 | **Orthogonality:** Orthonormal subspaces-Gram Schmidt orthogonalisation-Projections onto sub-spaces -The Regression Least Square | 3 |
| 2 | **Module 2 Matrix Algebra** | |
| 2.1 | **Determinants**-commutative rings-modules-multi linear functions-The grass man ring. | 1 |
| 2.2 | **Elementary canonical forms-** introduction-characteristic values-invariant subspaces-simultaneous triangulation and simultaneous diagonalization-direct sum decomposition | 3 |
| 2.3 | Principal Component Analysis-image processing Eigen Faces -Markov Matrices and the Google Matrix. | 4 |
| 3 | **Module 3 Probability and Statistical Theory:** | |
| 3.1 | **Introduction**: Probability and counting-**Conditional probability:** Bayes' Rule and law of total probability -Random Variables and their distributions **Expectation**: Definition-Linearity of the expectation -Geometric and Negative Binomial-Indicator Random Variable and the Fundamental Bridge | 2 |
| 3.2 | **Moments:** Moment generating functions- generating moments-**Transformations:** convolutions-beta-gamma-beta gamma connections. | 3 |
| 3.3 | **Markov chains:** Markov property and transition matrix-classification of states-stationary distribution-reversibility. Markov chain and Monte Carlo. | 3 |
| **4** | **Module 4** | |
| 4.1 | Optimisation problem, Formulation of optimisation problems and linear optimization - Review only. | 1 |
| 4.2 | **Classical Optimization Techniques** Single variable | 3 |

| | | |
|---|---|---|
| | optimization, Multivariable optimization with equality constraints- Direct substitution, method of Lagrange multipliers, Multivariable optimization with equality constraints- Kuhn-Tucker conditions. | |
| 4.3 | **Non-linear Programming: Unconstrained Optimization Techniques** Direct Search Methods: Random search methods, Grid search method, Univariate method, Hookes and Jeeves' method, Powell's method; Indirect Search Methods: Steepest descent method, Fletcher-Reeves method, Newton's method | 4 |
| **5** | **Module 5** | |
| 5.1 | **Nonlinear Programming: Constrained Optimization Techniques** Direct search methods: Random search methods, Basic approach in methods of feasible directions | 2 |
| 5.2 | Zoutendijk's method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming. | 4 |
| 5.3 | Recent developments in optimization techniques: Genetic Algorithm, Simulated Annealing, Neural Network based optimization, Particle Swarm Optimization, Ant colony Optimization. | 2 |

**Reference Books**


1. G. Strang, Introduction to Linear Algebra. Wellesley, MA: Wellesley Cambridge Press, fifth ed., 2016.
2. K. Hoffman and R. Kunze, Linear algebra. Prentice-Hall mathematics series, Prentice-Hall India Ltd, 2015.
3. J. Blitzstein and J. Hwang, Introduction to Probability. Chapman & Hall/CRC Texts in Statistical Science, CRC Press, 2014.
4. Singiresu S Rao, *Engineering Optimization Theory and Practice*,5/e, John Wiley & Sons 2020.
5. Edwin K P Chong, Stanislaw H Zak, *An introduction to Optimization*, 2e, Wiley India.

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221TIA003 | KINEMATICS, DYNAMICS AND CONTROL OF ROBOTS | PROGRAM CORE 1 | 3 | 0 | 0 | 3 |

**Preamble** This course helps the student with the basic idea of Robots. Concepts like trajectory planning and obstacle avoidance and kinematics of robots are introduced. Discussion on various mobile robots and robotic manipulators are also included as part of the course to get an overall idea on robotics

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Familiarise with anatomy, specifications and standard robot configurations |
| **CO 2** | Obtain the forward and inverse kinematic model of a robotic manipulator |
| **CO 3** | Plan trajectories for robots |
| **CO 4** | Obtain the dynamic model of robots |
| **CO 5** | Design controllers for robotic manipulators |
| **CO 6** | Design controllers for mobile robots |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 2 | | | 3 | |
| **CO 2** | 3 | | 2 | | | 3 | |
| **CO 3** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 6** | 3 | | 2 | 3 | 3 | 3 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

**Continuous Internal Evaluation: 40 marks**

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects are not permitted. The project may include the implementation of theoretical computation using software packages. The test papers hall include a minimum 80% of the syllabus.

*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination :**60 marks**
**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.
*Each question can carry 7 marks.*

**Model Question Paper**

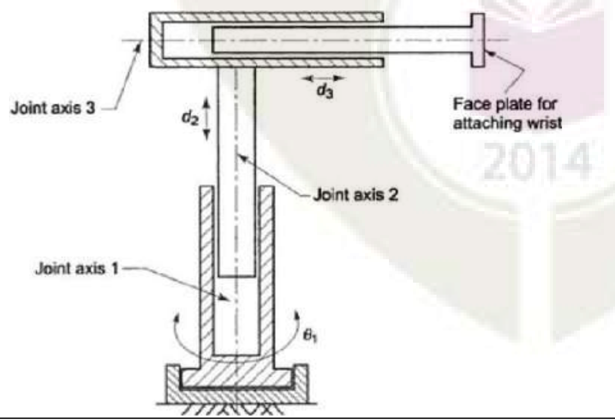
**Slot: B**

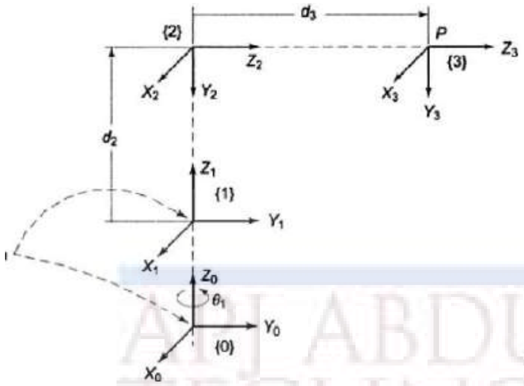
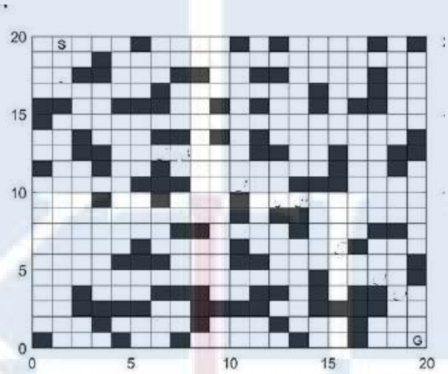
**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**
**FIRST SEMESTER M.TECH DEGREE EXAMINATION**
**MONTH & YEAR**

Course code: **221TIA003**

Course Name:**Kinematics Dynamics and Control of Robots**

**Max. Marks: 60** **Duration: 2.5 Hours**

| | |
|---|---|
| | **PART A** <br> **Answer all Questions. Each question carries 5 Marks** |
| 1 | What do you mean by DOF? What are redundant manipulators? Explain with the help of an example. |
| 2 | If a point$P = [30 - 11]^T$, find the new location of the point P, if it is (i) rotated by $\pi$ about z-axis of fixed frame and then translated by 3 units along y axis (ii) it is first translated by 3 units along y axis and then rotated about z axis by$\pi$. Are the two locations same. Explain why the final position in two cases is same or different. |
| 3 | One revolute joint of SCARA robotic manipulator is to move from $30^0$to $120^0$ in 7 seconds. If the joint has initial and final velocity of 1.0deg/sec and 1.2deg/s respectively. Determine the cubic polynomial to interpolate a smooth trajectory. Also obtain the velocity and acceleration profiles of the joint. |
| 4 | Compare position vs force control. |
| 5 | Compare a differential drive WMR and a car like WMR. |
| | **PART A** <br> **Answer any 5 Questions. Each question carries 7 Marks** |
| 6 | Explain how robots are classified based on work envelope geometries and drive technologies. |
| 7 | For the following cylindrical robot arm, compute the position and orientation of the tool tip. <br>   |

| | |
|---|---|
| |  |
| 8 | Determine the joint angles $\theta_1$, $\theta_2$, $\theta_3$ of a 3 axis robot if the origin of {3} is located at $[0.707, 1.707, 0.000]^T$ and the orientation of {3} with respect to {0} is given by the rotation matrix $R = [0.5 - 0.86600.8660.50001]$ . Given $T_0^3 = [C_{123} - S_{123} 0 L_1 C_1 + L_2 C_{12} S_{123} C_{123} 0 L_1 S_1 + L_2 S_{12} 00100001]$ |
| 9 | Which algorithm can be used to find a path from start to goal in the following scenario? Explain the algorithm.<br> |
| 10 | Obtain the dynamic model of a 1DOF robotic manipulator. |
| 11 | Suppose a robotic manipulator is to be designed to erase a white board, which control scheme can be used? Give the details of the controller. |
| 12 | Design a control scheme to drive a differential drive robot to follow a circular trajectory |

# Syllabus

## Module I:

### Introduction

Robots, Robotics; Types of Robots- Manipulators, Mobile Robots-wheeled & Legged Robots, Aerial Robots; Anatomy of a robotic manipulator-links, joints, actuators, sensors, controller; open kinematic vs closed kinematic chain; degrees of freedom; Robot considerations for an application, Classification of End effectors - mechanical grippers, special tools, Magnetic grippers, Vacuum grippers, adhesive grippers, Active and passive grippers, selection and design considerations of grippers in robot.

Robot configurations-PPP, RPP, RRP, RRR; features of SCARA, PUMA Robots; Classification of robots based on drive technologies and motion control methods.

Case study- sensors and actuators of robots (demo/assignment only)

## Module II

### Kinematics

Robot Coordinate Systems- Fundamental and composite rotations, homogeneous co-ordinates and transformations, Kinematic parameters, D-H representation, Direct Kinematics, Necessity of kinematic modelling, The Arm equation- forward Kinematic analysis of a typical robots up to 3 DOF. The inverse kinematics problem, general properties of solutions, Inverse kinematics of robots up to 3 DOF. Tool configuration vector and Jacobian.
Linear and angular velocities of rigid body, Linear and angular velocities of 3R manipulator, relation between joint and end effector velocities.

Inverse kinematics of 3DOF manipulator with concurrent wrist (demo/assignment only)

## Module III

### Trajectory Planning and Dynamics of Robots

Trajectory Planning- joint space trajectory planning-cubic polynomial, linear trajectory with parabolic blends; Cartesian space planning. Obstacle avoidance methods- Artificial Potential field, A* algorithms.

Dynamics- Necessity of dynamic modelling, dynamic model of a robot using Lagrange’s equation, dynamic modelling of 1DOF robot, modelling including motor and gearbox, 2R planar manipulator.

## Module IV

### Control of robotic manipulators

Necessity of a control system in a robot, block diagram typical robot control system, position control, force control.
PID control, PD gravity control, Computed torque control, Variable Structure control, Impedance control, digital control of a single link manipulator.

Case study- Control of a single link and two link manipulator using MATLAB/ROS. (Assignment/demo only)

**Module V**

**Control of mobile robots**

Basic understanding of Differential-Drive WMR, Car-Like WMR, Three-Wheeled Omnidirectional Mobile Robot, Kinematic model of a differential drive and a steered mobile robot.

Control of mobile robots- Control of differential drive robot and steered robot based on its kinematic model, Control of differential drive robot to move to a point, follow a line, follow a trajectory, to achieve an orientation. Control of a steered robot to move to a point, follow a line, follow a trajectory, to achieve an orientation.

Case study- design and implementation of a controller for a differential drive robot capable of moving to a point, following a line and following a path using MATLAB (Assignment/demo only)

**References**


1. Robert. J. Schilling , "Fundamentals of robotics – Analysis and control", Prentice Hall of India 1996.
2. R K Mittal and I J Nagrath, "Robotics and Control", Tata McGraw Hill, New Delhi,2003.
3. Introduction to Robotics by S K Saha, Mc Graw Hill Education
4. Introduction to Robotics (Mechanics and control), John. J. Craig, Pearson Education Asia 2002.
5. AshitavaGhosal, "Robotics-Fundamental concepts and analysis", Oxford University press.
6. Introduction to Autonomous Mobile Robots , R Siegwart, IR Nourbakhsh, D Scaramuzza, , MIT Press, USA, 2011.
7. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB


**Course plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction** | |
| 1.1 | Robots, Robotics; Types of Robots- Manipulators, Mobile Robots-wheeled & Legged Robots, Aerial Robots; Anatomy of a robotic manipulator-links, joints, actuators, sensors, controller; open kinematic vs closed kinematic chain, ; degrees of freedom; | 2 |
| 1.2 | Robot considerations for an application- Number of Axes, Capacity and Speed, Reach and Stroke, Tool Orientation, Repeatability, Precision and Accuracy, Operating environment | 1 |

| | | |
|---|---|---|
| 1.3 | Classification of End effectors - mechanical grippers, special tools, Magnetic grippers, Vacuum grippers, adhesive grippers, Active and passive grippers, selection and design considerations of grippers in robot. | 2 |
| 1.4 | Robot configurations-PPP, RPP, RRP, RRR; features of SCARA, PUMA Robots; Classification of robots based on drive technologies and motion control methods. Case study- sensors and actuators of robots (demo/assignment only) | 3 |
| 2 | **Kinematics** | |
| 2.1 | Robot Coordinate Systems- Fundamental and composite rotations, homogeneous co-ordinates and transformations | 2 |
| 2.2 | Kinematic parameters, D-H representation, Direct Kinematics, Necessity of kinematic modelling, The Arm equation- forward Kinematic analysis of a typical robots up to 3 DOF. | 2 |
| 2.3 | The inverse kinematics problem, general properties of solutions, Inverse kinematics of robots up to 3 DOF. | 1 |
| 2.4 | Tool configuration vector and Jacobian, Linear and angular velocities of rigid body, Linear and angular velocities of 3R manipulator, relation between joint and end effector velocities. | 2 |
| 2.5 | Inverse kinematics of 3DOF manipulator with concurrent wrist (demo/assignment only) | 1 |
| 3 | **Trajectory Planning and Dynamics of Robots** | |
| 3.1 | Trajectory Planning- joint space trajectory planning-cubic polynomial, linear trajectory with parabolic blends; | 2 |
| 3.2 | Cartesian space planning | 1 |
| 3.3 | Obstacle avoidance methods- Artificial Potential field, A* algorithms | 2 |
| 3.4 | Dynamics- Necessity of dynamic modelling, dynamic model of a robot using Lagrange's equation, dynamic modelling of 1DOF robot, modelling including motor and gearbox, 2R planar manipulator. | 3 |
| 4 | **Control of robotic manipulators** | |
| 4.1 | Necessity of a control system in a robot, block diagram typical robot control system, position control, force control. | 3 |
| 4.2 | PID control, PD gravity control, Computed torque control, Variable Structure control, Impedance control, digital control of a single link manipulator | 4 |
| 4.3 | Case study- Control of a single link and two link manipulator using MATLAB/ROS. (Assignment/demo only) | 1 |
| 5 | **Control of mobile robots** | |
| 5.1 | Basic understanding of Differential-Drive WMR, Car-Like WMR, Three-Wheeled Omnidirectional Mobile Robot, Kinematic model of a differential drive and a steered mobile robot. | 2 |
| 5.2 | Control of mobile robots- Control of differential drive robot and steered robot based on its kinematic model, | 2 |

| | | |
|---|---|---|
| 5.3 | Control of differential drive robot to move to a point, follow a line, follow a trajectory, to achieve an orientation. | 2 |
| 5.4 | Control of a steered robot to move to a point, follow a line, follow a trajectory, to achieve an orientation. | 1 |
| 5.5 | Case study- design and implementation of a controller for a differential drive robot capable of moving to a point, following a line and following a path using MATLAB (Assignment/demo only) | 1 |

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| **221TIA004** | **INDUSTRIAL AUTOMATION** | **PROGRAM CORE 2** | **3** | **0** | **0** | **3** |

**Preamble** This course introduces the basic types, levels and strategies of automation. The course includes continuous and discrete control systems. The concepts of hydraulic/ pneumatic circuits and applications is also included

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Acquire basic knowledge in industrial automation systems. |
| **CO 2** | Explain the fundamental principles of industrial automation components like CNC, Material handling and material storage systems. |
| **CO 3** | Develop hydraulic/ pneumatic circuits based on practical applications. |
| **CO 4** | Explain Manufacturing cells and automated inspection methods. |
| **CO 5** | Explain the Control Technologies and Building Blocks of Automation Systems. |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 2 | | 2 | 2 | 2 | | |
| **CO 2** | 2 | | 2 | 3 | 2 | 3 | |
| **CO 3** | 2 | | 2 | 3 | 3 | 3 | |
| **CO 4** | 2 | | 2 | 2 | 3 | 1 | |
| **CO 5** | 2 | | 2 | 2 | 2 | 1 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30 % |
| Analyse | 30 % |
| Evaluate | 20 % |
| Create | 20 % |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

**Continuous Internal Evaluation: 40 marks**

Micro Evaluation shall only be based on application, analysis or design-based questions.

