DFSRDA AGBOT: FIRST SEMESTER (COURSE STRUCTURE)

Course and Examination Scheme of Certificate course (DFSRDA-AGBOT)

Subject Code	Subject Name	Teaching Scheme			Examination Scheme								
		Hours per Week		No. of Credits	Theory					Practical			
		Theory	Practical		Duration of Paper (Hrs.)	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks
DFSRDA-AGBOT-101T	Fundamentals of Agribots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-102T	CAD/CAM/CAE in Agriculture	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-103T	Mechatronics in Agricultural Robots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-104T	Computing for Agricultural Robots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-105T	Maintenance in Agricultural Robots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-106P	Mini Project	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA - AGBOT-107P	Practical on Hydraulic and Pneumatic	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA - AGBOT-108P	Practical on CAD/CAM/CAE	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA - AGBOT-109P	Practical on Mechatronics (Sensors, Actuators and Controllers)	-	02	1	2 Hrs	-	-	-	-	25	25	50	25

DFSRDA-AGBOT: SECOND SEMESTER (COURSE STRUCTURE)

Course and Examination Scheme of Certificate course (DFSRDA-AGBOT)

Subject Code	Subject Name	Teaching Scheme			Examination Scheme								
		Hours per Week		No. of Credits (T+P)	Theory					Practical			
		Theory	Practical		Duration of Paper (Hrs.)	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks
DFSRDA-AGBOT-201T	CDKS in Agri-Bots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-202T	SSPN in Agri-Bots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGBOT-203T	SPM in Agri-Bots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA - AGBOT-204T	FPA in Agri-Bots	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGBOT-205T	Elective I	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGBOT-206T	Elective II	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGBOT-207P	Major Project	-	04	2	4 Hrs	-	-	-	-	50	50	50	50
DFSRDA-AGBOT-208P	Agri Bots Technology Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGBOT-209 P	Practical on Image Processing	-	02	1	2 Hrs	-	-	-	-	25	25	50	25

DFSRDA-AGBOT-101: Fundamentals of Agri-BOT

THEORY

1. **Robot Definition**: Definition of robots, Evolution of robots, Laws of robots, International Robotic Standards, Why Robots? Types of robots, Selection of robots.
2. **Robot Classifications**: Degrees of freedom; degrees of movements, robot configuration; accuracy and repeatability, specification of a robot, actuators and sensors, drives and
3. **Coordinate Transformation**: Direct kinematic problem in robotics, geometry based direct kinematic analysis coordinate & vector transformation using matrices, the orientation mtrix & translator vector, homogeneous transformation matrices, three dimensional homogeneous transformations.
4. **Trajectory interpolation**: Introduction, the necessity of interpolators, the generation of motion commands, the trajectory planning, basic structure of interpolators. The solvability of the inverse kinematics problem, particular solutions for the inverse kinematics problem – two axis planar mechanisms, example of three-axis spherical mechanism, specific solutions for six-axis manipulators.
5. **Autonomous mobile robots**: Introduction, locomotion - key issues for locomotion, legged mobile robots, leg configurations & stability , examples of legged robot locomotion , Wheeled mobile robots, wheeled locomotion-the design space, wheeled locomotion: case studies.
6. **Mobile robot kinematics**: Introduction, kinematics models & constraints, representing robot position, forward kinematics models, wheel kinematics constraints, robot kinematics constraints, examples robot kinematics models & constraints. Mobile robot maneuverability- degree of mobility, degree of steerability, robot maneuverability. Mobile robot workspace- degree of freedom, holonomic robots, path & trajectory considerations. Motion control - open loop control, feedback control.

Text / Reference Books

1. Robotics & Control – R.K. Mittal & I.J. Nagrath – TMH Publications
2. Robotics for engineers - Yoram Korean- McGrew Hill Co.
3. Industrial Robotics Technology programming and Applications - M.P.Groover, M.Weiss, R.N.Nagel, N.G.Odrey.
4. Robotics Control Sensing, Vision and Intelligence - K.S.Fu, R.C.Gonzalex, C.S.G.Lee- McGrew hill Book co.
5. Kinematics and Synthesis of linkages - Hartenberg and Denavit - McGrew Hill Book Co
6. Kinematics and Linkage Design - A.S. Hall - Prentice Hall
7. Kinematics and Dynamics of Machinary - J.Hirchhorn - McGrew HillBook Company.

DFSRDA-AGBOT-102: CAD/CAM/CAE in Agri-BOT

THEORY

1. Criteria for selection of CAD workstations, Design Process, Design criteria, Geometric modeling, entities, 2D & 3D Primitives.
2. 2D & 3D Geometric Transformations: Translation, Scaling, Rotation, Reflection and Shearing, concatenation. Graphics standards: 302 KS IGES, PDES. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse, Conis. Synthetic curves – Cubic, Bezier, B-Spline, NURBS.
3. Surface entities, Surface Representation. Analytic Surface – Plane Surface, Ruled Surface, Surface of Revolution, Tabulated Cylinder. Synthetic Surface-Cubic, Bezier, B-spline, Coons. Graph Based Model, Boolean Models, Instances, Cell Decomposition & Spatial – Occupancy Enumeration, Boundary Representation (B-rep) & Constructive Solid Geometry (CSG). Feature Based Modeling, Assembling Modeling, Behavioral Modeling, ConceptualDesign & Top Down assembly.
4. Introduction of ANSYS, Basics of ANSYS workbench, Introduction to FEA, Engineering data, Material Properties, Basics of Meshing, named selection, meshing methods, element types, Boundary conditions setup, Cell zones – fluid/solid, General guidelines, Different boundary conditions.
5. Study solver and types of solver methods. Types of Analysis: Structural Analysis, Modal Analysis, Thermal analysis, Thermal-electric analysis, Natural Frequencies. Introductions to Fluid flow, Basics of CFD Analysis, Fluent, Electromagnetic analysis, Post processing methods, Report preparation. Design Optimization.
6. Introduction to CAM: Basics of additive manufacturing, File Formats, Model Repair and Validation, Pre & Post-processing, Multiple Materials, Material Selection, and types of materials, Hybrids, Composite Materials current and future directions. Process & FDM, SLA, PLA methods, Prototyping fundamentals, Data Conversion, and transmission, Checking and preparing, Building, Post processing.

