INDUSTRIAL ARTIFICIAL INTELLIGENCE AND ANALYTICS
ENIE 445

Lecture : 3 **Year : IV**
Tutorial : 2 **Part : I**
Practical : 1

Course Objectives:
The objective of this course is to introduce the principles of artificial intelligence and machine learning and their applications in industrial engineering systems. It focuses on data driven analysis, feature engineering and supervised and unsupervised learning techniques to support decision making in production, supply chain and maintenance.

1 Introduction to AI and Machine Learning (4 hours)

1.1 Evolution of AI and its role in industrial systems
1.2 Data science versus AI versus machine learning versus optimization in industrial engineering
1.3 Types of machine learning: Supervised, unsupervised, reinforcement learning (Conceptual)
1.4 Typical AI–ML workflow: Data preparation, model development, evaluation and deployment
1.5 Overview of AI enabled industrial systems: Smart manufacturing, maintenance, logistics and decision support

2 Application of AI in Industries (4 hours)

2.1 Market and trend analysis
2.2 Production process
2.3 Supply chain and operations management
2.4 Monitoring, diagnosis and maintenance
2.5 Intralogistics and material handling systems

3 Introduction to Data Science (8 hours)

3.1 Definition and scope
    3.1.1 Roles in AI and machine learning
    3.1.2 Relationship among data science, AI, ML and analytics
3.2 Data analytics workflow
3.3 Data types and sources
    3.3.1 Structured, semi-structured and unstructured data
    3.3.2 Operational, process, maintenance and transactional data
    3.3.3 Noise, variability, missing and uncertainty in data
    3.3.4 Time-series nature of most industrial datasets

3.4 Introductory data structures for data analysis
   3.4.1 Scalars, vectors and matrices in engineering data representation
   3.4.2 Tabular data structures: rows, columns, attributes and records
   3.4.3 Concept of arrays, lists and dictionaries for storing data
   3.4.4 Indexing and referencing data elements

4 Data Preparation and Feature Engineering (6 hours)

4.1 Types of data based on structure, statistical nature and application domains
   4.1.1 Time-series (Energy, production)
   4.1.2 Transactional (Orders, inventory)
   4.1.3 Sensor and maintenance data
4.2 Feature engineering
   4.2.1 Data cleaning
   4.2.2 Feature transformation
   4.2.3 Feature extraction
   4.2.4 Feature selection
4.3 Introduction to exploratory data analysis (EDA)

5 Supervised and Unsupervised Learning Fundamentals (7 hours)

5.1 Inductive learning
5.2 Supervised learning: Classification
5.3 Supervised learning: Regression
5.4 Unsupervised learning: Clustering, association rule learning and dimensionality reduction (PCA and ICA)
5.5 Model optimization: Hyperparameter tuning, bias-variance trade-off
5.6 Model evaluation: Metrics for classification (Confusion matrix, accuracy, precision and recall) and regression (MAE, RMSE and R2) and graphical analysis (ROC curves, residual plots and learning curves)

6 Introduction to Neural Networks (12 hours)

6.1 Fundamentals of artificial neural networks:
   6.1.1 Forward propagation, back propagation, gradient descent, activation functions
   6.1.2 Optimizers in ANN: SGD, BGD, MBGD, Adagrad
   6.1.3 Applications of NN in industries
6.2 Convolution neural network architectures
   6.2.1 Key components: Input layer, convolution layer, pooling layer, FCN
   6.2.2 Applications of CNN in computer vision and NLP in industries
6.3 Recurrent neural networks fundamentals
   6.3.1 Need and advantage over ANN
   6.3.2 Architecture, back propagation through time (BPTT)
   6.3.3 Drawbacks of simple RNN
   6.3.4 Introduction of LSTM and transformers

7 Emerging AI Techniques and Applications (4 hours)

7.1 Classical AI and machine learning versus deep learning versus generative and agentic AI

7.2 Advanced AI methods and concepts: Self-supervised learning, transfer learning, physics-informed machine learning

7.3 Emerging concepts in mechanical engineering systems: Industry 4.0, IoT, IIoT

7.4 Autonomous vehicles, digital twins and cyber-physical systems (CPS) and autonomous decision-making frameworks

7.5 Ethical, validation and practical considerations in AI-assisted systems

Tutorial (30 hours)

1. Exploration of data handling libraries in Python (NumPy, Pandas, Matplotlib and Seaborn) using industrial sensor datasets
2. Analysis of historical demand and sales data to identify trends and evaluate AI-based strategic forecasting models
3. Modeling of production process variability to predict product quality and productivity using supervised learning algorithms
4. Application of feature engineering and dimensionality reduction techniques to optimize industrial process parameters
5. Formulation of demand forecasting problems in supply chain contexts to justify AI technique selection for inventory planning
6. Classification of supply chain performance indicators to support automated supplier selection and risk management
7. Detection of abnormal system behavior through sensor data interpretation for early-stage fault diagnosis
8. Prediction of equipment degradation trends to support predictive maintenance and decision-making frameworks