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:**

The end semester examination will be conducted by KTU. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

**Syllabus and Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction to automated systems** | |
| 1.1 | Introduction: Automation in Production System, Principles and Strategies of Automation, Classification and Overview of Manufacturing Systems. | **3** |
| 1.2 | Basic Elements of an Automated System, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines | **3** |
| 1.3 | Automated Manufacturing Systems: Components | **2** |
| 2 | **Numerical control, Material handling and storage systems** | |
| 2.1 | Numerical control-concepts-evolution – CNC Structure of CNC machines, components, ball screws and guideways. | **2** |
| 2.2 | Spindle, bearings and mountings, Drive systems. Automated tool changers and pallet changers. Accessories | **2** |
| 2.3 | Material handling and storage systems: Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems | **3** |
| 3 | **Automation System Design** | |
| 3.1 | Design of fluid power circuits –cascade, KV-map and step counter method. | **4** |
| 3.2 | Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters | **3** |
| 3.3 | interfacing pneumatic and hydraulic circuits with PLCs | **2** |
| 4 | **Manufacturing Cells and Quality Control Systems.** | |
| 4.1 | Manufacturing Cells, GT and Cellular Manufacturing, FMS, CIM. | **3** |
| 4.2 | Overview of Automatic Identification Methods. | **2** |
| 4.3 | Automated Inspection: Principles and Practices, Inspection Technologies. | **3** |
| 5 | **Control Technologies in Automation and Building Blocks of Automation Systems** | |
| 5.1 | Industrial Control Systems, Process Industries Versus Discrete-Manufacturing Industries, Continuous Versus Discrete Control. | **3** |
| 5.2 | Building Blocks of Automation Systems: Networks, Analog & Digital I/O Modules, SCADA Systems & RTU. | **3** |
| 5.3 | Distributed Control System: Functional Requirements, Configurations | **2** |

**Reference Books**

1. YoramKoren,“Computer Control of Manufacturing Systems”,TataMcGraw HillEdition2005.
2. Automation, Production Systems and Computer Integrated Manufacturing M.P.Groover, Pearson Education.5th edition, 2009.
3. W.Bolton, “Mechatronics:A MultidisciplinaryApproach,4/E”, Pearson Education India.
4. Anthony Esposito, Fluid power with applications, Pearson Education, 6th Edition, 2003.
5. Peter Rohner, Fluid Power logic circuit design. The Macmillan Press Ltd., London, 1979
6. Radhakrishnan P, “CNC Machines”, New Central Book Agency,1992.
7.HMT “Mechatronics”, TataMcGraw-Hill,1998.
8. Computer Based Industrial Control- Krishna Kant, EEE-PHI,2nd edition,2010
9. Chapman and Hall, “Standard Handbook of Industrial Automation”, Onsidine DM C &Onsidine GDC”, NJ, 1986

**Model Question Paper** ID4

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

**FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year**

**Stream: Robotics and Automation**

**Course Code: 221TIA004**

**Course Name: INDUSTRIAL AUTOMATION**

**Max. Marks: 60** **Duration: 2.5 Hours**

## PART A

| | | | |
|---|---|---|---|
| | | ***Answer all questions, each carries 5 marks.*** | **Marks** |
| 1 | | Briefly explain the different types of automation. | (5) |
| 2 | | Briefly explain static load, dynamic load and thermal load in relation to a machine tool structure. | (5) |
| 3 | | With a neat sketch explain the use of a pressure switch in an electro pneumatic circuit. | (5) |
| 4 | | Explain the MICLASS and OPITZ classification and coding systems. | (5) |
| 5 | | Explain continuous and discrete control with respect to an industrial control system. | (5) |

## PART B

***Answer any 5 full question, each question carries 7 marks.***

| | | | |
|---|---|---|---|
| 6 | a | Explain the different types of industrial layouts and their applications. | (4) |
| | b | With neat sketch explain different types of automated transfer lines. | (3) |
| 7 | a | Explain the different types of industrial trucks used for material handling. | (4) |
| | b | Write short note on different types of spindle bearings. | (3) |
| 8 | | Design and draw hydraulic circuit for $A_1A_0B_1B_0$ sequencing operation using Karnaugh-Veitch method. | (7) |
| 9 | | A double acting cylinder is used to perform continuous to and fro | (7) |

motion. Cylinder has to move forward 10 sec after PB1 button is pressed and once to and fro reciprocation starts it should continue till stop button PB2 is pressed. Limit switches are used for end position sensing. Design an electro pneumatic circuit to implement this task.

| | | | |
|---|---|---|---|
| 10 | a | Briefly explain FMS and CIM. | (4) |
| | b | Explain any two noncontact inspection methods. | (3) |
| 11 | a | Distinguish Random order FMS and Dedicated FMS. | (4) |
| | b | Briefly explain the capabilities of computer process control. | (3) |
| 12 | | Explain the SCADA system with its components. | (7) |

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221LIA001 | ROBOTICS LAB | LABORATORY | 0 | 0 | 2 | 1 |

**Preamble:** The lab introduces the student to a Robot Operating System and familiarisation of a few ROS tools. It provides students with exposure to the common Robotic manipulators with at least 3DOF arm and mobile robots

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Understand the applications of ROS in real world complex scenarios |
| **CO 2** | Work with turtlesim, Gazebo, MoveIt and Rviz |
| **CO 3** | Interface ROS with hardware and analyse the issues in hardware interfacing |
| **CO 4** | Joint space and cartesian space trajectory planning of robotic manipulator |
| **CO 5** | Test basic control algorithms in mobile robots to move to a point, to follow a line, to follow a path and for obstacle avoidance. |
| **CO 6** | Calibrate sensors used in robots and design and develop sensor-based systems in robots |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 3 | |
| **CO6** | 3 | | 3 | 3 | 3 | 3 | |

**Pre-requisites**

ROS Installed Ubuntu System—UBUNTU 16.04LTS/18.04LTS
Basic knowledge of Linux command line tools
Basic programming in Python—2.7/3.5/3.6
Robotics Basics

**ROS Essentials**

- Installing and Configuring Your ROS Environment—ROS kinetic/ Melodic/ Compatible versions
- Familiarisation with ROS (Master, nodes, topics, messages, services, parameters and actions)
- Familiarisation with ROS Tools – Gazebo ,Moveit , Rviz
- Creating Workspace and Package in ROS

**Preliminary study**

- Writing a Simple Publisher and Subscriber, Simple Service and Client, Recording and playing back data, Reading messages from a bag file(Python/C++)

- Getting Started with Turtlesim
- Familiarisation with Rviz -- Markers: Sending Basic Shapes -- use visualization_msgs/Marker messages to send basic shapes, to send points and lines (C++), Interactive Markers: Writing a Simple Interactive Marker Server, Basic Controls
- Introduction to tf -- broadcast the state of a robot to tf, get access to frame transformations, Adding a frame, waitForTransform function, Setting up your robot using tf, publish the state of your robot to tf, using the robot state publisher.

**List of Experiments**

1. Building a Visual Robot Model with URDF from Scratch, Building a Movable Robot Model with URDF, Adding Physical and Collision Properties to a URDF Model.
2. Familiarisation with Gazebo--How to get Gazebo up and running, Creating and Spawning Custom URDF Objects in Simulation, Gazebo ROS API for C-Turtle, Simulate a Spinning Top, Gazebo Plugin - how to create a gazebo plugin, Create a Gazebo Plugin that Talks to ROS
3. Create a Gazebo Custom World (Building Editor, Gazebo 3D Models), Add Sensor plugins like Laser, Kinect, etc. to URDF of mobile robot
4. Create a 3DOF robotic arm from scratch
5. Familiarisation with MoveIt through its RViz plugin, Motion Planning with the Panda or other robot models. Create Moveit package for robotic arm simulation and add controllers, Plan a path for a 3DOF Robotic Arm and execute the same, Move the 3DOF arm to a desired goal point. Attach 2DOF gripper as the end effector of 3DOF arm and execute gripping operations, Execute Pick and Place Operation.
6. Familiarisation with 2D navigation stack, Basic ROS Navigation, Start robots in simulation. Execute SLAM Mapping (Lidar based) using a differentially driven mobile robot
7. Execute AMCL Navigation in a known environment using a differentially driven mobile robot

**Hardware experiments**

1. Familiarise ROS Serial Arduino for hardware interface.
2. Obstacle avoidance using a differentially driven mobile robot
3. Robotic Manipulator- Joint space and Cartesian space trajectory planning for a pick and place task.
4. Control of mobile robot for moving to a point(xg, yg) , following a line (ax+by+c=0), moving to a specific target orientation (θg) (Closed loop control considering kinematic models)
5. Sensor based experiment- Calibration of sensors-sonar, IR sensors and obtain the calibration curve, Object detection using any one standard algorithm, Object tracking and visual servoing, Following a moving target/ Object tracking from a moving vehicle

**ROS based Mini Project** (any one –compulsory)

1. Design and develop a servo controlled robotic manipulator (1 DOF) with visual feedback for pick and place task
2. Design and develop a mobile robot capable of obstacle avoidance and localisation
3. Assemble a quadcopter drone kit and make it hover.

**Text Books:**



1. Lentin Joseph, "Robot Operating Systems (ROS) for Absolute Beginners, Apress, 2018
2. Aaron Martinez, Enrique Fernández, "Learning ROS for Robotics Programming", Packt Publishing Ltd, 2013.
3. Robin Tommy, Ajithkumar Narayanan Manaparampil, Rinu Michael, Building Smart Robots Using ROS: Design, Build, Simulate, Prototype and Control Smart Robots Using ROS, Machine Learning and React Native Platform ,

**Reference Books:**

1. Jason M O'Kane, "A Gentle Introduction to ROS", CreateSpace, 2013.
2. AnisKoubaa, "Robot Operating System (ROS) – The Complete Reference (Vol.3), Springer, 2018.
3. Kumar Bipin, "Robot Operating System Cookbook", Packt Publishing, 2018.
4. Wyatt Newman, "A Systematic Approach to learning Robot Programming with ROS", CRC Press, 2017.
5. Patrick Gabriel, "ROS by Example: A do it yourself guide to Robot Operating System", Lulu, 2012.
6. Introduction to Robotics ( Mechanics and control), John. J. Craig, Pearson Education Asia 2002.
7. Introduction to Robotics by S K Saha, Mc Graw Hill Education
8. R K Mittal and I J Nagrath, "Robotics and Control", Tata McGraw Hill, New Delhi,2003.
9. AshitavaGhosal, "Robotics-Fundamental concepts and analysis", Oxford University press.
10. Robotics Technology and Flexible Automation, Second Edition, S. R. Deb
11. Introduction to Autonomous Mobile Robots, Siegwart, Roland, Cambridge, Mass. : MIT Press, 2nd ed.
12. Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Peter Corke, Springer

# SEMESTER I

## PROGRAM ELECTIVE I

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221EIA012 | DESIGN OF ROBOTIC SYSTEMS | PROGRAM ELECTIVE 1 | 3 | 0 | 0 | 3 |

**Preamble:** This course mainly deals with mechanical, electrical and electronic design of a robotic system. It also covers the basic programming of simple controller used in a robotic system. Finally, the overall design of a robotic manipulator and a mobile robot meant for specific application is covered.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Understand systematic design phases involved in the development of robotic systems |
| **CO 2** | Select suitable machine elements and design mechanical systems for robots |
| **CO 3** | Select suitable sensors and actuators for a specific robotic application |
| **CO 4** | Build, integrate and program controllers for robots |
| **CO 5** | Design and development of a robotic system based on the requirements |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 3 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination (%) |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed Original publications
*(minimum 10 publications shall be referred)* : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination :**60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks.*

## Syllabus

**Module 1**

Introduction to Design- Definition, steps in design process, preferred numbers, standards and codes in design. Shock and impact loads, fatigue loading, endurance limit stress, factors affecting endurance limit, factor of safety, material selection for robotic systems.

**Module 2**

**Types and selection of** threaded fasteners, springs, couplings, bearings, power transmission elements - Gears, belt drives, shafts. International standards on fasteners, bearings and couplings. Selection of ball screws and LM guideways (understanding data sheets).

**Module 3**

Embedded System Board Study (Arduino Uno)

Arduino Uno Board: Board Study (Board level Block schematic) - Chip (Features only - Architecture not needed), GPIO, Memory, Programming Interface

Programming: Arduino IDE, Sample Code (LED, Switch, DC motor, Stepper motor control, PWM), Integration of LCD module, communication module, I2C bus based sensors etc with Arduino. Integration projects based on these interfaces

**Module 4**

Selection of sensors, selection of actuators based on load and applications, Motor type and capacity- selection based on the characteristics, Power considerations, motor control -PWM, H bridge, chopper circuits, Driver circuits for motors. Servo motors- types and characteristics Pneumatic/Hydraulic actuators and control. Proportional hydraulics and pneumatics.

Case studies- Speed control of DC a motor with encoder using Arduino and Raspberry Pi. Position control of a simple two element robotic arm and error analysis (Demo/Assignment only)

**Module 5**

Given the work envelope (spherical, rectangular) - how to design a robotic manipulator-link dimensions, weight considerations, identify suitable sensors and actuators for the manipulator- for pick and place task. Mathematical model of the robot and designing suitable controller for the robot. Robot considerations for an application, selection and design considerations of grippers in robot.