Text / Reference Books

1. CAD/CAM: Computer-Aided Design and Manufacturing by M Groover and E. Zimmers, Pearson Education, 1983.
2. CAD/CAM in Practice by A J Medland, Springer science and media, 2012.
3. CAD/CAM Theory and Practice Ibrahim Zeid, McGraw-Hill, 1991
4. Computer Aided Manufacturing by P N Rao, Publisher: McGraw Hill Education (1July 2017)

DFSRDA-AGBOT-103: Mechatronics in Agri-BOT

THEORY

1. **Sensors and Measurement of parameter**: Principles and classification of transducers, guidelines for selection and application of transducers, basic requirements of transducers. Different types of transducers, displacement, strain gauge, LVDT, potentiometer, capacitive & inductive, Piezoelectric, temperature, optical, Hall Effect transducers. Measurement of length, angle, area, temperature, pressure flow, speed force, torque, vibration, level, concentration (conductivity and ph.) measurement- sensors in robotics-tactile sensors-proximity and range sensors- miscellaneous sensors and sensor based systems-use of sensors in robotics.
2. **Fundamentals of Electric drives** - Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, nature and classification of load torque, equivalent moment of inertia, modes of operation.
3. **Control Speed control and drive** classification, closed loop control, current limit control, speed control, position control, torque control, PLL control, multi-motor drive control, digital control. DC motor control, speed control, position control, proportional control, PID controllers. Control system modeling: System concept, differential equations and transfer functions. Modeling of electric systems, translational and rotational mechanical systems, and Simple electromechanical systems. Practical controllers - Introduction to P, PI and PID controllers.
4. **Pneumatic Drives**: Merits of Fluid power & its utility for increasing productivity through Low Cost Automation, Transmission of Fluid Power through various types of Cylinders), Symbolic representation of Pneumatic elements (CETOP), Compressors and Air supply system including airline installations, signaling & control system. Pneumatic control elements (control valves & remote control system), Basic pneumatic circuits for controlling single & double acting cylinder, Basic pneumatic circuits, Advanced pneumatic circuits for controlling multi-cylinders (operable). Advanced pneumatic circuits for controlling multi-cylinders (inoperable circuits), Electro pneumatics with relay logic, and Pneumatics system with PID controls, Application of fluidics a non-moving part logic.
5. **PLC** :Evolution of PLC's - Sequential and programmable controllers - Architecture-Programming of PLC - Relay logic - Ladder logic - Gates, Flip flops and Timers. Communication in PLC's: Requirement of communication networks of PLC - connecting PLC to computer -Interlocks and alarms - Case study of Tank level control system and Sequential switching of motors.

6. **Block diagram representation of systems** – Block diagram reduction methods – Closed loop transfer function, determination of signal flow graph. Mason's gain formula – Examples. Time domain analysis: Test signals- time response of first order and second order systems- time domain specifications-types and order of systems generalized error coefficient-steady state errors- concepts of stability-root locus. Frequency domain analysis: Introduction – correlation between time and frequency response – stability analysis using Bode plots, Polar plots. Compensators: Realization of basic compensators – cascade compensation in time domain and frequency domain and feedback compensation – design of lag, lead, lag-lead compensator using Bode plot and Root locus.

Text / Reference Books

1. W. Shepherd, and L. N. Hully, "Power Electronics and Motor control", (2e), Cambridge University, 1995.
2. Gopal K. Dubbey,"Fundamentals of Electric Drives", (2e), Narosa Publishers, 2001.
3. R. Krishnan, "Electric Motor Drives Modeling, Analysis, and Control", (2e), Prentice Hall, 2001
4. Anthony Esposito, "Fluid power with applications", Pearson Education, 2003.
5. Sadhu Singh. "Computer Aided Design and Manufacturing", Khanna Publishers, New Delhi, 1998
6. Applied Nonlinear Control, by Slotine and Li, Prentice-Hall, 1991, ISBN 0-13-040890-5.
7. Ogata, K., Modern Control Engineering, Prentice-Hall, [2002]
8. Gibson, J. E., Nonlinear AutomaticControl, McGraw-Hill, [1963]
9. Khalil, Hasan K., Nonlinear Systems, Macmillan Publishing, [1992]

DFSRDA-AGBOT-104: Computing for Agri-BOT

THEORY

1. **Image acquisition**: Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.
2. **Image analysis**: image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, discrete cosine transform to images, image scaling, standard video formats.
3. **3D vision and Stereo vision**: Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2d and 3d geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods, Epipolar geometry, triangulation, rotational matrix, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3d reconstruction.
4. **Motion estimation and tracking**: Optical flow estimation, object tracking with Kalman filtering, feature extraction & object recognition
5. **Introduction to programming languages**:. Methods of programing a Robot (ROS robot programing, raspberry pie, aurdino), robot language structure, the textual robot languages. Online and Offline programming. Flex Pendent. RAPID introduction, Constant, data objects and variables, data declaration, expressions, using data and aggregates in expression, Functions, function call in expression, priority between operators, Various Instructions, WAIT, SIGNAL and DELAY commands.
6. **Case studies/application**: Face recognition, vehicle tracking, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

Text / Reference Books

1. Milan Sonka, Vaclav Hlavac, Roger Boyle, Image Processing, Analysis and Machine Vision", (2/e), 1998.
2. Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, (2/e), Pearson education, 2003.
3. Boguslaw Cyganek & J. Paul Siebert, An Introduction to 3D Computer Vision Techniques and Algorithms, Wiley, 2009.
4. E.R. Davies, Royal Holloway, Machine Vision: Theory, Algorithms and Practicalities, (3/e), University of London, December 2004.
5. R. Jain, R. Kasturi, B. G. Schunck, Machine Vision, McGraw-Hill, New York, 1995.

DFSRDA-AGBOT-105: Maintenance in Agri-BOT

THEORY

1. **Industrial safety**: Safety in the use of Power Presses (all types), Shearing, Bending, Rolling, Drawing, Turning, Boring, Milling, Shaping, Planning broaching, planting, Grinding, CNCs. Preventive maintenance, periodic checks for safe operation. Associated hazards and their prevention. Workplace Inspection, type of workplace inspection, Importance of consultation in safety. PPE RIA Safety standards. Application Safety, Safety categories, OSHAS.
2. **Electrical safety**: Safe limits of amperages, voltages, distance from lines, etc., Joints and connections, Overload and Short circuit protection, Earthing standards and earth fault protection , Protection against voltage fluctuations, Effects of shock on human body Hazards from Borrowed neutrals, Electrical equipment in hazardous atmosphere, Criteria in their selection, installation, maintenance and use, Control of hazards due to static electricity.
3. **General safety consideration in material handling**: Ropes, Chains, Sling, Hoops, Clamps, Arresting gears, Prime movers. Ergonomic consideration in material handling, design, installation, operation and maintenance of Conveying equipment, hoisting, traveling and slewing mechanisms.
4. **Ergonomic consideration**: in material handling, design, installation, operation and maintenance of driving gear for hoisting mechanism. Traveling mechanism Selection, operation and maintenance of Industrial Trucks, Mobile Cranes, Tower crane, Checklist, Competent persons. Storage and Retrieval of common goods of various shapes and sizes in a general store of a big industry.
5. **Quality Control and Safety Standards**: Quality objectives, Quality control, Quality Assurance – Process variability, ISO 9000 and TQM concepts, Quality management: Quality circles, tools, Zero defect management, 6 sigma–Quality Function Deployment (QFD). The Components and benefits of safety management system.
6. **Maintenance**: Objectives, Types of maintenance, preventive, predictive, break down maintenance. Reliability and maintainability analysis. Failure data analysis, reliability, MTBT, MTTR, Batch tub curve, series parallel and stand by system.