Practical (15 hours)

1. Study the structure of industrial data and perform data loading, cleaning, basic statistics and visualization to understand trends, variability and system behavior
2. Extract, select and preprocess relevant features from process or maintenance datasets and analyze their impact on model performance
3. Develop regression and classification models to predict demand, equipment condition, or product quality and evaluate their performance
4. Apply clustering and dimensionality reduction techniques to identify operating modes, abnormal behavior and hidden patterns in industrial systems
5. Perform an end to end analysis using historical degradation data to generate insights for maintenance planning and industrial decision support

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Mark distribution*
1	4	4
2, 7	8	12
3	8	10
4	6	10
5	7	12
6	12	12
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Anderson, J. (2020). Data engineering teams. Manning.
2. Bishop, C. M. (2006). Pattern recognition and machine learning. Springer.
3. Figoli, F. A., Mattioli, F., Rampino, L. (2022). Artificial intelligence in the design process. FrancoAngeli.
4. Hossain, E. (2024). Machine learning crash course for engineers. Springer.
5. Karumanchi, N. (2023). Data structures and algorithms made easy. CareerMonk Publications.
6. Kumar, K., Zindani, D., Davim, J. P. (Eds.). (2021). Artificial intelligence in mechanical and industrial engineering. CRC Press.
7. Lee, J. (2020). Industrial AI: Applications with sustainable performance. Shanghai Jiao Tong University Press.
8. Simeone, O. (2023). Machine learning for engineers. Cambridge University Press.
9. Sweigart, A. (2019). Automate the boring stuff with Python: Practical programming for total beginners. No Starch Press.

AUTOMOTIVE TECHNOLOGY
ENIE 446

Lecture : 3 **Year : IV**
Tutorial : 2 **Part : I**
Practical : 1

Course Objectives:
The objective of the course is to equip students with a thorough understanding of core vehicle systems, including the engine, drivetrain, suspension, steering, brakes and electrical and electronic components. The course also explores recent advancements in the field, with particular emphasis on electric and hybrid vehicles and their impact on modern automotive engineering.

1 Introduction (2 hours)

- 1.1 History and evolution of automobiles
- 1.2 Classification of vehicles: By propulsion, layout and application
- 1.3 Overview of major automotive systems
- 1.4 Automotive industry standards and safety regulations

2 Engine Combustion Systems (10 hours)

- 2.1 Internal combustion engines
  - 2.1.1 Engine architecture: Components, configurations and design parameters
  - 2.1.2 Operation of 2-stroke and 4-stroke cycle engines
  - 2.1.3 Performance comparison of SI and CI engines
  - 2.1.4 Comparison of air standard cycle, fuel air cycle and real cycle
- 2.2 Fuel supply systems
  - 2.2.1 Fuel properties: Calorific value, octane/cetane rating, volatility and stoichiometry
  - 2.2.2 Air-fuel mixture
  - 2.2.3 Carburetion versus electronic fuel injection: Working principles and limitations
  - 2.2.4 SI engine injection systems: TBI, MPFI and GDI
  - 2.2.5 Diesel injection systems: Jerk pump, common rail direct injection (CRDI) and electronic diesel control
  - 2.2.6 Injection timing, spray characteristics and atomization
- 2.3 Ignition and combustion
  - 2.3.1 Combustion and flame propagation in SI engine
  - 2.3.2 Abnormal combustion: Knock, pre-ignition, detonation

- 2.3.3 Ignition system types: Magneto, battery, transistorized and electronic
- 2.3.4 Spark timing, advance mechanisms and ignition map
- 2.3.5 Combustion chamber geometry and its effect on performance and emissions
- 2.3.6 Combustion in CI engines: Ignition delay, heat release and rate of pressure rise

3 Engine Cooling and Lubrication (6 hours)

- 3.1 Overview of air and liquid cooling systems
- 3.2 Effects of engine overcooling and overheating
- 3.3 Hydrodynamic lubrication theory and its application to engine components
- 3.4 Lubrication system types: wet sump, dry sump and pressure feed
- 3.5 Engine oil: Viscosity, classification (SAE, API), additives and degradation

4 Power Transmission and Drivetrain (5 hours)

- 4.1 Clutch, types and operation
- 4.2 Manual transmission: Gear ratio selection, synchronizers and design considerations
- 4.3 Automatic transmission: Planetary gear sets, hydraulic control and operation
- 4.4 Continuous variable transmission (CVT), Dual clutch transmission (DCT)
- 4.5 Torque converter: construction, torque multiplication and lock-up clutch
- 4.6 Transfer case and four-wheel drive systems
- 4.7 Propeller shaft design, universal joints and Rzeppa joints
- 4.8 Differential: Open, limited slip and locking differentials; axles