Design of a mobile robot with given specifications- choice of suitable configuration, actuators and sensors for the robot, torque and speed requirements of the motors- **case study**- design of a differential drive robot to carry a pay load of 2kg, 75 kg , whether to choose kinematic model or dynamic model to design the controller, design of controller for the same.

Calibration of Robots, Calibration of work object coordinate system.

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Module 1** | |
| 1.1 | Introduction to Design- Definition, steps in design process, preferred numbers, standards and codes in design. | 2 |
| 1.2 | Shock and impact loads, fatigue loading, endurance limit stress, factors affecting endurance limit, factor of safety, | 4 |
| 1.3 | material selection for robotic systems | 2 |
| 2 | **Module 2** | |
| 2.1 | Types and selection of threaded fasteners, springs, couplings, bearings, | 2 |
| 2.2 | Types and selection of power transmission elements - Gears, belt drives, shafts | 2 |
| 2.3 | International standards on fasteners, bearings and couplings. | 2 |

| | | | |
|---|---|---|---|
| 2.4 | Selection of ball screws and LM guideways | 2 | ID4 |
| 3 | **Module 3** | | |
| 3.1 | Embedded System Board Study (Arduino Uno)<br><br>Arduino Uno Board: Board Study (Board level Block schematic) - Chip (Features only - Architecture not needed), GPIO, Memory, Programming Interface | 3 | |
| 3.2 | Programming: Arduino IDE, Sample Code (LED, Switch, DC motor, Stepper motor control, PWM), Integration of LCD module, communication module, I2C bus based sensors etc with Arduino. Integration projects based on these interfaces | 5 | |
| 4 | **Module 4** | | |
| 4.1 | Selection of sensors, selection of actuators based on load and applications | 2 | |
| 4.2 | Motor type and capacity- selection based on the characteristics, Power considerations, motor control -PWM, H bridge, chopper circuits, Driver circuits for motors. Servo motors- types and characteristics | 3 | |
| 4.3 | Pneumatic/Hydraulic actuators and control. Proportional hydraulics and pneumatics | 3 | |
| 4.4 | Case studies- Speed control of DC a motor with encoder using Arduino and Raspberry Pi. Position control of a simple two element robotic arm and error analysis (Demo/Assignment only) | 1 | |
| 5 | **Module 5** | | |
| 5.1 | Given the work envelope (spherical, rectangular) - how to design a robotic manipulator-link dimensions, weight considerations, identify suitable sensors and actuators for the manipulator- for pick and place task. | 2 | |
| 5.2 | Mathematical model of the robot and designing suitable controller for the robot. | 2 | |
| 5.3 | Robot considerations for an application, selection and design considerations of grippers in robot. | 1 | |
| 5.4 | Design of a mobile robot with given specifications- choice of suitable configuration, actuators and sensors for the robot, torque and speed requirements of the motors | 1 | |
| 5.5 | **case study**- design of a differential drive robot to carry a pay load of 2kg, 75 kg , whether to choose kinematic model or dynamic model to design the controller, design of controller for the same | 1 | |

| | | |
|---|---|---|
| 5.6 | Calibration of Robots, Calibration of work object coordinate system. | ID4<br>1 |

**Data Books(Permitted reference in the university examinations)**

1. Mahadevan, K., and K. Balaveera Reddy, Design Data Handbook, Mechanical Engineers in SI and Metric Units. CBS Publishers & Distributors, New Delhi, 2018.
2. PSG Design Data, DPV Printers, Coimbatore, 2012

**References**


1. Shigley, Mechanical Engineering Design, McGraw Hill 2003
2. V B Bhandari, Design of Machine Elements, McGraw Hill 2016
3. Sharma and Aggarwal, A Text book of Machine Design
4. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB
5. Introduction to Robotics by S K Saha, Mc Graw Hill Education
6. James Arthur, "Arduino: The complete guide to Arduino for beginners, including projects, tips, tricks", and programming, Ingram, 1e, 2019
7. Michael McRoberts, "Beginning Arduino", Apress, 1e, 2011

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221EIA021 | MACHINE LEARNING | PROGRAM ELECTIVE 1 | 3 | 0 | 0 | 3 |

**Preamble:** Machine learning techniques are indispensable for computing applications in robotic systems. This course is designed with the objective of providing a foundation to the theory behind machine learning and its application in robotic systems. This course will equip the students with mathematical framework for the machine learning necessary for various computing applications in robotic systems.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Familiarise machine learning algorithms and apply it in robotics |
| **CO 2** | Apply regression models in robotics |
| **CO 3** | Familiarise neural networks and its application in robotics |
| **CO 4** | Explain the development of hypothesis and apply it in robotics |
| **CO 5** | Solve problem using support vector machines and dimensionality reduction |
| **CO 6** | Apply unsupervised learning techniques in anomaly detection |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 6** | 3 | | 3 | 3 | 3 | 2 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30% |
| Analyse | 30% |
| Evaluate | 20% |
| Create | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed Original publications
*(minimum 10 publications shall be referred)* : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern: 60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks*

**Model Question Paper**

**SLOT D**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**

**FIRST SEMESTER M.TECH DEGREE EXAMINATION**

**MONTH & YEAR**

Course code: **221EIA021**

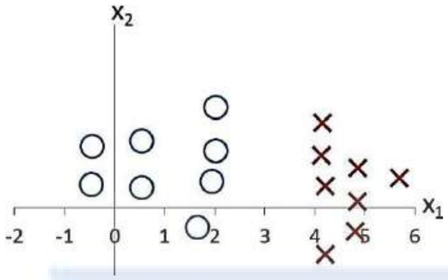
Course Name: **Machine Learning**

**Max. Marks: 60** **Duration: 2.5 Hours**

**PART A**

**Answer all Questions. Each question carries 5 Marks**

| | |
|---|---|
| 1 | Suppose you are working on stock market prediction. You would like to predict whether or not a certain company will win a patent infringement lawsuit (by training on data of companies that had to defend against similar lawsuits). Explain briefly about the algorithm used to solve the above problem. |
| 2 | Consider the problem of predicting how well a student does in her/his second year of college, given how well she/he did in first year. Specifically, let x be equal to the number of "A" grades (including A-. A and A+ grades) that a student receives in their first year of college. Build a model to predict the value of y, which define as the number of "A" grades they get in their second year. Suppose you set $\theta_0 = -1$, $\theta_1 = 2$ in the linear regression hypothesis. Find $h_\theta(6)$ ?<br>X Y<br>1 2<br>0 1<br>4 3<br>3 2 |
| 3 | Suppose you are learning to recognize cars from 100×100 pixel images (grayscale, not RGB). Let the features be pixel intensity values. If you train logistic regression including all the quadratic terms (xi, xj) as features, about how many features will you have? |
| 4 | Suppose the data sample S contains n = 40 examples and that hypothesis h commits r = 12 errors over this data. Find the confidence interval. Explain the steps to find the 95% confidence interval. |
| 5 | Consider the training set to the right, where "x" denotes positive examples (y=1) and "o" denotes negative examples (y=0). Suppose you train an SVM (which will predict 1 when $\theta_0+\theta_1x_1+\theta_2x_2 \geq 0$). Find values might the SVM give for $\theta_0$, $\theta_1$, $\theta_2$? |




**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

6 An adaptive controller adjusts parameters of a petroleum refinery's operation in real time. The controller optimizes the yield/cost/quality trade on the basis of specified marginal costs without sticking strictly to the set points originally suggested by engineers. Explain the algorithm suitable for this operation.

7 Many substances that can burn (such as gasoline and alcohol) have a chemical structure based on carbon atoms; for this reason they are called hydrocarbons. A chemist wants to understand how the number of carbon atoms in a molecule affects how much energy is released when that molecule combusts (meaning that it is burned). The chemist obtains the dataset below. In the column on the right, "kJ/mol" is the unit measuring the amount of energy released.

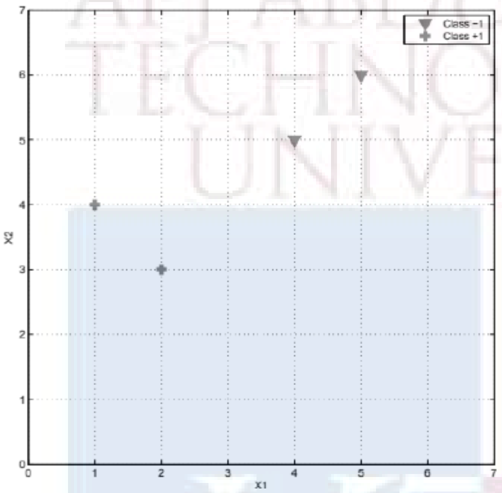
| Name of molecule | Number of hydrocarbons in molecule (x) | Heat released when burned (y) |
|---|---|---|
| Methane | 1 | 2 |
| Ethane | 2 | 4 |
| Propane | 3 | 5 |
| Butane | 4 | 4 |
| Pentane | 5 | 5 |

You would like to use linear regression to estimate the amount of energy released (y) as a function of the number of carbon atoms (x). Find the values of $\theta_1$ and $\theta_0$.

8 Let $J(\theta)=2\theta^3+2$. Let $\theta=1$, and $\epsilon=0.01$. Use the formula $\frac{J(\theta+\epsilon)-J(\theta-\epsilon)}{2\epsilon}$ to numerically compute an approximation to the derivative at $\theta=1$. What value do you get when $\theta=1$, the true/exact derivative is $\frac{dJ(\theta)}{d\theta}=6$ and also write the explanation for each steps.

9 You are about to test a hypothesis h whose $error_D(h)$ is known to be in the range between 0.2 and 0.6. What is the minimum number of examples you must collect to assure that the width of the two-sided 95% confidence interval will be smaller than 0.1?

10 Suppose you have a dataset with n = 10 features and m = 5000 examples. After training your logistic regression classifier with gradient descent, you find that it has underfit the training set and does not achieve the desired performance on the training or cross

| | |
|---|---|
| | validation sets. Explain the promising steps to avoid underfitting? |
| 11 | From a large set of primary care patient records, identify individuals who might have unusual health conditions. Explain briefly about the algorithm suitable for this task. |
| 12 | Support vector machines learn a decision boundary leading to the largest margin from both classes. You are training SVM on a tiny dataset with 4 points shown in figure below. This dataset consists of two examples with class label -1 (denoted with plus), and two examples with class label +1 (denoted with triangles).   Find the weight vector w and bias b. What's the equation corresponding to the decision boundary? Circle the support vectors and draw the decision boundary |

**Syllabus and Course Plan**

**Module 1**

Definition of ML – definitions by Arthur Samuel and Tom Mitchell – scope and application of ML. ML algorithms, supervised learning – Regression and Classification**:** Linear regression with one variable – model representation – cost function – Gradient descent for linear regression – learning rate. Un-supervised learning – cocktail party problem, reinforcement learning, recommender systems

**Module 2**

Linear algebra – inverse and transpose of matrices - significance of eigenvalues and eigenvectors – singular value decomposition. Linear regression with multiple variables – multiple features – Polynomial regression – Normal equation – Non-invertibility. Logistic regression for classification – hypothesis representation – decision boundary – multiclass classification

**Module 3**

**Neural Networks:** Representation – Non-linear hypothesis, neurons and the brain – weights, effective inputs, threshold and activation function. The McCulloch-Pitts neuron model - single and multi-layer neural network. Learning – General learning rule for one neuron – perceptron and delta learning rules – back propagation algorithm.

**Module 4**

**Evaluating Hypotheses:** Estimating hypothesis accuracy – sample error and true error. Basics of sampling theory - the Binomial Distribution – estimators, bias and variance – confidence intervals. Central Limit Theorem for deriving confidence intervals, hypothesis testing. Paired r test for comparing learning algorithms

**Module 5**

**Support vector machines (SVM) and Dimensionality Reduction**: Large margin classification - applications of SVM - linear and non-linear SVM - kernels, data compression and dimensionality reduction - Principle Component Analysis (PCA) – choosing the number of principle components. **Unsupervised learning and anomaly detection:** k-Means algorithm – optimization objective – choosing the number of clusters, hierarchicalagglomeration, scope of anomaly detection - Gaussian distribution. Developing and evaluating an anomaly detection system - anomalydetectionvs.supervisedlearning – choosing what features to use – multivariate Gaussian Distribution – anomaly detection using multivariate Gaussian Distribution

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Module 1** | |
| 1.1 | Definition of ML – definitions by Arthur Samuel and Tom Mitchell – scope and application of ML. | 2 |
| 1.2 | ML algorithms, supervised learning – Regression and Classification**:** Linear regression with one variable – model representation – cost function – Gradient descent for linear regression – learning rate. | 3 |
| 1.3 | unsupervised learning – cocktail party problem, reinforcement learning, recommender systems | 3 |
| 2 | **Module 2** | |
| 2.1 | Linear algebra – inverse and transpose of matrices - significance of eigenvalues and eigenvectors – singular value decomposition. | 1 |
| 2.2 | Linear regression with multiple variables – multiple features – Polynomial regression – Normal equation – Non-invertibility | 3 |
| 2.3 | Logistic regression for classification – hypothesis representation – decision boundary – multiclass classification | 4 |
| 3 | **Module 3** | |

| | | |
|---|---|---|
| 3.1 | **Neural Networks:** Representation – Non-linear hypothesis, neurons and the brain – weights, effective inputs, threshold and activation function. | 2 |
| 3.2 | The McCulloch-Pitts neuron model - single and multi-layer neural network | 3 |
| 3.3 | Learning – General learning rule for one neuron – perceptron and delta learning rules – back propagation algorithm | 3 |
| 4 | **Module 4** | |
| 4.1 | **Evaluating Hypotheses:** Estimating hypothesis accuracy – sample error and true error. Basics of sampling theory - the Binomial Distribution – estimators, bias and variance – confidence intervals. | 3 |
| 4.2 | Central Limit Theorem for deriving confidence intervals, hypothesis testing. | 2 |
| 4.3 | Paired r test for comparing learning algorithms | 3 |
| 5 | **Module 5** | |
| 5.1 | **Support vector machines (SVM) and Dimensionality Reduction**: Large margin classification - applications of SVM - linear and non-linear SVM - kernels, data compression and dimensionality reduction - Principle Component Analysis (PCA) – choosing the number of principle components. | 3 |
| 5.2 | **Unsupervised learning and anomaly detection:** k-Means algorithm – optimization objective – choosing the number of clusters, hierarchicalagglomeration, scope of anomaly detection - Gaussian distribution. | 2 |
| 5.3 | Developing and Evaluating an anomaly detection system - anomalydetectionvs.supervisedlearning – choosing what features to use – multivariate Gaussian Distribution – anomaly detection using multivariate Gaussian Distribution | 3 |

**Reference Books**


1. EthemAlpaydin, Introduction to Machine Learning, Second Edition, The MIT Press Cambridge, Massachusetts, London, England 2010.
2. Tom M. Mitchell, "Machine learning", McGraw Hill Education, 2017.
3. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer 2011.
4. Trevor Hastie, Robert Tibshirani, Jerome H. Friedman, The Elements of Statistical Learning, springer 2$^{nd}$ edition, 2009.
5. Max Kuhn and Kjell Johnson, Applied predictive modelling. Springer, 2013.
6. Sebastian Raschka and VahidMirjalili, Python Machine Learning. Packt Publishing, 2017.