Text / Reference Books

1. Industrial Engineering & Production Management, Martand Telsang, S. Chand & co.
2. Maynard H.B.: Industrial Engineering Handbook, McGraw Hill.
3. Industrial Engineering. & Management, Arun Vishwanath, SciTech Publication.
4. Industrial Engineering and Management, N.V.S. Raju, Cengage Publication.
5. Statistical Quality Control, E. Grant & R. S. Leavenworth, McGraw Hill.
6. Motion & Time study by R.M. Barnes, John Wiley.

DFSRDA -AGBOT-107P: Mini Project

Student shall prepare a working model of any Agricultural robotic system. Computer / mathematical model or simulation is not acceptable. Student shall submit a report with photograph of the model. A teacher shall be allotted for each batch and the workload shall be 2 hour / batch per week.

DFSRDA -AGBOT-108P: Practical on Hydraulic and Pneumatic

List of Experiments :

1. Study of Basic pneumatic circuit for the working of single and double acting cylinder.
2. Study of Basic hydraulic circuit for the working of double acting cylinder and a hydraulic motor.
3. Study of Speed control circuits. Different Metering Methods Inlet & outlet flow control (meter-in & meter-out circuit)
4. Study of Circuits for the Use of different direction control valves and valve actuation in single and double acting cylinder, and multi-actuation circuit.
5. Study Hydraulic or Pneumatic Sequencing circuit.
6. Study of Electro Pneumatics circuit, based on the industrial application.
7. Study of Electro hydraulics circuit, based on the industrial application.
8. Write a PLC program to latch and unlatch an output by sealing.
9. Write a PLC program to latch and unlatch an output with time delay.
10. Write/Draw a PLC program to operate 4 outputs simultaneously with time delay.
11. Write a PLC program for A motor is connected to PLC. Run this motor in the forward and reverse direction using ladder diagram programming language.
12. Experimental study of pneumatically sorting station, conveyer belt and diversion mechanism.

DFSRDA -AGBOT-109P: Practical on CAD/CAM/CAE

List of Experiments :

1. Introduction to CAD software's
2. Performance on CAD software for 3D design modeling of agricultural equipment's
3. Introduction to CAM Software
4. Introduction to CAE software
5. Experiment of Structural Analysis
6. Experiment of Thermal Analysis
7. Experiment of Modal Analysis
8. Experiment of CFD Analysis
9. Experiment of Electromagnetic Analysis

DFSRDA -AGBOT-110P: Mechatronics (Sensors, Actuators and Controllers)

List of Experiments :

1. Study of Agricultural sensors and actuators
2. Study of Industrial sensors and actuators
3. Study and Experiment on Solar Kit to test the solar panel efficiency.
4. Study of Industry 4.0 trainer Kit-1
5. Study of Industry 4.0 trainer Kit-2
6. Interpretation of Agricultural sensors, PLC and actuators hardware and programming
7. Automatic irrigation system based on soil moisture level
8. Testing of soil temperature and humidity
9. Experimentation on water level measurement
10. PLC based water pump operation for irrigation

DFSRDA-AGBOT-201: CDKS in Agri-BOT

THEORY

1. **Introduction to CDKS**: Climate change and its impact on Agriculture, Climate Smart Agriculture Technologies, Digital Farming Solutions, Agricultural robotics and digital farming, Challenges of robotics for precision agriculture: Digitalization, Automation, and Optimization.
2. **Introduction to Precision Agriculture Technologies**: Importance of Precision Agriculture and mapping in farming for decision making, Benefits of PA, Economic of precision agriculture & determining equipment and software.
3. **Introduction to Protected Cultivation**: Greenhouse Introduction, Types of Greenhouse, Greenhouse Environment, Crops management in greenhouse, equipment needed, Greenhouse automation.
4. **Agricultural Robot Applications**: Harvesting and picking, weed control, Autonomous mowing, pruning, seeding, spraying and thinning, Phenotyping, Sorting and packing, Utility platforms robots, Soil moisture, nutrient status analysis by robots, Smart cameras for weed-crop segmentation.
5. **Robotics application in Field Crops**: Design and operation of robotic system, Robots in soil analysis and fertility mapping Field scouting and data collection robots, Localization and mapping, Robotic Vision, Crop monitoring, weeding robot, crop harvesting robot in field crops.
6. **Robotics application in Protected Cultivation**: Novel technologies for crop monitoring, robotic greenhouses/robot farming, Greenhouse scouting robot, Greenhouse spraying robot, harvesting robot.

Text / Reference Books

1. Push Button Agriculture: Robotics, Drones, Satellite-Guided Soil and Crop Management K.R. Krishna, CRC Press
2. Agricultural Robotics: The Future of Robotic Agriculture, UK-RAS White papers
3. Precision Farming B.L. Jana Agrotech publishing academy
4. Robotics and Automation for improving agriculture. Burleigh Dodds Science Publishing,
5. Handbook of Agricultural Engineering, ICAR Publication, 6th edition
6. Agricultural Automation: Fundamentals and Practices by Qin Zhang and Francis J Pierce; CRC Press

DFSRDA-AGBOT-202: SSPN in Agri-BOT

THEORY

1. **Seed, Seedling, Nursery**: Introduction; Definition, Scope and Importance, component, Selection of components seedling, Nursery preparation and development Techniques. Factor affecting on development Seed, Seedling, Nursery production:- Introduction, Climatic parameter, Soil parameter, Nutrients management, Quality Seed and Nursery Plant, Handling and transportation.
2. **Seed Processing**:-Introduction, seed Production and technology Principal of Seed Processing seed, Pre-cleaning and Conditioning Equipment, Dimension Sizing Equipment, Separators, Seed Treating Equipment, Accessory Equipment, Material Handling, Storage, Transportation.
3. **Hightech Polyhouse**:- Introduction, Components, Classifications, Design Specifications, Tools and Instrument used in Polyhouse, Disease and Pest Management in Hightech polyhouse, Irrigation system Heating systems, cooling system, Fertigation and Plant Bio Enhancers, Phototropic control, Control system, Media Preparation, Problem Management.
4. **Agricultural robotics in SSPN**: Introduction; Overview of Robot in Farming System, Agricultural robot Vehicles, Robot Management, Field Crop or Nursery Seedling Production Automation system. Automation system in Seed Processing.
5. **Robotics and automation in Hitech Polyhouse management**: Introduction; Definition Heading and Pruning Automation in Polyhouse Production. Mechanical Mass Harvesting of Fruits, Nuts and Vegetables, Horticultural Aspects of Robotic Harvesting, Design Aspects, System development.

1. **Robotic Grafting**: Introduction, Requirements and Technique of Grafting, precaution, Used of robots in grafting and working principal.