5 Chassis Systems (10 hours)

5.1 Suspension and steering
- 5.1.1 Role of suspension in vehicle dynamics and ride comfort
- 5.1.2 Spring types: Leaf, coil, torsion bar
- 5.1.3 Suspension configurations: MacPherson strut, double wishbone, multi-link and solid axle
- 5.1.4 Shock absorbers: Damping theory
- 5.1.5 Active and semi-active suspension systems
- 5.1.6 Basic principle of steering system
- 5.1.7 Steering geometry and its parameters
- 5.1.8 Hydraulic and electro-hydraulic power steering
- 5.1.9 Electric power steering (EPS)

5.2 Braking Systems
- 5.2.1 Hydraulic braking system: Master cylinder, wheel cylinder, brake lines and fluid
- 5.2.2 Disc and drum brakes: Design, heat dissipation and fade characteristics
- 5.2.3 Pneumatic braking system
- 5.2.4 Anti-lock braking system (ABS): Wheel slip control logic
- 5.2.5 Electronic brakeforce distribution (EBD)

5.3 Wheels and tires
- 5.3.1 Wheels and its types
- 5.3.2 Types of tire and its specification
- 5.3.3 Factors affecting tire life
- 5.3.4 Tire rotation and tire changing
- 5.3.5 Wheel alignment and wheel balancing

6 Vehicle Electrical, Electronics and Emission Systems (8 hours)

- 6.1 Vehicle Electrical Systems
  - 6.1.1 Automotive batteries: Types and maintenance
  - 6.1.2 Charging system: Alternators and regulators
  - 6.1.3 Starting system: Starter motors and circuits
  - 6.1.4 Lighting, instrumentation and wiring harness
- 6.2 Automotive electronics
  - 6.2.1 Sensors, actuators and electronic control units (ECUs)
  - 6.2.2 Controller area network (CAN) bus system
  - 6.2.3 Engine management system (EMS)
  - 6.2.4 Introduction to ADAS
- 6.3 Emissions and emission control systems
  - 6.3.1 Exhaust system and exhaust gases
  - 6.3.2 Emission standards: EURO, BS-VI and EPA norms
  - 6.3.3 Emission control devices: Catalytic converter, EGR, DPF and evaporative control system

7 Electric, Hybrid Vehicles and Future Trends (4 hours)

- 7.1 Electric and hybrid vehicles
  - 7.1.1 EV architecture, motor types and working principle
  - 7.1.2 Battery systems, battery management system (BMS) and charging infrastructure
  - 7.1.3 Hybrid configurations: Series, parallel and plug-in hybrid
- 7.2 Future trends in automotive technology
  - 7.2.1 Autonomous and connected vehicles
  - 7.2.2 AI and IoT applications in automotive systems
  - 7.2.3 Sustainable mobility and alternative fuels

Tutorial (30 hours)

1. Comparison of thermodynamic cycles (Otto, Diesel, Dual cycle) and with real cycle in PV, Ts diagram
2. Injector calculations, air-fuel ratio and spray analysis
3. Ignition timing analysis using p-V diagrams
4. Gear ratio calculations and torque flow
5. Braking force, braking distance calculation and skid analysis
6. Electrical circuit diagram reading and analysis
7. Sensor data interpretation and EMS mapping

Practical (15 hours)

1. Automotive component identification (Physical/digital models)
2. Engine disassembly and component study
3. Fuel injectors and injection pump study
4. Ignition circuit and Ignition timing analysis
5. Inspection of cooling and lubrication systems

6. Gearbox disassembly and function study
7. Demonstrating suspension setup, steering geometry and alignment
8. Disc and drum brake dismantling and assembling
9. Wheel alignment setting and wheel balancing
10. Lighting, charging and starting circuits analysis and diagnostic tools
11. Exhaust gas analysis and emission testing
12. Trouble codes and ECU diagnostics

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	2	2
2	10	14
3	6	8
4	5	6
5	10	14
6	8	10
7	4	6
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Singh, K. (2020). Automobile engineering (Vols. 1–2). Standard Publishers and Distributors.
2. Heywood, J. B. (2018). Internal combustion engine fundamentals. McGraw Hill.
3. Robert Bosch GmbH. (2022). Automotive handbook. Wiley.
4. Crolla, D. A., Foster, D. E., Kobayashi, T., Vaughan, N. D. (2009). Automotive engineering: Powertrain, chassis system and vehicle body. Butterworth-Heinemann.
5. Gillespie, T. D. (1992). Fundamentals of vehicle dynamics (Latest Edition). SAE International.
6. Ehsani, M., Gao, Y., Longo, S., Ebrahimi, K. (2018). Modern electric, hybrid electric, and fuel cell vehicles: Fundamental theory and design. CRC Press.
7. Ribbens, W. B. (2017). Understanding automotive electronics: An engineering perspective. Butterworth-Heinemann.