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221EIA015 | ARTIFICIAL INTELLIGENCE FOR ROBOTICS | PROGRAM ELECTIVE 1 | 3 | 0 | 0 | 3 |

**Preamble:** This course will deal with the fundamental principles of Artificial Intelligence including knowledge representation, reasoning, decision making and programming techniques. The course will also support developing an understanding of the theoretical relationships between these algorithms.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Interpret supervised and unsupervised learning algorithms |
| **CO 2** | Use CNN and RNN for different robotic applications |
| **CO 3** | Use computer vision for robotic applications |
| **CO 4** | Localise a robot in any scenario |
| **CO 5** | Use RL for robotic applications |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 2** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 3** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 2 | 3 | 3 | 3 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination (%) |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed Original publications

| | |
|---|---|
| *(minimum 10 publications shall be referred)* | : 15 marks |
| Course based task/Seminar/Data collection and interpretation | : 15 marks |
| Test paper, 1 no. | : 10 marks |

*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination :**60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks.*

**Model Question Paper**

**SLOT**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**
**SECOND SEMESTER M.TECH DEGREE EXAMINATION**
**MONTH &YEAR**

Course code:

Course Name:**Artificial Intelligence for Robotics**

**Max. Marks: 60** **Duration: 2.5 Hours**

**PART A**

**Answer all Questions. Each question carries 5 Marks**

1 Consider the following set of training examples:

| Instance | Classification | $a_1$ | $a_2$ |
|---|---|---|---|
| 1 | + | T | T |
| 2 | + | T | T |
| 3 | - | T | F |
| 4 | + | F | F |
| 5 | - | F | T |
| 6 | - | F | T |

What is the information gain of $a_2$ relative to these training examples? Provide the equation for calculating the information gain as well as the intermediate results.

2 In a reinforcement learning problem, it is decided to describe the state space using an approximate function and to minimize the RMSE close to zero, uniformly throughout the state space. Is it a wise design? Elaborate your answer.

3 Distinguish between the Roberts Cross Edge and Sobel Edge Detector.

4 A mobile robot, working in an indoor environment, wants to rank unexplored regions and to make rational choices. How can it be done? Explain the method in detail.

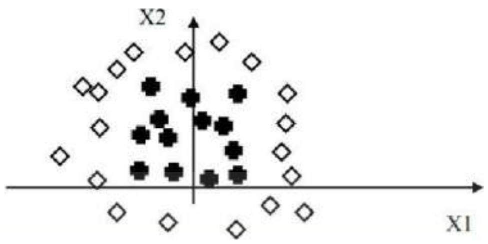
5 How policy evaluation and policy iteration are done in Dynamic Programming?

**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

6 Derive the gradient descent training rule assuming that the target function representation is: $o_d = w_0 + w_1x_1 + \ldots + w_nx_n$. Define explicitly the cost/error function E, assuming that a set of training examples D is provided, where each training example $d \in D$ is associated with the target output $t_d$.

7 Suppose that we want to build a neural network that classifies two dimensional data (i.e., X = [x1, x2]) into two classes: diamonds and crosses. We have a set of training data that is plotted as follows:




Draw a network that can solve this classification problem. Justify your choice of the number of nodes and the architecture. Draw the decision boundary that your network can find on the diagram.

**8** A 4 x 4 gray-scale image is given below:

| | | | |
|---|---|---|---|
| 5 | 6 | 7 | 8 |
| 0 | 6 | 7 | 8 |
| 5 | 6 | 15 | 8 |
| 5 | 6 | 7 | 8 |

Filter the image with a 3x3 median filter, after zero padding.

**9** Describe image formation in the eye with brightness adaptation and discrimination.

**10** Explain in detail how the non-linearity in state transition and measurements is accounted in Extended Kalman Filter algorithm.

**11** Explain the Bayesian method of using sensor model to update the occupancy grid.

**12** Consider the standard grid problem, where a robot is required to traverse a grid of 4×4 dimensions to reach its goal (1 or 16). There are 2 terminal states here: 1 and 16 and 14 non-terminal states given by [2, 3,…., 15]. We need to evaluate a random policy, in which the probability of every action {up, down, left, right} is equal to 0.25. The reward is -1 for all transitions. Start by initializing values of all states as zeros. Take discount factor as 1. Using Bellman equation, find the value of the state 6, after the second and third iterations.

| | | | |
|---|---|---|---|
| **1** | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | **16** |

## Syllabus

**Module 1**

Probability and Expectation Basics, Bayes Optimal, Stochastic Average Approximation, Stochastic Gradient Descent; Supervised Learning Algorithms, Unsupervised Learning Algorithms, Reinforcement based learning-overview with basic elements agent, environment, action, state, reward only; Challenges Motivating Deep Learning.

**Module 2**

Deep Feedforward Networks, Convolutional Networks-basic outline and functions of each layers only, Sequence Modeling: Recurrent and Recursive Nets - Need for sequence models, basic RNN architecture and types

**Case study**-line follower robot using CNN, Speech Recognition using RNN overview

**Module 3**

Machine vision - Introduction, Computer vision – Introduction.

Image formation, Basic image processing operations - edge detection, texture, optical flow, segmentation. challenges in image detection, Image features optimization.
Case study- application of AI in ball Tracking in football game, crop monitoring using drones, traffic sign detection, pedestrian detection.

**Module 4**

Robotics - Robotic perception, Localization and mapping, Machine learning in robot perception, Application domains
Case study- Use of AI in typical pick and place task, localization of a differential drive robot.

**Module 5**

Reinforcement learning Overview, Policy based and Value based approaches , Monte Carlo Methods, Temporal-Difference Learning (Q-learning, SARSA).
Case study- Role of RL in typical pick and place task, RL for stabilization of bipedal humanoid

**Text /Reference books**

**1)** Ian Goodfellow, YoshuaBengio, Aaron Courville, Deep Learning, MIT Press, 2016
**2)** Stuart J. Russell and Peter Norvig, Artificial Intelligence - A Modern Approach
Third Edition,Pearson, 2016
**3)** Bishop, C. ,M., Pattern Recognition and Machine Learning, Springer, 2006.
**4)** Berthold Klaus, Paul Horn "Robot vision" The MIT Press, 1987.
**5)** Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer; 2011th
edition (19 October 2010).

6) Grigorescu, Sorin, et al. "A survey of deep learning techniques for autonomous driving." Journal of Field Robotics 37.3 (2020): 362-386.

**Course plan**

| No | Topic | Total Lecture Hrs |
|---|---|---|
| 1.1 | Probability and Expectation Basics, Bayes Optimal, Stochastic Average Approximation, Stochastic Gradient Descent | 2 |
| 1.2 | Supervised Learning Algorithms, Unsupervised Learning Algorithms,Reinforcement based learning-overview with basic elements agent, environment, action, state, reward only; Challenges Motivating Deep Learning | 4 |
| 2.1 | Deep Feedforward Networks, Convolutional Networks-basic outline and functions of each layers only, SequenceModeling: Recurrent and Recursive Nets - Need for sequence models, basic RNN architecture and types<br><br>**Case study**-line follower robot using CNN, Speech Recognition using RNN overview | 4 |
| 3.1 | Machine vision - Introduction, Computer vision - Introduction | 1 |
| 3.2 | Image formation, Basic image processing operations - edge detection, texture, optical flow, segmentation. challenges in image detection, Image features optimization. | 4 |
| 3.3 | **Case study**- application of AI in ball Tracking in football game, crop monitoring using drones, traffic sign detection, pedestrian detection | 2 |
| | | |
| 4.1 | Robotics - Robotic perception, Localization and mapping, Machine learning in robot perception, Application domains | 5 |
| 4.2 | **Case study**- Use of AI in typical pick and place task, localization of a differential drive robot | 2 |
| | | |
| 5.1 | Reinforcement learning Overview, Policy based and Value based approaches , Monte Carlo Methods, Temporal-Difference Learning (Q-learning, SARSA) | 4 |
| 5.2 | Case study- Role of RL in typical pick and place task, RL for stabilization of bipedal humanoid | 3 |

# SEMESTER I

## PROGRAM ELECTIVE II

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221EIA018 | INDUSTRY 4.0 AND INDUSTRIAL INTERNET OF THINGS (IIOT) | PROGRAM ELECTIVE 2 | 3 | 0 | 0 | 3 |

**Preamble:** Industry 4.0 concerns the transformation of industrial processes through the integration of modern technologies such as sensors, communication, and computational processing. Industrial Internet of Things (IIoT) is an application of IoT in industries to modify the various existing industrial systems. IIoT links the automation system with enterprise, planning and product lifecycle.

**Course Outcomes:** After the completion of the course, the student will be able to

| | |
|---|---|
| **CO 1** | Explain the drivers and enablers of Industry 4.0 |
| **CO 2** | Able to outline the various systems used in IIoT Architecture |
| **CO 3** | Apply Big Data Analytics, Software Defined Networks Security, and Fog Computing in IIoT applications |
| **CO 4** | Explain IIoT Application domains |
| **CO 5** | Discuss the opportunities, challenges brought about by Industry 5.0 and how organizations and individuals should prepare to reap the benefits |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 2 | | | 3 | |
| **CO 2** | 3 | | 2 | | | 3 | |
| **CO 3** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 6** | 3 | | 2 | | | | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed Original publications

*(minimum 10 publications shall be referred)* : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination : **60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks.*

**Syllabus**

**Module I**

The Various Industrial Revolutions, Introduction to Sensing & actuation, Communication, and Networking.

Industry 4.0: Globalization, The Fourth Revolution, LEAN Production Systems, Cyber-Physical Systems, and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Cybersecurity in Industry 4.0.

**Module II**

Industrial Processes- Industrial Sensing & Actuation, IIoT-Introduction, Industrial IoT: Business Model and Reference Architecture.

Industrial IoT -Layers: IIoT Sensing, IIoT Processing-, IIoT Communication.,IIoT Communication, IIoT Networking.

**Module III**

Big Data Analytics and Software Defined Networks: IIoT Analytics - Introduction, Machine Learning and Data Science.

SDN in IIoT-Data Center Networks, Industrial IoT.

Security and Fog Computing - Fog Computing in IIoT, Security in IIoT , Industrial IoT- Application Domains.

**Module IV**

Industrial IoT- Application Domains: Healthcare, Power Plants, Inventory Management & Quality Control

Plant Safety and Security (Including AR and VR safety applications), Facility Management.

Industrial IoT- Application Domains: Oil, chemical, and pharmaceutical industry, Applications of UAVs in Industries, Real case studies.

**Module V**

Introduction to Industry 5.0, Opportunities and Challenges, Future of Works and Skills for Workers in the Industry 5.0 Era, Strategies for competing in an Industry 5.0 world.

**Reference Books**

1. "Industry 4.0: The Industrial Internet of Things", by Alasdair Gilchrist Apress, 2017
2. "Industrial Internet of Things: Cyber Manufacturing Systems "by Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat ,Springer , 2017.
3. "Introduction to Industrial Internet of Things and Industry 4.0". by Sudip Misra, Chandana Roy, Anandarup Mukherjee. CRC Press; 1st edition (15 December 2020)

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | **Industry 4.0** | |
| 1.1 | The various Industrial Revolutions | 1 |
| 1.2 | Introduction to Sensing & actuation, Communication, and Networking | 2 |
| 1.3 | Globalization, The Fourth Revolution, LEAN Production Systems | 2 |
| 1.4 | Cyber-Physical Systems, Digital twins, Next Generation Sensors, Collaborative Platform, and Product Lifecycle Management | 2 |
| 1.5 | Cybersecurity in Industry 4.0 | 1 |
| **2** | **Introduction to IIoT** | |
| 2.1 | Basics of IIoT: Industrial Processes- Industrial Sensing & Actuation | 2 |
| 2.2 | Industrial IoT: Business Model and Reference Architecture | 2 |
| 2.3 | Industrial IoT -Layers: IIoT Sensing, IIoT Processing-, IIoT Communication, IIoT Networking | 4 |
| **3** | **IIoT Data Analytics** | |
| 3.1 | Big Data Analytics and Software Defined Networks: IIoT Analytics - Introduction, Machine Learning, and Data Science. | 3 |
| 3.2 | Big Data Analytics and Software Defined Networks: SDN in IIoT-Data Center Networks, Industrial IoT | 3 |
| 3.3 | Security and Fog Computing: Fog Computing in IIoT, Security in IIoT, Industrial IoT- Application Domains | 3 |
| **4** | **IIoT- Application Domains** | |
| 4.1 | Industrial IoT- Application Domains: Healthcare, Power Plants, Inventory Management & Quality Control | 3 |
| 4.2 | Plant Safety and Security (Including AR and VR safety applications), Facility Management | 2 |
| 4.3 | Industrial IoT- Application Domains: Oil, chemical, and pharmaceutical industry, Applications of UAVs in Industries -**Real case studies** | 4 |
| **5** | **Introduction to Industry 5.0** | |
| 5.1 | Introduction to Industry 5.0, Opportunities and Challenges | 2 |
| 5.2 | Future of works and skills for workers in the industry 5.0 Era | 2 |
| 5.3 | Strategies for competing in an Industry 5.0 world | 2 |

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221EIA019 | COMPUTER VISION | PROGRAM ELECTIVE 2 | 3 | 0 | 0 | 3 |

**Preamble:** Image processing is a method to perform certain operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image.Computer vision is a field of artificial intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs and take actions or make recommendations based on that information.Students will be able to learn image processing fundamentals, understand the different types of algorithms in image processing and computer vision, develop in-depth knowledge of image and video processing tasks such as image representation, image transforms, image enhancement, Image restoration, image segmentation and image compression.