Text / Reference Books

1. Unit Operations of Agricultural Processing, 2nd Edition, (2004) By Sahay K.M. & Singh K.K.
2. Agricultural Automations: Fundamentals and Practices, 1st Edition, (2013) By Qin Zhang and Francis J. Pierce; CRC Press.
3. Seed Processing and Handling. Seed Technology Laboratory Mississippi State University, Mississippi
4. Unit Operation of Agricultural Processing; K M Sahay, K K Singh, Vikas Publishing House PVT LTD
5. Hand Book of Agriculture Engineering ICAR.
6. Hand Book of Agriculture ICAR

DFSRDA-AGBOT-203: SPM in Agri-BOT

THEORY

1. **Introduction to farm production system and operations**: Evolution of Operations and System Management in Agriculture; Agricultural Operations; Management of Agricultural Operations; Energy Inputs and Outputs in Agricultural Operations, Types of Farm Machinery; Choosing a Machinery System; Effectiveness and Efficiency of Agricultural Machinery; Cost calculation; Advances and Future Trends in Agricultural Machinery.
2. **Robotics in land development and soil related activities**: Introduction; Objectives of land development; Principle of operation; advanced machines/ Robots for land development operation, (Ploughing, Zero tillage system), Robots in soil analysis and soil fertility mapping.
3. **Robotics in sowing and planting**: Introduction; Objectives of Sowing/Planting; Principle of operation; Advanced Machines/Robots for Sowing or Planting of Crops, vegetables and Orchards (Robots and potted plants in greenhouses, Harvey).
4. **Robotics in intercultural, plant protection and allied activities**: Introduction; Objectives of Intercultural operation; Principle of operation; advanced machines/ Robots for weeding, precision spraying, challenges in current robotic sprayers, Pruning and Thinning operation (hedging and pruning automation in vineyard production, hedging and pruning automation in orchard production, Robotic pruning and thinning), Recent advancements in Automation of chemical application systems (Variable rate application, controllers for VRA, Selective application, Robotic Application)
5. **Robotics in harvesting**: Introduction; Objectives of harvesting operation; Principle of operation; Classification of mechanical harvesters, advanced machines/ Robots for harvesting, field crop harvesting, Cotton Harvesting, Mechanical Mass harvesting of fruits, Nuts and vegetables. (robotic lettuce pickers of California, Pumpkin Harvesters, robots to harvest greenhouse vegetables, Robots to harvest fruit crops)
6. **Economics of Agribots**: Agricultural Robots and their influence on Human Farm Labour, Agricultural robots and economic aspects of farming

Text / Reference Books

1. Operations Management in Agriculture by Dionysis Bochtis, Claus Aage Gron Sorensen, Dimitrios Kateris; Academic Press: An Imprint of Elsevier
2. Agricultural Automation: Fundamentals and Practices by Qin Zhang and Francis J Pierce; CRC Press
3. www.fao.org/3/w7365e04.htm#1.3 agricultural systems classification and order hierarchy
4. Agricultural Robotics: The Future of Robotic Agriculture
5. Robotics and automation for improving agriculture by John Billingsley; BurleighDodds Science Publishing
6. Handbook of Agricultural Engineering, ICAR Publication, 6th edition.
7. Push Button Agriculture by K. R. Krishna; CRC Press.

DFSRDA-AGBOT-204: FPA in Agri-BOT

THEORY

1. **Food Processing**: Introduction; Post Harvest and Food Processing Unit Operations; Material Handling, Packaging and Transportation; Novel Food processing techniques.
2. **Agricultural robotics in FPA**: Introduction; Current manufacturing procedures; Automation in food sector; Specification for a food sector robot; Future trends; Conclusion.
3. **Robotics and automation in the fresh produce**: Introduction; Machine vision system as a key technology; Vegetable preprocessing and grading systems; Information flow for food traceability and farming guidance; Future trends; Conclusion.
4. **Robotics and automation in Unit Operations Food Processing**: Introduction; Types of unit operations and machines; Working principle, Automation in primary food processing operations in different food industries; Future trends; Conclusion.
5. **Robotics and automation for packaging**: Introduction; Principles; Types of packaging; Automation in packaging of different agricultural fresh produce and food products; Case study of a reconfigurable system for carton folding; Future trends; Conclusion. Robotics and automation in transportation and material handling: Types of transportation and material handlings; Future trends; Conclusion.
6. **Automation for a sustainable food industry**: computer aided analysis and control engineering methods: Introduction; Definition of sustainability and links with the food industry; Automation and sustainability in food manufacturing; Tools for automated sustainable design and operation in food engineering; Advanced tools and methods for sustainable food engineering with potential applications; Software technologies for automated sustainable design; Conclusion and future trends; Sources of further information and advice.

Text / Reference Books

1. *Robotics and Automation in the Food Industry. Current and Future Technologies;Woodhead Publishing Series in Food Science, Technology and Nutrition, (2013) Editedby Darwin G. Caldwell.*
2. Food Processing Technology, Principles and Practice, Fourth Edition, By P.J. Fellows.
3. Unit Operations of Agricultural Processing, 2nd Edition, (2004) By Sahay K.M. & Singh K.K.
4. Agricultural Automations: Fundamentals and Practices, 1st Edition, (2013) By Qin Zhang and Francis J. Pierce; CRC Press.

DFSRDA-AGBOT-207P: Major Project

The project work may conform to anyone of the below stated types of broad based work.

1. Detailed design of some Agricultural system. This may comprise of machines, thermal/ hydraulic / pneumatic system, design of some small industrial product developments.
2. Detailed experimental / practical verification of some Agricultural Robotic systems.
3. Detailed study of some agricultural equipment/implement integrated with digital technology and artificial intelligence. This study may comprise of various aspects such as rapid prototyping, grafting techniques, reverse engineering, robotic devices/vehicles and programming, data acquisition systems, plant layout, mechanical handling systems, assembly shop, quality control system, maintenance system, various service systems, design, development and planning functions, techno-economic studies etc., feasibility of small scale industry.
4. Software development for particular application / design / analysis etc.
5. Any other relevant area to agriculture.

Group of students shall be considered for the project work. Group of Student is expected to prepare a project report and shall present a seminar on it.

DFSRDA-AGBOT-208P: Agri Bots Technology Lab

List of Experiments :

1. Experiment on Grafting Robot
2. Experiment on Cotton Picking Robot
3. Experiment on 3D Printer
4. Experiment on 3D Scanner
5. Experiment on Jackal J 100
6. Experiment on Husky A200
7. Experiment on Mobile Platform (Scissor lift)
8. Experimental study of Refrigerated Van
9. Experimental Study of Cold Storage Unit
10. Experimental Study of Gator type vehicle for agricultural implements

DFSRDA-AGBOT- 209 P: Practical on Image Processing

List of Experiments :

1. Experiment on Stereo Vision Camera
2. Experiment on Real Sense Cameras
3. Experiment on Zed 2 Camera
4. Experiment on CCD Camera
5. Experiment on Multi Spectral Camera
6. Experiment on Spectro-radiometer
7. Experimental Analysis on PIX 4D software
8. Experimental Analysis MAT Lab Software
9. Experimental Analysis on QGIS software.