FINITE ELEMENT METHOD
ENIE 447

Lecture : 3 | **Year : IV**
Tutorial : 2 | **Part : I**
Practical : 1

Course Objectives:
The objective of this course is to provide introduction develop skills of finite element analysis for discrete and continuous problems. It focuses applications of finite element method for heat transfer and solid mechanics problems using linear and higher order elements.

1 Introduction (5 hours)

1.1 Finite element method: Definition, evolution, applications
1.2 Terminologies: Element, nodes, mesh, degree of freedom
1.3 Boundary value problems
1.4 Mathematical modeling of physical systems
1.5 Basic steps of finite element method
1.6 Finite element method implementation
1.7 Eigen values and eigen vectors

2 Direct Stiffness Method for Discrete Elements (6 hours)

2.1 Spring, bar and shaft elements: Stiffness matrix, system assembly, solution
2.2 Truss (2D and 3D), beam and frame elements: Stiffness matrix, system assembly, solution
2.3 Methods of handling boundary conditions
2.4 Penalty method

3 Finite Element Formulation for Continuum Problems (9 hours)

3.1 Forms of continuum problems
3.2 Differential and variational formulation
3.3 Strong and weak form
3.4 Need of weighted integral method
3.5 Methods of weighted residual
3.6 Ritz method

4 Interpolation Functions and Numerical Integration (8 hours)

4.1 Piecewise defined interpolation function: Types of interpolation functions, requirements of interpolation function and selection of the order of a polynomial interpolation function

4.2 Polynomial interpolation function: Polynomial interpolation functions for one-dimensional problems, two-dimensional problems (Triangular and rectangular elements)
4.3 General interpolation functions: Lagrange, Hermite and serendipity interpolation functions
4.4 Integration methods: Integration in terms of local coordinates, numerical integration in terms of natural coordinates
4.5 Requirements of convergence of a displacement model

5 Applications in General One-Dimensional Problems (10 hours)

5.1 One-dimensional problem governed by second order ordinary differential equation: Finite element formulation using linear and quadratic elements
5.2 One-dimensional bar problem: Finite element formulation of a bar problem
5.3 One-dimensional beam problem: Interpolation functions for a beam element, finite element formulation of a beam problem using weak formulation
5.4 1-D heat transfer: Plane wall and fin
5.5 Formulating element mass matrices for 1D element
5.6 Computation of Eigen value and vector for simple one-dimensional analysis

6 Application in Elasticity (7 hours)

6.1 Governing equation for elasticity
6.2 Basic concepts of plane stress and plane strain
6.3 Finite element formulation of two dimensional elasticity problems using triangular and rectangular elements
6.4 Introduction to axisymmetric problems: Formulation of axisymmetric triangular element

Tutorial (30 hours)

1. Simple numerical problems on eigenvalues and eigenvectors, boundary conditions: Elimination method, penalty method
2. FEM formulation using: Linear elements, quadratic elements, bar problem: Stiffness matrix derivation, force vector formulation, beam problem: Interpolation functions, FEM formulation
3. Weighted residual methods (Conceptual problems), variational calculus basics, Ritz method applications with simple numerical
4. Polynomial interpolation (1D, 2D cases), simple numerical on Local versus global coordinate systems, requirements of interpolation functions
5. Numerical on1D heat conduction (Plane wall, fin)
6. Simple numerical in governing equations of elasticity, plane stress versus plane strain problems, 2D elasticity using FEM, axisymmetric problems

Practical (15 hours)

Using programming and simulation (ANSYS, STAAD, RISA, MATLAB)

1. Spring, bar and shaft elements
2. Plane truss and space truss
3. Beam and frame elements
4. Continuous system problems
5. One-dimensional problems
6. Two-dimensional problems

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	5	6
2	6	8
3	9	12
4	8	10
5	10	14
6	7	10
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Reddy, J. N. (2019). Introduction to the finite element method. McGraw Hill.
2. Logan, D. L. (2023). A first course in the finite element method. Cengage Learning.
3. Moaveni, S. (2011). Finite element analysis: Theory and application with ANSYS. Pearson.
4. Rao, S. S. (2018). The finite element method in engineering. Elsevier.
5. Zienkiewicz, O. C., Taylor, R. L., Govindjee, S. (2024). The finite element method: Its basis and fundamentals. Elsevier.
6. Chandrupatla, T. R., Belegundu, A. D., Ramesh, T., Ray, C. (2012). Introduction to finite elements in engineering. Pearson.