**Prerequisite:** A sound knowledge of the fundamentals and basics of digital signal processing techniques.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Understand and apply the fundamentals, concepts and terminologies in image processing and computer vision. |
| **CO 2** | Understand and analyse the principles of image restoration and segmentation and illustrate the methods and algorithms for image restoration and segmentation. |
| **CO 3** | Understand and analyse the principles of image compression and video processing and illustrate the methods and algorithms for image compression and video processing. |
| **CO 4** | Analyze and evaluate the performance of depth estimation and multi-camera views. for computer vision. |
| **CO 5** | Evaluate critically the techniques for motion analysis and optical flow in computer vision. |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 2 | 3 | | 2 | | | |
| **CO 2** | 2 | 2 | | | 3 | | |
| **CO 3** | 3 | 2 | | | 2 | 2 | 3 |
| **CO 4** | | | | | 2 | 2 | 2 |
| **CO 5** | 3 | 2 | | 3 | | | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 20 % |
| Analyse | 40 % |
| Evaluate | 20 % |
| Create | 20 % |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation: 40 marks**

Preparing a review article based on peer reviewed

Original publications (minimum 10 Publications shall be referred): 15 marks

Course based task/Seminar/Data Collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus. include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

**Model Question Paper** ID4

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

FIRST SEMESTER M.TECH DEGREE EXAMINATION, (**Model Question Paper)**

**Discipline: ELECTRONICS & COMMUNICATION ENGINEERING**

**Course Code: 221EIA019**

**Course Name: COMPUTER VISION**

Max. Marks: 60 Duration: 2.5Hours

**PART A**

Answer all Questions. Each Question Carries 5 marks.

| | | | |
|---|---|---|---|
| 1 | Explain the properties of Fourier transform specific to image processing. | CO1 | |
| 2 | Explain basic principles of LoG and DoG filters. Discuss the merits and demerits compared with other type of filters. Discuss the shape of LoG(x, y, σ) with an indicative plot. | CO1 | |
| 3 | Explain the basic principles of transform coding. Give the block schematic of a transform coder. Compare the performance of different transforms based coders with a graph. | CO2 | |
| 4 | Illustrate the concept of depth estimation. What is stereo dept estimation ? | CO2 | |
| 5 | Comment on Phong Lighting Model. Why shading is important in computer vision? DisccussPhong shading. | CO3 | |

**PART – B**

Answer any 5 full questions ; Each question carries 7 marks.

| | | | | |
|---|---|---|---|---|
| 6. a) | Compare and contrast spatial and spectral domain processing of images. Discuss some applications that require these type of processing. Write a MATLAB program snippet for generating a checker box pattern of size 8 × 8. | 4 | CO1 | |
| 6. b) | Briefly explain edges in images. What do you mean by edge magnitude and edge direcion? Discuss some techniques for edge sharpening. | 3 | CO2 | |
| 7.a) | Let f represents a M × N image. If the DFT and IDFT of f is given by P f Q and $P^{-1} f Q^{-1}$ respectively, then give expression for all transformation matrices. | 3 | CO1 | |
| 7. b) | Let f (x, y) be a continous image function. The image is sampled at | 4 | CO2 | |

| | | | | |
|---|---|---|---|---|
| | points x = j△x, y = k△y, for j = 1, ..., M and k = 1, ..., N. Where △x and △y are sampling intervals. Find expression for the sampled image fs (x, y). Also represent the sampled image in the frequency domain. (Hint: Assume ideal sampling using shifted dirac functions δ.) | | ID4 | |
| 8.a) | Explain the significance of Weiner filter in image restoration. Obtain expression for Wiener filter transfer function. | 4 | CO2 | |
| 8.b) | List the steps involved in image restoration using Weiner filter. With a neat block schematic explain the digital implementation of Wiener filter. | 3 | CO1 | |
| 9. a) | For the number plate identification of vehicles, the pre-processing step uses segmentation. Explain a suitable technique for this. Illustrate how do you arrive on thresholds ? | 4 | CO3 | |
| 9.b) | Explain region merging technique. Discuss the criterion for merging two different regions in an image. | 3 | CO1 | |
| 10.a) | Discuss the principles of fixed length and variable length encoding techniques. The word MISSISSIPPI RIVER is to be encoded using Huffman coding technique. Draw the Huffman tree and determine the Huffman code for the same. | 4 | CO3 | |
| 10.b) | Compare and contrast lossy and loss-less compression techniques. Discuss entropy based compression techniques. Also explain fundamental properties of information. | 3 | CO5 | |
| 11.a) | What is homography estimation? Explain the significance of homography matrix. | 3 | CO5 | |
| 11.b) | Illustrate how RANSAC helps in estimating a mathematical model from a data set that contains outliers. | 4 | CO2 | |
| 12.a) | Explain how to segment the foreground objects from the background of a sequence ? Discuss the principles of background subtraction. | 3 | CO2 | |
| 12.b) | What do you mean by motion estimation? How do we estimate parameters? | 4 | CO1 | |

## Syllabus

**Module - 1 ( Image Representation ) :**

Image Representation: Gray scale and colour images, image sampling and quantization. Two dimensional orthogonal transforms: DFT, WHT, Haar transform, KLT, DCT. Image representation using SIFT, GIST and HOG features. Image enhancement - Filters in spatial and frequency domains, histogram- based processing, homomorphic filtering.

**Module -2 (Image Resoration and Segmentaton)**

Image Restoration: Degradation models, PSF, circulant and block-circulant matrices, deconvolution, restoration using inverse filtering, Wiener filtering and maximum entropy-based methods. Image segmentation: pixel classification, bi-level thresholding, multi- level thresholding. Edge detection, edge sharpening, edge profiles, edge operators, LoG, DoG. Hough transform.

**Module 3 (Image Compression and Video Processing)**

Fundamental Concepts of Image Compression: Compression models - Information theoretic perspective - Fundamental coding theorem-Lossless compression: Huffman Coding-arithmetic coding – bit plane coding - run length coding - Lossy compression: Transform coding - Image compression standards. Video processing: Representation of digital video, Spatio-temporal sampling; Motion estimation; video filtering; Video compression, video coding standards.

**Module -4 (Depth estimation and Multi-camera views)**

Depth estimation and Multi-camera views: Perspective, binocular stereopsis: Camera and epipolar geometry; homography, rectification, DLT, RANSAC, 3-D reconstruction framework; auto-calibration.

**Module -5 ( Motion Analysis )**

Motion Analysis: Background subtraction and modeling, Optical flow, KLT, spatio-temporal analysis, dynamic stereo; motion parameter estimation. Light at surfaces- Phong Model, shape from texture, color, motion and edges.

**Text Book**

1. Fundamentals of Digital Image Processing, A. K. Jain, Prentice Hall of India, 1989.

2. Digital Image Processing , R. C. Gonzalez, R. E. Woods, Digital Image Processing, Pearson Education, 2nd Edition, 2002.

3. Computer Vision algorithms and Applications, Richard Szeliski, Springer, New York, 2nd Edition, 2022.

**Reference Books**


1. Digital Image Processing, 4th Edition, WileyInterscience, W. K. Pratt, Prentice Hall,2007.

2. Digital Image Processing, A. Rosenfold and A. C. Kak, Vols. 1 and 2, Prentice Hall, 2014.

3. Digital Image Restoration, H. C. Andrew and B. R. Hunt, Prentice Hall, 1977

4. Machine Vision, R. Jain, R. Kasturi and B.G. Schunck, McGraw-Hill International Edition, 1995

5. Digital VideoProcessing,A. M. Tekalp, Digital Video Processing , Prentice-Hall, 1995

6. Handbook of Image & Video Processing, A. Bovik, Academic Press, 2000.

7. Dictionary of Computer Vision and Image Processing, Second Edition, R. B. Fisher, T. P. Breckon, K. Dawson-Howe et al., ISBN:9781119941866, John Wiley & Sons Ltd., 2016


**Course Plan**

| No | Topic | No. of Lectures [40Hrs] |
|---|---|---|
| 1 | **Image Representation** | |
| 1.1 | Image Representation: Gray scale and colour Images, image sampling and quantization. | 2 |
| 1.2 | Two dimensional orthogonal transforms: DFT, WHT, Haar transform, KLT, DCT. | 2 |
| 1.3 | Image representation using SIFT, GIST and HOG features. | 2 |
| 1.4 | Image enhancement - filters in spatial and frequency domains, histogram- based processing, homomorphic filtering. | 3 |
| 2 | **Image Restoration and Segmentation** | |
| 2.1 | Image Restoration: Degradation Models, PSF, circulant and block-circulant matrices, deconvolution, restoration using inverse filtering. | 2 |
| 2.2 | Wiener filtering and maximum entropy-based methods. | 2 |
| 2.3 | Image Segmentation: Pixel classification, Bi-level thresholding, Multi- level thresholding. | 3 |
| 2.4 | Edge detection, edge sharpening, edge profiles, edge operators, LoG, DoG. Hough transform. | 2 |
| 3 | **Image Compression and video Processing** | |
| 3.1 | Fundamental Concepts of Image Compression: Compression models- Information theoretic perspective - Fundamental coding theorem. | 2 |

| | | |
|---|---|---|
| 3.2 | Lossless Compression: Huffman Coding- Arithmetic coding – Bit plane coding - Run length coding. | ID4 |
| 3.3 | Lossy compression: Transform coding - Image compression standards. | 3 |
| 3.4 | Video Processing: Representation of Digital Video, Spatio-temporal sampling; Motion Estimation; Video Filtering; Video Compression, Video coding standards. | 3 |
| 4 | **Depth estimation and Multi-camera views** | |
| 4.1 | Depth estimation and Multi-camera views: Perspective, Binocular Stereopsis. | 2 |
| 4.2 | Camera and Epipolar Geometry; Homography, Rectification. | |
| 4.3 | DLT, RANSAC, 3-D reconstruction framework. | 3 |
| 4.4 | Auto-calibration. | 2 |
| 5 | **Motion Analysis** | |
| 5.1 | Motion Analysis: Background Subtraction and Modeling. | 2 |
| 5.2 | Optical Flow, KLT, Spatio-Temporal Analysis, Dynamic Stereo. | 2 |
| 5.3 | Motion parameter estimation. | 1 |
| 5.4 | Light at Surfaces: Phong Model, Shape from Texture, color, motion and edges. | 2 |

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| **221EIA020** | **ROBOT MOTION PLANNING** | **PROGRAM ELECTIVE 2** | **3** | **0** | **0** | **3** |

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Specify the configuration of a robot using configuration space |
| **CO 2** | Plan motion for robots using classical motion planning paradigms |
| **CO 3** | Plan paths for robots using graph search and sensor-based motion planning algorithms |
| **CO 4** | Estimate the position a robot using Kalman filter |
| **CO 5** | Simultaneously localize and obtain the map using simple SLAM algorithms |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 2 | 2 | 2 | 3 | |
| **CO 2** | 3 | | 2 | 2 | 2 | 3 | |
| **CO 3** | 3 | | 2 | 2 | 2 | 3 | |
| **CO 4** | 3 | | 2 | 2 | 2 | 3 | |
| **CO 5** | 3 | | 2 | 2 | 2 | 3 | |
| **CO 6** | 3 | | 2 | 2 | 2 | 3 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination (%) |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or designbased questions (for bothinternal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed Original publications
*(minimum 10 publications shall be referred)* : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination :**60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks.*

**Model Question Paper**

**Slot: E**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**
**FIRST SEMESTER M.TECH DEGREE EXAMINATION**
**MONTH & YEAR**

Course code: **221EIA020**

Course Name:**Robot Motion Planning**

**Max. Marks: 60** **Duration: 2.5 Hours**

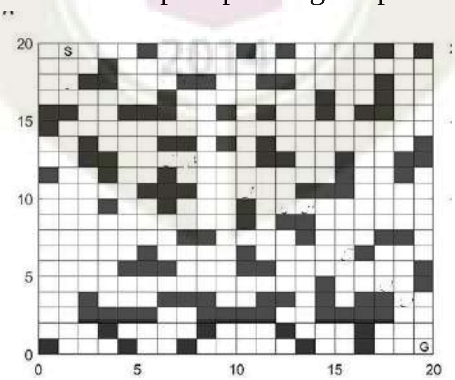
**PART A**

**Answer all Questions. Each question carries 5 Marks**

| | |
|---|---|
| 1 | What do you mean by configuration space? How its important in robot motion planning? |
| 2 | What is Potential field algorithm? How it's implemented in a mobile robot? |
| 3 | What are the characteristics of sampling based planners? |
| 4 | What is tangent bug algorithm? What are its advantages compared to other bug algorithms? |
| 5 | In which context we use Kalman filters? Can we implement Kalman filter in all systems? |

**PART A**

**Answer any 5 Questions. Each question carries 7 Marks**

| | |
|---|---|
| 6 | Compare Homeomorphism and Diffeomorphism. |
| 7 | In which context roadmap algorithms are used in robot path motion planning? Explain any one road map based algorithm for robot motion planning. |
| 8 | Explain any one method of cell decomposition algorithm for robot motion planning. |
| | How will you practically implement a basic PRM? |
| 9 | Consider the following scenario. If there is a possibility of pop-up obstacles on the way, which algorithm can be used for path panning. Explain the algorithm.  |
| 10 | Find the path for the following scenario using Bug1 and Bug2 algorithms. |

| | |
|---|---|
| |  |
| 11 | How will you implement SLAM with the help of Kalman filter? |
| 12 | How EKF can be used for Range and Bearing Localization? |

## Syllabus

### Module 1

An overview of robot motion planning problems; Review of basic kinematics of rigid body motion.

**Configuration Space**- Specifying a robots configuration, Obstacles and configuration space- Circular mobile robot, Two joint planar arm, the dimension of the configuration space, The topology of configuration space- Homeomorphisms and Diffeomorphisms, Differentiable Manifolds, Connectedness and Compactness, Not All Configuration Spaces are Manifolds, Matrix Representations of Rigid-Body Configuration, Parameterizations of SO(3), Example Configuration Spaces, Transforming Configuration and Velocity Representations

### Module II

**The classical motion planning paradigms I**: roadmaps-visibility maps, generalised Voronoi diagram; potential field method- Attractive & repulsive potential, gradient descent, Gradient Descent, Computing Distance for Implementation in the Plane- Mobile Robot Implementation, Brushfire Algorithm: a Method to Compute Distance on a Grid, local minima problem, wavefront planner, navigation potential functions- Sphere-Space, Star-Space; potential Functions in Non-Euclidean Spaces, Relationship between Forces in the Workspace and Configuration Space, Potential Functions for Rigid-Body Robots.

### Module III

**The classical motion planning paradigms** II- The cellular decomposition and approximate cellular decomposition approaches- Trapezoidal Decomposition, Morse Cell Decompositions, Boustrophedon Decomposition, Morse Decomposition Definition, Examples of Morse Decomposition: Variable Slice, Probabilistic Roadmaps- Basic PRM, A Practical Implementation of Basic PRM, PRM Sampling Strategies, PRM Connection Strategies, Rapidly-Exploring Random Trees.

**Module IV**

Graph search and discrete planning algorithms- Dijkstra's algorithm, A* algorithm.

**Sensor-Based Motion Planning Algorithms: -** the "Bug" algorithms, Bug1 and Bug2, Tangent Bug, Implementation, the incremental Voronoi Graph, D* algorithm.

**Module V**

Kalman Filtering- to estimate the state of robot, Probabilistic Estimation, Linear Kalman Filtering, Overview, A Simple Observer, Observing with Probability Distributions, The Kalman Filter, Kalman Filter for Dead Reckoning, Observability in Linear Systems, Extended Kalman Filter, EKF for Range and Bearing Localization, Kalman Filter for SLAM, Simple SLAM, Range and Bearing SLAM.

**References**

1. Howie Choset, Kevin Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun. Principles of Robot Motion: Theory, Algorithms, and Implementations Prentice Hall of India
2. Choset, Howie M. "Principles of robot motion: theory, algorithms, and implementation". MIT press, 2005.
3. Planning Algorithms by Steve LaValle (Cambridge Univ. Press, New York, 2006).
4. Robot Motion Planning by J.C. Latombe.
5. Probabilistic Robotics (by Sebastian Thrun, Wolfram Burgard, and Dieter Fox Lynch). MIT Press, 2005.