DFSRDA AGDRONE: FIRST SEMESTER (COURSE STRUCTURE)

Course and Examination Scheme of Certificate course (DFSRDA-AGDRONE)

Subject code	Subject Name	Teaching Scheme			Examination Scheme								
		Hours Per Week		No. of Credits	Theory					Practical			
		Theory	Practical		Duration of Papers	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks
DFSRDA-AGDRO-101	Fundamentals of Agri-DRONE	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-102	CAD/CAM in Agri-DRONE	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-103	Agri-DRONE Mechatronics	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-104	Agri-DRONE Computing	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-105	Agri-DRONE Maintenance	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-107P	Mini Project	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGDRO-108P	Mechatronics Lab	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGDRO-109P	Image Processing Lab	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGDRO-110P	Sensors, Actuators and PLC Lab	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
IIIP	Technical Seminar Presentation												

DFSRDA AGDRONE: SECOND SEMESTER (COURSE STRUCTURE)

Course and Examination Scheme of Certificate course (DFSRDA-AGDRONE)

Subject code	Subject Name	Teaching Scheme			Examination Scheme								
		Hours Per Week		No. of Credits	Theory					Practical			
		Theory	Practical		Duration of Papers	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min. Passing Marks
DFSRDA-AGDRO-201	Agri-DRONE in CDKS	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-202	Agri-DRONE in SSPN	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-203	Agri-DRONE in SPM	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-204	Agri-DRONE in FPA	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-205	Elective-I	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-206	Elective-II	4	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGDRO-207P	Major Project	-	2	1	2 Hrs	-	-	-	-	50	50	100	50
DFSRDA-AGDRO-208P	Agri-DRONE Hardware Lab	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGDRO-209P	Agri-DRONE Software Lab	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGDRO-210P	CAD/CAM/CAE Lab	-	2	1	2 Hrs	-	-	-	-	25	25	50	25
2115	Technical Seminar Presentation			1									

DFSRDA-AGDRO-101: Fundamentals of Agri-DRONE

THEORY

1. **Introduction to Drone**: Definition of drones, Anatomy of Drone, Importance of Drone Technology, History of Drone, Types of Drone as per structure, Need of Drone Technology in Agriculture.
2. **Components of Drone**: Introduction, Antenna, Propellers, Motor, Camera and its accessories, Ground Station, chassis, Propellers, Battery and charger, Types of Battery, battery function in drone, Flight controller and its peripherals, GNSS & RTK Module, Flight Controller, ESC (Electronic speed Controller), Power Module, Radio Transmitter/Receiver.
3. **Working principles of Drone**: Introduction, Working Principle of drone, Definition of Propulsion, Propeller and vertical motion of Drone, Concept of drone flight, Take-off, and landing, Flight Modes and Maneuvering, Dynamics of an aerial system, Principal axes and rotation of aerial systems, on board flight control, Types of Platform and Propulsion system required for drone operation.
4. **Stability and Control of Drone**: Introduction to stability and Control of Drone, Definition of Stability, Definition of Control, Types of Stability required in Drone, Types of Control required in Drone
5. **Sensors used in drones**: Introduction of Sensor, Definition of Sensor, Working Principle of Sensor, Types of sensors, Accelerometer, Barometer, Gyro Sensor, Magnetometer, Time of Flight Sensors, Thermal Sensors, Chemical Sensors, Distance Sensors, Light - Pulse Distance Sensor, Radio Detection and Ranging and Sonar -Pulse Distance Sensing, Sensors such as Hyperspectral, Multispectral, Thermal and RGB and other payloads.
6. **Regulation and Maintenance of Drone**: Introduction, Basic Air. Regulations, DGCA regulation, foreign regulatory, FCC compliance, sUAS registration and Federal Aircraft Regulations (FARs). Maintenance of Drones includes flight control box, ground station, Maintenance of ground equipment, batteries and Payloads, Scheduled servicing, Repair

Text / Reference Books –

1. "Agricultural Drones", book by Krishna K.R, Published by CRC Press with ISBN:
   9781771885959, 9781771885959. (Link: https://bit.ly/36zfiFN)
2. "Unmanned Aerial Vehicle: Design, Planning & Mission Using Agri Drones" book by Karad Sachin by International Publication Lambert Academic with ISBN-978-620-2-
   91776-6. (Link: https://bit.ly/2SsBn0H)
3. "Unmanned Aerial Vehicle: Applications in Agriculture and Environment" book by Ram Avtar, published by Springer, with ISBN number:978-3-030-27156-5.(Link: https://bit.ly/34xchDg)
4. ASA Test Prep. Remote Pilot Test Prep — UAS: Study & Prepare. Wellfleet Press, 2016. 978-1577151326.
5. Austin, Unmanned Aircraft Systems: UAVS Design, Development and Deployment. Wiley, 2010. 978-0-470-05819-0.
6. Baichtal, Building Your Own Drones: A Beginners' Guide to Drones, UAVs, and ROVs. Que Publishing, 2016. 978-0789755988.

7. Beard & McLain, Small Unmanned Aircraft: Theory and Practice. Princeton University Press, 2012. 978- 0691149219.
8. Cares & Dickmann, Operations Research for Unmanned Systems. Wiley, 2016. 978-1- 118-91894-4.
9. Chao & Chen, Remote Sensing and Actuation Using Unmanned Vehicles. Wiley, 2012. 978-1-118-12276-1
10. Cheng, Aerial Photography and Videography Using Drones. Peachpit Press, 2015. 978-
    0-13-412277-9.
11. Leisure & Nolan, Unmanned Aviation Systems: The Definitive Guide. eAcademicBooks, 2016. (E-book).
12. Marshall, UAS Integration into Civil Airspace: Policy, Regulations and Strategy. Wiley, 2017. 978-1-118-33949-7.
13. Marshall et al, Introduction to Unmanned Aircraft Systems, 2nd Ed. CRC Press, 2016. 978-1482263930.
14. Sebbane, Smart Autonomous Aircraft: Flight Control and Planing for UAV. CRC Press, 2015. 978-8229915

DFSRDA-AGDRO-102: CAD/CAM in Agri- DRONE

THEORY

1. Criteria for selection of CAD workstations, Design Process, Design criteria, Geometric modeling, entities, 2D & 3D Primitives.
2. 2D & 3D Geometric Transformations: Translation, Scaling, Rotation, Reflection and Shearing, concatenation. Graphics standards: 302 KS IGES, PDES. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse, Conis. Synthetic curves – Cubic, Bezier, B-Spline, NURBS.
3. Surface entities, Surface Representation. Analytic Surface – Plane Surface, Ruled Surface, Surface of Revolution, Tabulated Cylinder. Synthetic Surface-Cubic, Bezier, B- spline, Coons. Graph Based Model, Boolean Models, Instances, Cell Decomposition & Spatial – Occupancy Enumeration, Boundary Representation (B-rep) & Constructive Solid Geometry (CSG).
4. Feature Based Modeling, Assembling Modeling, Behavioral Modeling, Conceptual Design & Top Down assembly. Capabilities of Modeling & Analysis Packages such as solid works, Unigraphics, Ansys, Hypermesh. Computer Aided Design of mechanical parts and Interference Detection by Motion analysis. Stack-up analysis.

Text / Reference Books

1. CAD/CAM: Computer-Aided Design and Manufacturing by M Groover and E. Zimmers, Pearson Education, 1983.
2. CAD/CAM in Practice by A J Medland, Springer science and media, 2012.
3. CAD/CAM Theory and Practice Ibrahim Zeid, McGraw-Hill, 1991

DFSRDA-AGDRO-103: Agri-DRONE Mechatronics

THEORY

1. **Fundamentals of UAV Mechatronics**: Introduction, Definition, Role of Mechatronics in Agri-Drones, Components of Mechatronics, Engineering involved in Mechatronics.
2. **Sensors and Measurement Systems**: Definition of sensors, Difference between sensors and transducers, Classification of sensors, Types of Imaging sensors, GPS/DGPS, Lidar,Vision Sensor, RGB-D Camera ,Obstacle Detection Sensor, Attitude Sensor, MEMS Sensor, Posture Sensor, Definition of Measurement, Types of Measurement.
3. **Electronics Control Systems of UAV**: Definition of Control system, Types of Control Systems, Linear Control(PID Control And Gain Scheduling),Nonlinear Control, Neural Network, Fuzzy Logic and Swarm Control, Flight Controller, Electronic Speed Controller(ESC),ESC Programing, Transmitter, Receiver, Function of Remote Controller, Role of Microprocessor, Microcontroller, Arduino.
4. **Electrical Involvement in UAV**: Define signal, Types of signals, AC vs DC Signals, Power systems of UAV, Types of Batteries, Bullet Connectors, Wiring Flight Controller and Receiver, Types UAV Motors, Working Principle of BLDC Motor, Servo Motors.
5. **Hardware System of UAV**: Design of Airframe, Landing gear, Propeller's, Material Properties of Airframe, Landing Gear and Propellers. Attachment of propellers and motors, Types of Spraying Nozzles, Payload Types.
6. **UAV Communications And Softwares**: Ground Wireless Base stations, Wireless Network, Three Dimensional MIMO And Millimeter Wave-Communication, Internet of things, Cellular connectivity, GPS/DGPS, Areal Channel modelling And waveform Design, Development of UAV wireless communications. Drone Mapping Software: Pix4D, 3dr, Microdrones, mdCockpit, mdFlightSim, Bently, GlobalMapper, Agisoft Metashape and DroneDeploy, ArcGIS, QGIS, ARDAS.

Text / Reference Books

1. "Building Your won Drones" :By Greg Wiegand, Printed In UAS,ISBN 13:9780 789755988:(Link: https://bit.ly/33DaoWq)
2. "The Complete Guide to Drones Extended 2nd Edition": (English, Paperback, Juniper Adam); ISBN: 9781781575383, 9781781575383; Publisher: Octopus Publishing Group: (Link: https://bit.ly/30Nj8ro)
3. "Agricultural Drones": By Simon Rose, :(Link: https://amzn.to/2SByJ8P)
4. "Wireless Communication And Networking for UAV": By walid Saad, Mehedi Benis, Mohammad mozzafari: Cambridge University Press: (link: https://bit.ly/2SCHcZu)
5. Build a Drone : (English, Paperback, Davies Barry) ISBN: 9781510707054; Publisher: Skyhorse Publishing;(Link: https://bit.ly/2SzEALZ)
6. Handbook of Research on Advancements in Robotics and Mechatronics (2 Volumes): Publisher: Octopus Publishing Group;ISBN: 9781781575383, 9781781575383;(Link: https://bit.ly/30Nj8ro).
7. Open Drone Map: The Missing Guide: A Practical Guide To Drone Mapping Using Free and Open Source Software: By Piero Tofanin; ISBN-13: 978-1086027563 ISBN-10:1086027566; Independently

published (July 28, 2019); (Link: https://amzn.to/3iHpD4X

8. Building Smart Drone Using ESP 8266 And Arduino: By Sayad Omar Faruk Towah (Link:https://bit.ly/3iGc0mB)

Online Resources

1. https://www.researchgate.net/publication/330963224_TELEMETRY_SYSTEM_OF_U NMANNED_AERIAL_VEHICLES
2. https://www.researchgate.net/publication/311413814_Mechatronic_Design_of_Unmanned_Aircraft_Systems
3. https://www.researchgate.net/publication/281450302_Mechatronic_System_Modeling_and_Analysis_of_Quad_Rotor_UAV
4. https://www.simplexitypd.com/blog/how-mechatronics-improve-drone-technology
5. https://www.researchgate.net/publication/308749358_Role_of_Remote_Sensing_and_GIS_in_Agrometeorology

DFSRDA-AGDRO-104: Agri-DRONE Computing

THEORY

1. **Introduction to Drone Programming**: Introduction, Definition of Coding, Types of Coding, Programming Languages used in Programming, What is Programming, Logic in programming, Integrated Development Environment (IDE), Application Programming Interface (API), Programming a drone.
2. **Computing Methods**: Linear Regression, Logistic Regression, Decision Tree, Support Vector Machine, KNN (K- Nearest Neighbors), K-Means, Random forest, Machine Vision Methods viz: Classification, Object Detection, Object Tracking, Semantic Segmentation, Instance Segmentation, Vegetation Indices (VI's) calculation, Basic Machine learning methods, Neural networks, Convolutional Neural Network (CNN).
3. **Image Processing Techniques**: Definition of Image Processing, Types of Image Processing Involved in Agriculture, Image Acquisition, Image Registration, Image Enhancement, Image segmentation, Feature extraction and classification and Photogrammetry.
4. **Drone Parameter for computing**: UAV Technical Parameters, Mission, Parameters, Environmental Parameters, Further Parameters, Variables and Bounds. Constraints for Mision: Flight Area, Flight Dynamics, Waypoints, Restricted Airspaces, Collision Avoidance, Fuel Consumption. Linearizing the Model-Approximating Euclidean Norms by Combinations of Other Norms, Linear Constraints for Norm Approximations, Minimum Velocity. Computational Results-Analyzing the CPU Time Sensitivity, Number of Waypoints, Analyzing a Particular Solution.
5. **Flight Planning, Mission and Control Software's**: Architecture, Flight Computer, The Mission Payload Controller, Communication Infrastructure, Mission Control: Remote Execution, Data Streaming, Subsystem Grouping, Scouting and Planning
6. **Drone Mapping Software**: Pix4D, 3dr, Microdrones, mdCockpit, mdFlightSim, Bently, GlobalMapper, Agisoft Metashape and Drone Deploy. Remote sensing application software: ArcGIS, QGIS, ARDAS.