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221EIA014 | MOBILE ROBOTICS | PROGRAM ELECTIVE 2 | 3 | 0 | 0 | 3 |

**Preamble:** Mobile robotics is an indispensable subject in robotics. This course is designed with the objective of providing a foundation to the theory behind numerical computation and optimization techniques used in robotic systems. This course will equip the students with mathematical framework for the robotic systems and optimization techniques necessary for mobile robotic systems.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Familiarise types of locomotion for mobile Robots |
| **CO 2** | Derive the kinematic model of mobile robots |
| **CO 3** | Derive dynamic model of mobile robots |
| **CO 4** | Choose appropriate Sensors for mobile robot navigation |
| **CO 5** | Perform navigation and path planning mobile robots |
| **CO 6** | Control the mobile robots to follow different paths |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 6** | 3 | | 3 | 3 | 3 | 2 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30% |
| Analyse | 30% |
| Evaluate | 30% |
| Create | 10% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Preparing a review article based on peer reviewed Original publications
*(minimum 10 publications shall be referred)* : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:** 60 marks

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.

*Each question can carry 7 marks.*

**Model Question Paper**

**SLOT E**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**

**FIRST SEMESTER M.TECH DEGREE EXAMINATION**

**MONTH &YEAR**

Course code: **221EIA014**

Course Name: **Mobile Robotics**

**Max. Marks: 60** **Duration: 2.5 Hours**

**PART A**

**Answer all Questions. Each question carries 5 Marks**

| | |
|---|---|
| 1 | Discuss how leg configuration affect stability of robots. Which mobile robot configuration is preferred for movement in uneven terrains? Justify your answer. |
| 2 | What are the advantages of a mobile robot with Mecanum wheels compared to the conventional differential drive robot with ordinary wheels? |
| 3 | What is the necessity of dynamic modelling of mobile robot? Explain the steps to obtain the dynamic model of a differential drive mobile robot? (steps only) |
| 4 | Which all sensors may be needed for an autonomous mobile robot in an indoor environment to navigate as well as to find its own position. Justify your answer. |
| 5 | Discuss the dynamic window approach for obstacle avoidance in mobile robot. |

**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

| | |
|---|---|
| 6 | Which are the different wheel configurations possible for a wheeled mobile robot? Explain with the help of sketches. Also comment on the manoeuvrability of these configurations. |
| 7 | Derive the Kinematic model of a differential drive mobile robot. Also explain whether a differential drive mobile robot is holonomic or not. |
| 8 | Derive the dynamic modelling differential drive WMR using Newton-Euler method |
| 9 | Assume that a mobile robot is moving in an uneven terrain. Which all sensors may be needed to autonomously navigate in this terrain, Justify your answer, |
| 10 | What do you mean by localization? Explain any one method of localization a mobile robot. |
| 11 | Design a control scheme to drive a steered robot to follow a path. |

| | |
|---|---|
| 12 | A robot equipped with a differential drive starts at position x = 1.0 m, y = 2.0 m and with heading $\theta = \pi/2$. It has to move to the position x = 1.5m, y = 2.0 m, $\theta = \pi/2$ (all angles in radians). The movement of the vehicle is described by steering commands (vl = speed of left wheel, vr = speed of right wheel, t = driving time).<br>(a) What is the minimal number of steering commands (vl, vr, t) needed to guide the vehicle to the desired target location?<br>(b) What is the length of the shortest trajectory under this constraint |

## Syllabus and Course Plan

**Module I**

**Introduction**, key issues for locomotion, Wheeled Mobile Robots, Wheeled locomotion: The design space, wheeled locomotion: Case studies. Mobile manipulators, Legged Mobile Robots- Leg configurations and stability, Examples of legged robot locomotion, aerial robots, underwater robots and surface water robots

**Module 2**

Basic understanding of Differential-Drive WMR, Car-Like WMR, Three-Wheel Omnidirectional Mobile Robot, Four Mecanum-Wheel Omnidirectional Robot

**Kinematic model** of a differential drive and a steered mobile robot, degree of freedom and manoeuvrability, Degree of steerability, different wheel configurations, holonomic and non-holonomic robots. Omnidirectional Wheeled Mobile Robots.

**Module 3**

**Dynamics of mobile robot**: Lagrange-Euler method, Newton-Euler methods, Differential-Drive WMR, Dynamics of WMR with Slip, Car-Like WMR Dynamic Model, Three-Wheel Omnidirectional Mobile Robot.

Computer based dynamic (numerical) simulation of different wheeled mobile robots.-Demo/Assignment only

**Module 4**

**Sensors for mobile robot navigation**: Sensor classification, Characterizing sensor performance, Wheel /motor sensors, Heading sensors, Accelerometers, IMUs, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors.

**Robot navigation**: Localization, Error propagation model, Probabilistic map based localisation-Kalman method, Autonomous map building, Simultaneous localization and mapping (SLAM).

**Module 5**

**Path Planning**- local vs global path planning, Graph search, Potential field-based path planning; Map based path planning- Dijkstra's algorithm, A*, D* algorithms.
Obstacle avoidance- Bug algorithm, Vector field histogram, Dynamic window approach.

**Control of mobile robots**- Control of differential drive robot and steered robot based on its kinematic model, Case study- design and implementation of a differential drive robot capable of moving to a point, following a line and following a path.

Basics of Swarm robots, cooperative and collaborative robots, mobile manipulators.

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | **Module 1** | |
| 1.1 | Introduction, key issues for locomotion, Wheeled Mobile Robots | 2 |
| 1.2 | Wheeled locomotion: The design space, Wheeled locomotion: Case studies. Mobile manipulators, | 3 |
| 1.3 | Legged Mobile Robots- Leg configurations and stability, Examples of legged robot locomotion, aerial robots, underwater robots and surface water robots. | 3 |
| 2 | **Module 2** | |
| 2.1 | Basic understanding of Differential-Drive WMR, Car-Like WMR, Three-Wheel Omnidirectional Mobile Robot, Four Mecanum-Wheel Omnidirectional Robot | 2 |
| 2.2 | Kinematic model of a differential drive and a steered mobile robot, degree of freedom and manoeuvrability, Degree of steerability | 3 |
| 2.3 | Different wheel configurations, holonomic and non-holonomic robots. Omnidirectional Wheeled Mobile Robots. | 3 |
| 3 | **Module 3** | |
| 3.1 | Dynamics of mobile robot: Lagrange-Euler method, Newton-Euler methods | 2 |
| 3.2 | Differential-Drive WMR, Dynamics of WMR with Slip | 3 |
| 3.3 | Car-Like WMR Dynamic Model, Three-Wheel Omnidirectional Mobile Robot | 3 |
| 4 | **Module 4** | |

| | | |
|---|---|---|
| 4.1 | Sensors for mobile robot navigation: Sensor classification, Characterizing sensor performance, Wheel /motor sensors, Heading sensors, Accelerometers, IMUs, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors. | 3 |
| 4.2 | Robot navigation: Localization, Error propagation model, Probabilistic map based localisation-Kalman method | 3 |
| 4.3 | Autonomous map building, Simultaneous localization and mapping (SLAM) | 3 |
| 5 | **Module 4** | |
| 5.1 | Path Planning- local vs global path planning, Graph search, Potential field-based path planning; Map based path planning- Dijkstra' s algorithm, A*, D* algorithms | 3 |
| 5.2 | Control of mobile robots- Control of differential drive robot and steered robot based on its kinematic model, Case study- design and implementation of a differential drive robot capable of moving to a point, following a line and following a path. | 3 |
| 5.3 | Basics of Swarm robots, cooperative and collaborative robots, mobile manipulators. | 1 |

**Reference Books**


1. R. Siegwart, I. R. Nourbakhsh, "Introduction to Autonomous Mobile Robots", The MIT Press, 2011.
2. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.
3. Spyros G. Tzafestas, Introduction to Mobile Robot Control, Elsevier.
4. S. M. La Valle, "Planning Algorithms", Cambridge University Press, 2009.
5. Thrun, S., Burgard,W., and Fox, D., Probabilistic Robotics. MIT Press, Cambridge, MA, 2005.
6. Melgar, E. R., Diez, C. C., Arduino and Kinect Projects: Design, Build, Blow Their Minds, 2012.
7. H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun, Principles of Robot Motion: Theory, Algorithms and Implementations, PHI Ltd., 2005.

# SEMESTER II

**Discipline : INTERDISCIPLINARY**

**Stream : ID4**

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222TIA001 | CONTROL OF DYNAMIC SYSTEMS | DISCIPLINE CORE 2 | 3 | 0 | 0 | 3 |

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Model the systems using transfer function approach as well as state space approach |
| **CO 2** | Employ time domain analysis to predict and diagnose transient performance parameters of the system for standard input functions. |
| **CO3** | Compute the time domain and frequency domain specifications of a system |
| **CO4** | Analyze dynamic systems for their stability and performance using root locus and Bode plot |
| **CO5** | Identify the needs of different types of controllers and compensator to ascertain the required dynamic response from the system. |
| **CO6** | Analyse systems using state space approach |
| **CO7** | Understand a variety of methods for analyzing nonlinear systems |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 2 | | | 3 | |
| **CO 2** | 3 | | 2 | | | 3 | |
| **CO 3** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 6** | 3 | | 2 | 3 | 3 | 3 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).
Continuous Internal Evaluation: **40 marks**
Micro project/Course based project: 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no.: 10 marks
*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination : **60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.
*Each question can carry 7 marks.*

**Syllabus**

**Module I**

Control System- Definition, Open loop vs closed loop control systems- components of a typical control system- Necessity of a control system in a Robot, bird's eye view of typical actuators in robot control systems-hydraulic, pneumatic and electric actuators- over view of basic types-DC motors for speed control, DC and AC servo motors for position control, Brushless DC motors for speed control of quadcoptersand linear actuation mechanisms. Basic idea of feedbacks in robotic systems-sensors-eg. Linear and rotary encoders.

Linear time invariant Systems- Transfer function, Necessity of knowing the transfer function, Modelling -Mechanical and Electromechanical systems –block diagram representation - block diagram reduction, characteristic equation, signal flow graph, overview Mason's gain formula -

**Module II**

Time domain analysis of control systems: Transient and steady state responses - time domain specifications - first and second order systems - step responses of first and second order systems. steady state error analysis - static error coefficient of type 0,1, 2 systems - Dynamic error coefficients.

Concept of stability: Time response for various pole locations - stability of feedback system - Routh's stability criterion.

**Module III**

Root locus - General rules for constructing Root loci – stability from root loci - effect of addition of poles and zeros.

Frequency domain analysis: Frequency domain specifications- Analysis based on Bode plot - Log magnitude vs. phase plot.

Design of P, PI and PID controller using Ziegler-Nichols tuning method, Overview-Necessity of using Lag, lead and lag-lead compensators in Control Systems.

**Module IV**

State space analysis of systems: Introduction to state concept - state equation of linear continuous time systems, matrix representation of state equations. Phase variable and canonical forms of state representation-controllable, observable, diagonal and Jordan canonical forms- solution of time invariant autonomous systems, forced system-state transition matrix, relationship between state equations and transfer function. State feedback controller design: Controllability & observability-Kalman’s method. State feed-back design via pole placement technique.

Case study- Feedback control of a single link manipulator. (Assignment/demo only)

**Module V**

Nonlinear systems: Introduction - characteristics of nonlinear systems. Types of nonlinearities. Determination of describing function of nonlinearities (relay, dead zone and saturation only) - application of describing function for stability analysis of autonomous system with single nonlinearity. Singular points – Classification of singular points. Definition of stability- asymptotic stability and instability, overview of Lyapunov methods to stability of linear and nonlinear, continuous time systems.

Case study-kinematic modelling of a differential drive robotand controlling the same to move to a point (Assignment/demo only)

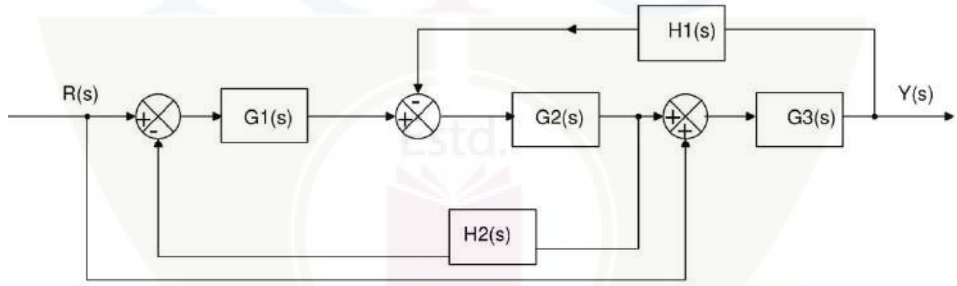
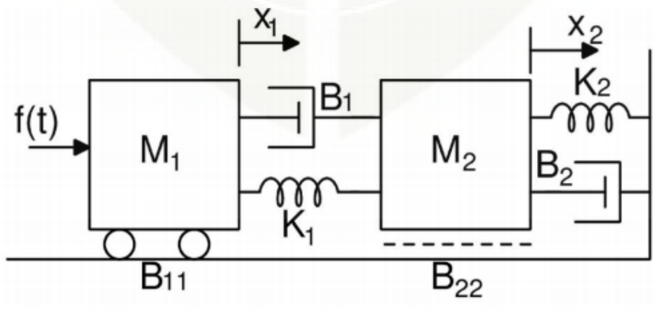
**References**


1. Nise N. S., Control Systems Engineering, 6/e, Wiley Eastern, 2010.
2. Dorf R. C. and R. H. Bishop, Modern Control Systems, Pearson Education, 2011.
3. Nagarath I. J. and Gopal M., Control System Engineering, Wiley Eastern, 2008.
4. Ogata K., Modern Control Engineering, Prentice Hall of India, New Delhi, 2010.
5. Hassan K Khalil, Nonlinear Systems, Prentice - Hall International (UK), 2002
6. Robotics- Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford University press
7. Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Peter Corke, Springer.