Text / Reference Books

1. "Exploring agricultural drones: The future of farming is precision agriculture, mapping, and spraying": (Link: https://bit.ly/2F46g8r).
2. "Exploring agricultural drones: The future of farming is precision agriculture, mapping, and spraying":(https://bit.ly/3nqwzY2)
3. "Unmanned Aerial Vechicle: Applications in Agriculture and Environment", By Avtar, Ram, ISBN Number: 978-3-030-27156-5 (Link: https:/bit.ly/3706Gsj)

DFSRDA-AGDRO-105: Agri-DRONE Maintenance

THEORY

1. **New Drone Set Up**: Preparation: Record Basic details; Parts Inspection: Unpack all Components, check all Components, Replace Broken or missing Components, Charge Batteries. Assembly: Read the Manual, Unfold Drone, Replace Missing or broken Components, Charge Batteries. Calibration: Calibrate Global Positioning System (GPS), Calibrate Compass, Calibrate Inertial Measurement Unit (IMU), Calibrate Return to Home (RTH), Check Storage Card is inserted. Testing: Perform Test Flight.
2. **Drone Pre & Post Flight**: Weather, Flight Details: Checklist of Record Basic Details, Purpose of flight, Describe alternative flight purpose, Check commercial drone license is valid, Check waiver for operational permission is valid, Check airspace authorization is valid. Batteries: Charge drone batteries, Charge controller batteries. Structural Check: Inspect all components for visible damage, Declare which components are in need of repair, Forward component repairs to maintenance, Clear obstructions and secure additional components. Calibration: Check and update firmware, Position antennas for signal strength, Check system instrument calibration, Calibrate compass, Calibrate Global Positioning System (GPS), Calibrate Inertial Measurement Unit (IMU), Calibrate RTH (Return to Home), Set maximum flight altitude. Pre-Launch: Position drone for launch, Check aircraft status LEDs, Reschedule flight date. Drone Post Flight Details: Record Flight Details; Disarming: Power Down Controller, Disconnect Controller Battery, Allow Controller Battery to Cool, Power Down Drone, Disconnect Drone Battery, Allow Drone Battery to Cool, Allow Motors to cool. Inspection: Inspect all components for visible damage, Wipe down Drone Unit. Storage: Prepare Drone for Next Mission, Remove and Secure Payload, Download or Transfer Data.
3. **Drone Troubleshooting**: Describe problems with drones. Equipment Check: Inspect all components for visible damage, Replace or Repair Damaged Components, Ensure all components are properly fitted and ensure all batteries are charged. System Reset: Power off drone, Power off control station, Remove Batteries, Reinsert Batteries, Power on Drone and Power on Control Station.
4. **Drone repair Maintenance report**: Preparation: Record Basic details, Declare Reports needed, Gather Tools, Check Spare Components. Safety: Review Safety Procedure; Repair: Service Chassis, Service Propellers, Service Motors, gimbal, indicator lights, screws, landing frame, batteries, compass, service GPS, service Electronic Speed Controller (ESC), Service Wiring, Camera.
5. **Routine Drone Maintenance**: Structural Inspection: Clean Chassis of Mud and Dirt, Inspect Chassis for Cracks, Check for loose screws, Check Propellers for damage, Check Propellers for free spinning, Check motors for debris and obstruction, Check state of wiring and soldier joints, Check unit camera is clean, Check landing gear condition Inspect antennae and Check control station for faulty components. Battery Check: Inspect charger for visible damage, Inspect battery packs for bulges or leakages, Charge all batteries. Software or Firmware: Update Drone Firmware, Update Control Station Software. Finishing Up: Forward Maintenance Report.
6. **Drone Testing & Compliance**: Equipment Check: Inspect all components for visible damage, Replace or repair damaged components, Check and Charge all batteries. Motors: Test Motors, Test Propellers. Camera: Test Gimbal, Test Camera. Navigation: Test Copass, Test GPS, Test IMU and Test RTH. Acquire Copies of local jurisdiction, Acquire Copies of State jurisdiction and Acquire

Copies of FAA jurisdiction. Pilot Certification: Check Remote Pilot Licensing Certificate. UAV Certification: Upload UAV Insurance Policy, Reconsider UAV Insurance Plan, Consider UAV Special Airworthiness Certificate, Find out Special Permission Certificate, Airspace Authorization Certificate. Training: Lookout for Training or retraining Necessary.
Text / Reference Books
1. Drone Maintenance And Repair: (Link: https://www.coptrz.com/drone-maintenance- and-repair-a-simple-guide/) 2. The Art of Drone Maintenance and Repair:(Link: https://bit.ly/30FhbgB) 3. Drone Post FlightChecklishttps://www.process.st/checklist/drone-post-flight-checklist/ **4.** EBOOK Introduction to Mechatronics and Measurement Systems 5e:By David G. Alciatore© 2018 | Published: June 17, 2018 (Link: https://bit.ly/371R9br)
Online Resources
1. https://www.process.st/checklist/uav-compliance-checklist/ 2. https://www.process.st/checklist/drone-troubleshooting-checklist/ 3. https://www.process.st/checklist/new-drone-setup-checklist/ 4. https://www.process.st/checklist/routine-drone-maintenance-checklist/ 5. https://www.process.st/checklist/drone-post-flight-checklist/ **6.** https://www.process.st/checklist/drone-repair-checklist/

DFSRDA -AGDRO-107P: Mini Project

Student shall prepare a working model of any Agricultural Drone. Computer / mathematical model or simulation is not acceptable. Student shall submit a detailed report with photograph of the model. A teacher shall be allotted for each batch and the workload shall be 2 hours / batch per week

DFSRDA -AGDRO-108P: Mechatronics Lab

List of Experiments:

1. Study of sensors and actuators
2. Study and Experiment on Solar Kit to test the solar panel efficiency.
3. Study of Industry 4.0 trainer Kit-1
4. Study of Industry 4.0 trainer Kit-2
5. Interpretation of Agricultural sensors, PLC and actuators hardware and programming
6. Automatic irrigation system based on soil moisture level
7. Testing of soil temperature and humidity
8. Experimentation on water level measurement
9. PLC based water pump operation for irrigation
10. Experimental study of pneumatically sorting station, conveyer belt and diversion mechanism.

DFSRDA-AGDRO- 109 P: Image Processing Lab

List of Experiments:

1. Experiment on Stereo Vision Camera
2. Experiment on Real Sense Cameras
3. Experiment on Zed 2 Camera
4. Experiment on CCD Camera
5. Experiment on Multi Spectral Camera
6. Experiment on Spectro-radiometer
7. Experimental Analysis on PIX 4D software
8. Experimental Analysis MAT Lab Software
9. Experimental Analysis on QGIS software.

DFSRDA - AGDRO -110P: Sensors, Actuators and PLC Lab

List of Experiments:

1. Study of Agricultural sensors and actuators
2. Study of Industrial sensors and actuators
3. Study of Basic pneumatic circuit for the working of single and double acting cylinder.
4. Study of Basic hydraulic circuit for the working of double acting cylinder and a hydraulic motor.
5. Study of Speed control circuits. Different Metering Methods Inlet & outlet flow control (meter-in & meter-out circuit)
6. Study of Circuits for the Use of different direction control valves and valve actuation in single and double acting cylinder, and multi-actuation circuit.
7. Study Hydraulic or Pneumatic Sequencing circuit.
8. Study of Electro Pneumatics circuit, based on the industrial application.
9. Study of Electro hydraulics circuit, based on the industrial application.
    (i) Write a PLC program to latch and unlatch an output by sealing.
    (ii) Write a PLC program to latch and unlatch an output with time delay.
10. Write/Draw a PLC program to operate 4 outputs simultaneously with time delay.
11. Write a PLC program for A motor is connected to PLC. Run this motor in the forward and reverse direction using ladder diagram programming language.