**Course Contents and Lecture Schedule**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | | |
| 1.1 | Control System- Definition, Open loop vs closed loop control systems-components of a typical control system- Necessity of a control system in a Robot | 1 |
| 1.2 | bird's eye view of typical actuators in robot control systems-hydraulic, pneumatic and electric actuators | 1 |
| 1.3 | Overview of use of Electric actuators like DC motors for speed control, DC and AC servo motors for position control, Brushless DC motors for speed control of quadcopters and linear actuation mechanisms | 1 |
| 1.4 | Basic idea of feedbacks in robotic systems-sensors-eg. Linear and rotary encoders. | 1 |
| 1.5 | Linear time invariant Systems- Transfer function, Necessity of knowing the transfer function of a system | 1 |
| 1.6 | Modelling -Mechanical and Electromechanical systems | 1 |
| 1.7 | Block diagram representation - block diagram reduction, characteristic equation, signal flow graph - overview of Mason's gain formula - | 2 |
| **2** | | |
| 2.1 | Time domain analysis of control systems: Transient and steady state responses | 2 |
| 2.2 | time domain specifications - first and second order systems - step responses of first and second order systems. steady state error analysis - static error coefficient of type 0,1, 2 systems - Dynamic error coefficients. | 3 |
| 2.3 | Concept of stability: Time response for various pole locations - stability of feedback system - Routh's stability criterion | 2 |
| **3** | | |
| 3.1 | Root locus - General rules for constructing Root loci – stability from root loci - effect of addition of poles and zeros | 3 |
| 3.2 | Frequency domain analysis: Frequency domain specifications- Analysis based on Bode plot - Log magnitude vs. phase plot. | 3 |
| 3.3 | Design of P, PI and PID controller using Ziegler-Nichols tuning method, Overview-Necessity of using Lag, lead and lag-lead compensators in Control Systems. | 2 |
| **4** | | |
| 4.1 | State space analysis of systems: Introduction to state concept - state equation of linear continuous time systems, matrix representation of state equations | 2 |

| | | |
|---|---|---|
| 4.2 | Phase variable and canonical forms of state representation-controllable, observable, diagonal and Jordan canonical forms | 2 |
| 4.3 | solution of time invariant autonomous systems, forced system-state transition matrix, relationship between state equations and transfer function. | 2 |
| 4.4 | State feedback controller design: Controllability & observability- Kalman's method- State feed-back design via pole placement technique | 1.5 |
| 4.5 | Case study- Feedback control of a single link manipulator – refer Robotics- Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford University press | 2 |
| **5** | | |
| 5.1 | Nonlinear systems: Introduction - characteristics of nonlinear systems. Types of nonlinearities. | 2 |
| 5.2 | Determination of describing function of nonlinearities (relay, dead zone and saturation only) - | 2 |
| 5.3 | application of describing function for stability analysis of autonomous system with single nonlinearity. | 1 |
| 5.4 | Singular points – Classification of singular points. Definition of stability- asymptotic stability and instability; overview of Lyapunov methods to stability of linear and nonlinear, continuous time systems. | 2 |
| 5.5 | Case study-kinematic modelling of a differential drive robot and controlling the same to move to a point- refer Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Peter Corke, Springer. | 2 |

| Model Question Paper | | | |
|---|---|---|---|
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>**Second Semester MTech DEGREE EXAMINATION** | | | |
| **Course Code: 222TIA001** | | | |
| **Course Name: Control of Dynamic Systems** | | | |
| Max. Marks: 60 | | | Duration: 2.5 Hours |
| PART A | | | |
| | | Answer all questions, each carries 5 marks. | Marks |
| 1 | | Draw the block schematic of a typical closed loop control system. Explain the components with respect to a robotic system. | (5) |
| 2 | | Obtain the unit step response of $\frac{5}{s+3}$. A unity feedback system has an open loop transfer function $\frac{20(s+3)}{(s+0.1)(s+5)}$. Determine steady state error for unit parabolic input? | (5) |
| 3 | | How do you determine the angle of departure of root locus branch from an open loop pole, using angle criterion? Also explain effect of addition of poles and zeros. | (5) |
| 4 | | Explain the terms (i) state (ii) state variables (iii) state vector. What are the advantages of state space representation. | (5) |
| 5 | | A robot is a linear or nonlinear system? Justify your answer. Can we use linear controllers in robots? If so how? | (5) |
| PART B | | | |
| **Answer any five questions, each carries 7 marks** | | | |
| 6 | | Obtain the transfer function using block diagram reduction techniques<br><br> | ( 7) |
| 7 | | Obtain the transfer function of<br><br> | (7) |
| 8 | | Determine the unit step response for the system with transfer function $G(s) =$ | (7 ) |

| | | | |
|---|---|---|---|
| | | $\frac{2}{s^2+4s+5}$ Also determine peak overshoot (Mp) and peak time (tp). | |
| 9 | | Test the stability of the unity negative feedback system with $G(s) = \frac{16}{s(s^5+s^4+8s^3+6s^2+20s+8}$ using Routh's stability criterion. Hence identify the location of roots of the system | (7) |
| 10 | | Determine the stability of the closed loop system $G(s) = \frac{K(s+1)}{(s^2+4s+8}$ using Root locus plot. Hence, determine the value of K such that the damping factor is 0.866 | (7) |
| 11 | a) | Obtain the state model of the system whose transfer function is given by $\frac{Y(s)}{U(s)} = \frac{10}{s^3+4s^2+2s+1}$ | (3) |
| | b) | Consider a linear system described by the transfer function $\frac{Y(s)}{U(s)} = \frac{10}{s(s+1)(s+2)}$. Design a feedback controller with a state feedback so that the closed loop poles are placed at -2, -1±j1. | (4) |
| 12 | | Investigate the stability of the following non-linear system using Lyapunov direct method $\dot{x_1} = x_2 \dot{x_2} = -x_1 - x_1^2 x_2$ | (7) |
| **** | | | |

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222TIA002 | SENSORS AND ACTUATORS FOR ROBOTS | PROGRAM CORE 3 | 3 | 0 | 0 | 3 |

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Analyse and select the most appropriate sensors and actuators for a robotic application |
| **CO 2** | Explain fundamental principle of working of sensors and actuators for robots |
| **CO 3** | Interpret typical manufacturer's data sheet of sensors and actuators and use them for selection in typical applications |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 2** | 3 | | 2 | 3 | 3 | 3 | |
| **CO 3** | 3 | | 2 | 3 | 3 | 3 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 30 |
| Analyse | 30 |
| Evaluate | 30 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Micro project/Course based project: 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no.: 10 marks

*(Test paper shall include minimum 80% of the syllabus.)*

**End Semester Examination Pattern:**

End Semester Examination : **60 marks**

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.
*Each question can carry 7 marks.*

**Syllabus**

**Module I**

Requirement of sensors in robots used in industry, agriculture, medical field, transportation, military, space and undersea exploration, human-robot interactions, robot control, robot navigation, tele-operational robot etc.

**Proprioceptive or Internal sensors** Position sensors- encoders- linear, rotary, incremental linear encoder, absolute linear encoder, Incremental rotary encoder, absolute rotary encoder; potentiometers; LVDTs; velocity sensors-optical encoders, tacho generator, Hall effect sensor, , acceleration sensors, Heading sensors- Compass, Gyroscope sensor, IMU, GPS, real time differential GPS, active optical and RF beacons, ultrasonic beacons, reflective beacons; Force sensors-strain gauge based and Piezo electric based, Torque sensors- Numerical Problems; Electronic skin, micro-cantilevers; Block schematic representations; Interpreting typical manufacturer's data sheet of internal sensors; Examples - the use of Proprioceptive sensors in robots.

**Module II**

**Exteroceptive or External sensors**-contact type, noncontact type; Tactile, proximity-detection of physical contact or closeness, contact switches, bumpers , inductive proximity, capacitive proximity; semiconductor displacement sensor; Range sensors- IR, sonar, laser range finder, optical triangulation (1D), structured light(2D), performance comparison range sensors; motion/ speed sensors-speed relative to fixed or moving objects, Doppler radar, Doppler sound; Block schematic representations; Numerical problems; Block schematic representations; Interpreting typical manufacturer's data sheet of external sensors; Examples - use of Exteroceptive sensors in robots.

**Module III**

Vision based sensors - Elements of vision sensor, image acquisition, image processing, edge detection, feature extraction, object recognition, pose estimation and visual servoing, hierarchy of a vision system, CCD and CMOS Cameras, Monochrome, stereovision, night vision cameras, still vs video cameras, kinect sensor; Block schematic representations.

Criteria for selection of sensors- range, dynamic range, sensitivity, Linearity, response time, band width, accuracy, repeatability & precision, Resolution & threshold, type of output, size and weight, environmental conditions, interfacing.

**Module IV**

Requirement of actuators for robotic applications, Pneumatic and Hydraulic actuators, physical components, comparison of hydraulic and pneumatic systems- Components of electro hydraulic and pneumatic systems; hydraulic and pneumatic actuators with proportional control valves.

**Electric actuators**- advantages, DC motors, DC and AC servo motors, various types of Stepper motors ; brushless DC motors ; PMSM; SRM; Motor characteristics, Selection of motors, block schematic of typical electric drive, closed loop speed and torque control.

Interpreting typical manufacturer's catalogue of actuators and using them for selection in typical applications.

**Module V**

Linear actuation mechanisms- Belt-driven and screw-driven actuators, Pneumatically and hydraulically driven linear actuators, Rack-and-pinion driven actuators, Linear motor driven actuators.

Transmission mechanisms-Cams and Cam followers, working principle. Gears and gear trains, ratchet and pawl, belt drive, advantages of belt drive, bearings classification and selection of bearings.

Electro thermal, electro-optical and electrochemical actuators, Piezo-actuators, pneumatic muscles

Micro-actuators - Electrostatic, Electromagnetic, Piezoelectric, Fluid, Thermal, Shape memory alloy, characteristics of microactuators - Stroke, Force/torque, Stiffness, Input energy, Efficiency, Linearity, Hysteresis, Response time, Drift, Bandwidth.

**References**

1. Robotics Engineering: An Integrated Approach, by Richard D. Klafter, Prentice Hall Inc.
2. Clarence W. de Silva, Sensors and Actuators: Control System Instrumentation, CRC Press 2007, ISBN-13: 978-1420044836
3. Introduction to Robotics, S K Saha, Mc Graw Hill Eduaction
4. D. Patranabis, "Sensors and Transducers", PHI Learning Private Limited.
5. W. Bolton, "Mechatronics", Pearson Education Limited.

6. Automation, Production Systems and Computer Integrated Manufacturing, Groover M.P, Prentice – Hall Ltd., 1997.
7. Pillai S. K. "A first course on electric drives", Wieley Eastern Ltd, New Delhi
8. Journal of sensors, Special issue- Sensors for Robotics, Aiguo Song , Guangming Song, Daniela Constantinescu, Lei Wang, and Quanjun Song, Volume 2013
9. Mechatronics: Integrated mechanical electronic systems By K.P. Ramachandran, G.K. Vijayaraghavan, Wiley India
10. Linear Electric Actuators by I. Boldea
11. Piezoelectric Actuators (Electrical Engineering Developments), 2012, by Joshua E. Segel

**Course Contents and Lecture Schedule**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | **Proprioceptive or Internal sensors** | |
| 1.1 | Requirement of sensors in robots used in industry, agriculture, medical field, transportation, military, space and undersea exploration, human-robot interactions, robot control, robot navigation, tele-operational robot etc. | 1 |
| 1.2 | Position sensors- encoders- linear, rotary, incremental linear encoder, absolute linear encoder, Incremental rotary encoder, absolute rotary encoder; potentiometers; LVDTs. | 1.5 |
| 1.3 | velocity sensors-optical encoders, tacho generator, Hall effect sensor, acceleration sensors | 1.5 |
| 1.4 | Heading sensors- Compass, Gyroscope sensor, IMU, GPS, real time differential GPS, | 1.5 |
| 1.5 | active optical and RF beacons, ultrasonic beacons, reflective beacons | 1 |
| 1.6 | Force sensors-strain gauge based and Piezo electric based, Torque sensors- Electronic skin, micro-cantilevers. Examples - use of Proprioceptive sensors in robots. | 1.5 |
| | **Note- Block schematic representations, Interpretation of typical manufacturer's data sheet and Numerical problems of the above mentioned sensors are to be covered.** | |
| **2** | **Exteroceptive or External sensors** | |
| 2.1 | contact type, noncontact type; Tactile, proximity- detection of physical contact or closeness, contact switches, bumpers , inductive proximity, capacitive proximity; semiconductor displacement sensor; | 2 |
| 2.2 | Range sensors- IR, sonar, laser range finder, optical triangulation (1D), structured light(2D), performance comparison range sensors; | 2 |
| 2.3 | Motion/ speed sensors-speed relative to fixed or moving objects, Doppler radar, Doppler sound; Numerical problems; Examples - use of Exteroceptive sensors in robots. | 2 |
| | **Note- Block schematic representations, Interpretation of typical manufacturer's data sheet and Numerical problems of the above** | |

| | | |
|---|---|---|
| | **mentioned sensors are to be covered.** | |
| **3** | | |
| 3.1 | Vision based sensors - Elements of vision sensor, image acquisition, image processing, edge detection, feature extraction, object recognition, pose estimation and visual servoing, hierarchy of a vision system | 3 |
| 3.2 | CCD and CMOS Cameras, Monochrome, stereovision, night vision cameras, still vs video cameras, kinect sensor. | 2 |
| 3.3 | Criteria for selection of sensors- range, dynamic range, sensitivity, Linearity, response time, band width, accuracy, repeatability & precision, Resolution & threshold, type of output, size and weight, environmental conditions, interfacing. | 2 |
| | | |
| **4** | **Actuators for Robots** | |
| 4.1 | Requirement of actuators for robotic applications, Pneumatic and Hydraulic actuators, physical components, comparison of hydraulic and pneumatic systems- Components of electro hydraulic and pneumatic systems; hydraulic and pneumatic actuators with proportional control valves. | 4 |
| 4.2 | **Electric actuators**- advantages, DC motors, DC and AC servo motors, various types of Stepper motors ; brushless DC motors ; PMSM; SRM; Motor characteristics, Selection of motors, block schematic of typical electric drive, closed loop speed and torque control. | 3 |
| | **Note: Interpreting typical manufacturer's catalogue of actuators and using them for selection in typical applications to be covered** | |
| **5** | | |
| 5.1 | Linear actuation mechanisms- Belt-driven and screw-driven actuators, Pneumatically and hydraulically driven linear actuators, Rack-and-pinion driven actuators, Linear motor driven actuators. | 2 |
| 5.2 | Transmission mechanisms-Cams and Cam followers, working principle. Gears and gear trains, ratchet and pawl, belt drive, advantages of belt drive, bearings classification and selection of bearings. | 2 |
| 5.3 | Electro thermal, electro-optical and electrochemical actuators, Piezo-actuators, pneumatic muscles | 1 |
| 5.4 | Micro-actuators - Electrostatic, Electromagnetic, Piezoelectric, Fluid, Thermal, Shape memory alloy, characteristics of microactuators - Stroke, Force/torque, Stiffness, Input energy, Efficiency, Linearity, Hysteresis, Response time, Drift, Bandwidth. | 2 |

**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**
**Second Semester MTech DEGREE EXAMINATION**

**Course Code: 222TIA002**

**Course Name: Sensors and Actuators for Robots**

Max. Marks: 60 | Duration: 2.5 Hours

PART A

| | | Answer all questions, each carries 5 marks. | Marks |
|---|---|---|---|
| 1 | | How proprioceptive sensors differ from exteroceptive sensors? Explain with the help of examples. | (5) |
| 2 | | Which are the sensors used to detect closeness of objects? And how will you compute the same? | (5) |
| 3 | | Can we compute depth of an object using camera? Justify your answer. | (5) |
| 4 | | If the payload of a robotic manipulator is a car, which actuator is preferred? Justify your answer.Which motors are generally used for position control applications? | (5) |
| 5 | | Which are the commonly used linear actuating mechanisms for robots?What are pneumatic muscles? | (5) |

**PART B**

**Answer any five questions, each carries 7 marks**

| | | | |
|---|---|---|---|
| 6 | | What is LVDT? What are the parameters that can be measured by this? Describe with a neat diagram the principle of operation and output characteristics of the same. | ( 7) |
| 7 | | What is Gyroscope? Enumerate various sources of errors in Gyroscopes? How will you rectify them while gyroscopes are used in robotic applications? | (7) |
| 8 | | Consider a scenario where a surveillance vehicle chases a car which violated traffic rules. Which all sensors are to be used in the surveillance vehicle to compute the position and relative velocity of the target vehicle (car)? Explain the working of the sensors being used. | (7 ) |
| 9 | | Which are the elements of a vision sensor? How will you extract features using vision sensor? | (7) |
| 10 | | Compare hydraulic and pneumatic actuators? | (7) |
| 11 | a) | In which context Brushless DC motors are used for robotic applications? Mention one application for the same. | (3) |
| | b) | How much power is required to lift a 20Kg weight by a DC motor if the lifting speed is 0.2m/s? | (4) |
| 12 | | Explain the working of Rack-and-pinion driven actuator with the help a diagram. | (7) |

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| COURSE CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222PIA100 | MINI PROJECT | PROJECT | 0 | 0 | 4 | 2 |

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem solving skills.

The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs.The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Evaluation Committee - Programme Coordinator, One Senior Professor and Guide.

| Sl. No | Type of evaluations | Mark | Evaluation criteria |
|---|---|---|---|
| 1 | Interim evaluation 1 | 20 | |
| 2 | Interim evaluation 2 | 20 | |
| 3 | Final evaluation by a Committee | 35 | Will be evaluating the level of completion and demonstration of functionality/ specifications, clarity of presentation, oral examination, work knowledge and involvement |
| 4 | Report | 15 | the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level( not more than 25% ) |
| 5 | Supervisor/Guide | 10 | |
| | Total Marks | 100 | |

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222LIA001 | AUTOMATION LAB 2 | LABORATORY 2 | 0 | 0 | 2 | 1 |

**Preamble:** The lab gives students exposure to various automation system components and to give them training to implement and program automation systems. The lab includes designing and developing hydraulic circuits, pneumatic circuits, and interfacing hydraulic and pneumatic circuits with PLC used in industrial automation areas.

**Pre-requisites:** Basic knowledge of electrical circuits and components like relays, timers, proximity sensors, etc.

**Course Outcomes:** After the completion of the course, the student will be able to

| | |
|---|---|
| **CO 1** | Develop different pneumatic and hydraulic circuits based on their applications. |
| **CO 2** | Develop multi-actuator circuits using different methods. |
| **CO 3** | Develop different electro-pneumatic and electro-hydraulic circuits based on their applications. |
| **CO 4** | Familiarize the basic concepts of interfacing PLCwith hydraulic/pneumatic circuits and interfacing SCADA with PLC/PC |
| **CO 5** | Understand the characteristics of proportional and servo valves and integrate them into automation schemes. |
| **CO 6** | Design and simulate Pneumatic and Hydraulic Circuits using Automation Studio Software. |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 3 | |
| **CO 6** | 3 | | 3 | 3 | 3 | 3 | |

**List of Experiments**

1. Experiments using hydraulic actuators and study their performance under various operating conditions.
2. Experiments using electro-hydraulic systems and study of their characteristics.
3. Experiments to implement logic sequencing using electro hydraulics.
4. Experiments using pneumatic actuators and study of their performance under various operating conditions.
5. Experiments in pneumatics logic.
6. Experiments in electro-pneumatics.
7. Experiments using proportional and servo-hydraulic valves.

8. Experiments on PLC.
9. Interfacing PLC with electro-hydraulics and electro-pneumatics.
10. Simulation of Pneumatic and Hydraulic Circuits using Automation Studio Software.
11. Interfacing SCADA with PLC and PC.

**Lab based Mini Project**

1.Design automation systems for various purposes.
2. Program and implement PLC based automation systems.

**Text Books:**


1. Antony Esposito, Fluid Power Systems and control Prentice-Hall, 1988
2. Peter Rohner, Fluid Power logic circuit design. The Macmillan Press Ltd.,London, 1979


**References:**


1. E.C.Fitch and J.B.Suryaatmadyn. Introduction to fluid logic, McGraw Hill, 1978
2. Herbert R. Merritt, Hydraulic control systems, John Wiley & Sons, Newyork, 1967
3. Dudbey. A. Peace, Basic Fluid Power, Prentice Hall Inc, 1967.
4. Standard Handbook of Industrial Automation, Considine D M C &Considine G D C, Chapman and Hall, NJ, 1986.
5. W.Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Person Education Limited, New Delhi, 2007.
6. Programmable Controllers – An Engineer’s Guide, 2nd Edition, E.A. Parr, Newnes, 1999.

# SEMESTER II

# PROGRAM ELECTIVE III

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222TIA012 | AUTONOMOUS VEHICLES | PROGRAM ELECTIVE 3 | 3 | 0 | 0 | 3 |

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Explain the rationale for and evolution of automotive electronics and the fundamental theory of operation of electronic control systems. |
| **CO 2** | Explain the automotive systems that have been replaced by electronic control systems and the advantage of doing so. |
| **CO3** | Explain the basics of how automotive ECUs function in conjunction with the vehicle data bus networks and sensors. |
| **CO4** | Explain the fundamental principles of data networking and its role in ADAS and future autonomous vehicles. |
| **CO5** | Outline the protocols and IP addressing; familiar with the theory and operation of legacy, new, and emerging ADAS systems and proposed autonomous vehicle systems. |

**SYLLABUS**

**Module 1**

**Introduction to Automated, Connected, and Intelligent Vehicles**

Introduction to the Concept of, Automotive Electronics, Automotive Electronics Overview, History & Evolution, Infotainment, Body, Chassis, and Powertrain Electronics, Advanced Driver Assistance Electronic Systems

**Connected and Autonomous Vehicle Technology**

Basic Control System Theory applied to Automobiles, Overview of the Operation of ECUs, Basic Cyber-Physical System Theory and Autonomous Vehicles, Role of Surroundings Sensing Systems and Autonomy, Role of Wireless Data Networks and Autonomy.

**Module 2**

**Sensor Technology for Advanced Driver Assistance Systems**

Basics of Radar Technology and Systems, Ultrasonic Sonar Systems, Lidar Sensor Technology and Systems, Camera Technology, Night Vision Technology, Other Sensors, Use of Sensor Data Fusion, Integration of Sensor Data to On-Board Control Systems

**Wireless Networking and Applications to Vehicle Autonomy**

Basics of Computer Networking – the Internet of Things, Wireless Networking Fundamentals, Integration of Wireless Networking and On-Board Vehicle Networks, Review of On-Board Networks – Use & Function

**Module 3**

Connected Car Technology, Connectivity Fundamentals, Navigation and Other Applications, Vehicle-to-Vehicle Technology and Applications, Vehicle-to-Roadside and Vehicle-to-Infrastructure Applications, Wireless Security Overview

**Module 4**

Advanced Driver Assistance System Technology, Basics of Theory of Operation, Applications – Legacy– New – Future, Integration of ADAS Technology into Vehicle Electronics System Examples, Driverless Car Technology - Moral, Legal, Roadblock Issues, Technical Issues, Security Issues

**Module 5**

Present Advanced Driver Assistance System Technology Examples, Troubleshooting and Maintenance of Advanced Driver Assistance Systems, Failure Modes – Self Calibration, Sensor Testing and Calibration, Redundant Systems, Standard Manufacturing Principles, Non-Passenger Car Advanced Driver Assistance Systems and Autonomous Operation, Trucking – Farming – Mining - Shipping & Rail – Military

**<u>Textbooks</u>**


- George Dimitrakopoulos, Aggelos Tsakanikas, Elias Panagiotopoulos, Autonomous Vehicles Technologies, Regulations, and Societal Impacts - Elsevier, ISBN: 9780323901376, 2021
- Michael E. McGrath, Autonomous Vehicles: Opportunities, Strategies, and Disruptions: Updated and Expanded Second Edition – ISBN: 9781706683599, 2019
- G. Mullett, Wireless Telecommunications Systems and Networks, Thomson – Delmar Learning, ISNB#1-4018-8659-0, 2006
- G. Mullett, Basic Telecommunications: The Physical Layer, Thomson – Delmar Learning, ISBN#1-4018-4339-5, 2003

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222EIA001 | DEEP LEARNING | PROGRAM ELECTIVE 3 | 3 | 0 | 0 | 3 |

**Preamble:** This course will introduce the theoretical foundations, algorithms, methodologies, and applications of neural networks and deep learning. It will help to design and develop an application-specific deep learning models and also provide the practical knowledge handling and analysing real world applications.

**Course Objective:** This course will introduce the theoretical foundations, algorithms, methodologies, and applications of neural networks and deep learning. It will help to design and develop an application-specific deep learning models and also provide the practical knowledge handling and analysing real world applications.

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | A student at the end of course should be able to Decide if DL is suitable for a given problem |
| **CO 2** | Have a good understanding of the fundamental issues and basics of machine learning |
| **CO 3** | Choose appropriate DL algorithm to solve the problem with appropriate hyper parameter |
| **CO 4** | Setting Feel comfortable to read and understand DL articles from reputed conferences, journals including NIPS, CVPR, ICCV, ICML, PAMI etc. |
| **CO 5** | Outline the concept of the feed forward neural network and its training process |
| **CO 6** | Build CNN and Recurrent Neural Network (RNN) models for different use cases |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | ✓ | ✓ | | | | | |
| **CO 2** | ✓ | ✓ | | | | | |
| **CO 3** | ✓ | ✓ | ✓ | ✓ | | | |
| **CO 4** | ✓ | ✓ | ✓ | ✓ | | | |
| **CO 5** | ✓ | ✓ | ✓ | ✓ | | | |
| **CO 6** | ✓ | ✓ | ✓ | ✓ | | | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination (%) |
|---|---|
| Apply | 25 |
| Analyse | 20 |
| Evaluate | 15 |
| Create | |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

**15 marks**

Preparing a review article based on peer reviewed original publications
(minimum 10 publications shall be referred) **15 marks**

Course based task/Seminar/Data collection and interpretation

Test paper, 1 no.
(Test paper shall include minimum 80% of the syllabus) **10 marks**

**End Semester Examination Pattern:**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

**Note:** The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

**Model Question Paper**

**QP CODE:**

**Reg No.:_________________**

**Name:_______________________________**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH. DEGREE EXAMINATION,**

**MONTH & YEAR**

**Course Code: 222EIA001**
**DEEP LEARNING**

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer ***ALL*** questions; each question carries 5 marks)

1. Discuss the different learning approaches used in machine learning
2. Explain the merits and demerits of using Auto encoders in Computer Vision.
3. What is the vanishing gradient problem and exploding gradient problem?
4. Give two benefits of using convolutional layers instead of fully connected ones for visual tasks.
5. Illustrate the workings of the RNN with an example of a single sequence defined on a vocabulary of four words

PART B

(Answer ***any FIVE*** questions; each question carries 7 marks)

6. "A computer program is said to learn from experience E with respect to some class oftasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E." What is your understanding of the terms task, performance and experience. Explain with two example

7. Compare Boltzmann Machine with Deep Belief Network.

8. Write an algorithm for back propagation which uses stochastic gradient descent method. Comment on the effect of adding momentum to the network.
9. Draw and explain the architecture of convolutional network ? Input to CNN architecture is a color image of size 112x112x3. The first convolution layer comprises of 64 kernels of size 5x5 applied with a stride of 2 and padding 0. What will be the number of parameters?

10. Explain the working of RNN and discuss how backpropagation through time is used in recurrent networks.

11. Derive update rules for parameters in the multi-layer neural network through the gradient descent.

12. What is the vanishing gradient problem and exploding gradient problem?

***********************************

**Syllabus and Course Plan**

| No | Topic | No. of Lectures (40) |
|---|---|---|
| 1 | **Introduction to Deep Learning** | |
| 1.1 | Introduction - What is Deep Learning? – Machine Learning Vs. Deep Learning, representation Learning | 1 |
| 1.2 | Width Vs. Depth of Neural Networks, Activation Functions: RELU, LRELU, ERELU], Boltzmann Machines, Auto Encoders. | 2 |
| 1.3 | Optimization Techniques, Gradient Descent, Batch Optimization | 2 |
| 1.4 | Back Propagation - Calculus of Back Propagation, | 3 |
| 2 | **Neural Networks** | |
| 2.1 | Bayesian Learning, Decision Surfaces Linear Classifiers, Machines with Hinge Loss | 2 |
| 2.2 | Unsupervised Training of Neural Networks, Restricted Boltzmann Machines, Auto Encoders | 2 |
| 2.3 | Perceptron and Multi-layer Perceptron – Hebbian Learning - Neural net as an Approximator | 2 |
| 2.4 | Training a neural network - Perceptron learning rule - Empirical Risk Minimization - Optimization by gradient descent | 2 |
| 3 | **Convergence in Neural networks** | |
| 3.1 | Convergence in Neural networks - Rates of Convergence – Loss Surfaces – Learning rate and Data normalization | 2 |
| 3.2 | RMSProp, Adagrad and Momentum , Stochatic Gradient Descent | 2 |
| 3.3 | Acceleration – Overfitting and Regularization | 2 |
| 3.4 | Choosing a Divergence Loss Function – Dropout – Batch Normalization | 2 |
| 4 | **Convolution Neural Network** | |
| 4.1 | Convolutional Neural Networks (CNN) - Weights as Templates – Translation Invariance | 2 |
| 4.2 | Training with shared parameters – Arriving at the convolutional model | 2 |
| 4.3 | Mathematical details of CNN | 2 |

| | | |
|---|---|---|
| 4.4 | Alexnet – Inception – VGG - Transfer Learning | 2 |
| 5 | **Recurrent Neural Network** | |
| 5.1 | Recurrent Neural Networks (RNNs) | 2 |
| 5.2 | Modeling sequences - Back propagation through time - Bidirectional RNNs | 3 |
| 5.3 | Exploding/vanishing gradients - Long Short-Term Memory Units (LSTMs) | 3 |

**Reference Books**


1. Ian Goodfellow, YoshuaBengio, Aaron Courville, Deep Learning, Online book, 2017

2. Michael Nielsen, Neural Networks and Deep Learning, Online book, 2016

3. Ian Goodfellow, YoshuaBengio and Aaron Courville, " Deep Learning", MIT Press, 2017.

4. Josh Patterson, Adam Gibson "Deep Learning: A Practitioner's Approach", O'Reilly Media, 2017

5. Umberto Michelucci "Applied Deep Learning. A Case-based Approach to Understanding Deep Neural Networks" Apress, 2018.

6. Kevin P. Murphy "Machine Learning: A Probabilistic Perspective", The MIT Press, 2012.

7. EthemAlpaydin,"Introduction to Machine Learning", MIT Press, Prentice Hall of India, Third Edition 2014.