DFSRDA-AGDRO-201: Agri-DRONE in CDKS

THEORY

1. **Introduction to CDKS**: Climate change and its impact on Agriculture, Climate Smart Agriculture Technologies, Digital Farming Solutions.
2. **Introduction to drones and its applications in agriculture**: definition of drones, History of drones, India and drones, Do's and Don'ts, Classification of drones,
3. **Drones in Agriculture** - Regulations and good practice: Important definitions and nomenclature, Safety and a shift towards a risk-based approach, Airspace and its regulatory framework in India.
4. **Remote Sensing, UAV's and Applications**: Introduction to Remote Sensing, Aerial imaging techniques, GIS for agriculture, planning a mission and acquiring the data, from acquisition to visualization of data.
5. **Drone technology as a tool for improving agricultural productivity**: Mapping and monitoring agriculture fields, Soil mapping, seed planting, Spraying, Institutionalizing drone mapping applications for disaster risk management in agriculture.
6. **Introduction to IoT, Drone and AI based Agriculture Monitoring System**: Introduction to IoT; Climate Smart Agriculture Technologies, Introduction to Artificial Intelligence, Data management system in agriculture.

Text / Reference Books

1. ATL Drone Module: Get, Set, Fly NITI Aayog, New Delhi
2. Agricultural Drones: A Peaceful Pursuit K.R. Krishna, CRC Press
3. Unmanned Aerial Vehicle Systems in Crop Production: A Compendium K.R. Krishna, CRC Press
4. IoT Based Smart Agricultural Automation System LAP LAMBERT Academic Publishing
5. Push Button Agriculture: Robotics, Drones, Satellite-Guided Soil and Crop Management K.R. Krishna, CRC Press
6. Precision Farming From Above: How Commercial Drone Systems are Helping Farmers Improve Crop Management, Increase Crop Yields and Create More Profitable Farms. Louise Jupp, Writing Matter Publishers
7. E- Agriculture in Action: Drones for Agriculture, FAO, UN
8. Handbook of Agricultural Engineering, ICAR Publication, 6th edition
9. GIS Applications in Agriculture, Vol-2, David E. Clay CRC Press
10. Precision Farming B. L. Jana Agrotech publishing academy

DFSRDA-AGDRO-202: Agri-DRONE in SSPN

THEORY

1. **Seed, Seedling, Nursery**: Introduction; Definition, Scope and Importance, component, Selection of components seedling, Nursery preparation and development Techniques. Factor affecting on development Seed, Seedling, Nursery production: - Introduction, Climatic parameter, Soil parameter, Nutrients management, Quality Seed and Nursery Plant, Handling and transportation
2. **Seed Processing**:-Introduction, seed Production and technology Principal of Seed Processing seed, Pre-cleaning and Conditioning Equipment, Dimension Sizing Equipment, Separators, Seed Treating Equipment, Accessory Equipment, Material Handling, Storage, Transportation.
3. **Hightech polyhouse**:- Introduction, Components, Classifications, Design Specifications, Tools and Instrument used in Polyhouse, Disease and Pest Management in Hightech polyhouse, Irrigation system Heating systems, cooling system, Fertigation and Plant Bio Enhancers, Phototropic control, Control system, Media Preparation, Problem Management
4. **Agri-Drones**: Introduction; UAVs, MAVs classification of drones relevant to monitoring, Image sensing, .
5. **Drones in Agricultural and Nursery Management**: Land clearing, ploughing, riding, contouring; soil fertilizer and fertilizer scheduling.
6. **Drones in agricultural crop production practices**: Drones and crop scouting; seed planting and crop growth monitoring; drones in scouting for crop disease incidence and control; pest infestation and its control; irrigation and intercultural operations; weeds and weedicide application; crop yield forecasting.

Text / Reference Books

1. Handbook of Agricultural Engineering, ICAR Publication, 6th edition
2. Operations Management in Agriculture by Dionysis Bochtis, Claus Aage Gron Sorensen, Dimitrios Kateris; Academic Press: An Imprint of Elsevier
3. Push Button Agriculture by K. R. Krishna; CRC Press.
4. www.fao.org/3/w7365e04.htm#1.3 agricultural systems classification and order hierarchy
5. Agricultural Robotics: The Future of Robotic Agriculture
6. Robotics and automation for improving agriculture by John Billingsley; Burleigh Dodds Science Publishing
7. Unmanned Aerial Systems in crop production: A Compendium by K. R. Krishna; CRC Press

DFSRDA-AGDRO-203: Agri-DRONE in SPM

THEORY

1. **Introduction to farm production system and operations**: Evolution of Operations and System Management in Agriculture; Agricultural Operations; Management of Agricultural Operations; Energy Inputs and Outputs in Agricultural Operations.
2. **Introduction to farm machinery**: Introduction; Types of Farm Machinery; Choosing a Machinery System; Effectiveness and Efficiency of Agricultural Machinery; Cost calculation; Advances and Future Trends in Agricultural Machinery.
3. **Agri-Drones**: Introduction; classification of drones relevant to Agricultural production; Characteristics of the drones.
4. **Drones in Agricultural soil management practices**: Land clearing, ploughing, riding, contouring; soil fertilizer and fertilizer scheduling.
5. **Drones in agricultural crop production practices**: Drones and crop scouting; seed planting and crop growth monitoring; drones in scouting for crop disease incidence and control; pest infestation and its control; irrigation and intercultural operations; weeds and weedicide application; crop yield forecasting.
6. **Economics of Agri-drones**: Introduction; effect of drones on farm Size, Farm Labour requirement and Farm worker Migration; Regulations for use of drones in Agriculture.

Text / Reference Books

1. Handbook of Agricultural Engineering, ICAR Publication, 6th edition
2. Operations Management in Agriculture by Dionysis Bochtis, Claus Aage Gron Sorensen, Dimitrios Kateris; Academic Press: An Imprint of Elsevier
3. Push Button Agriculture by K. R. Krishna; CRC Press.
4. Unmanned Aerial Systems in crop production: A Compendium by K. R. Krishna; CRC Press
5. www.fao.org/3w7365e04.htm#1.3 agricultural systems classification and order hierarchy.
6. Agricultural Robotics: The Future of Robotic Agriculture
7. Robotics and automation for improving agriculture by John Billingsley; Burleigh Dodds Science Publishing.

DFSRDA-AGDRO-204: Agri-DRONE in FPA

THEORY

1. **Food Processing**: Introduction; Post Harvest and Food Processing Unit Operations; Material Handling, Packaging and Transportation; Novel Food processing techniques.
2. **Agricultural AGV in FPA**: Introduction; Current manufacturing procedures; Automation in food sector; Specification for a food sector AGV; Future trends; Conclusion.
3. **Agri-Drones**: Introduction; Classification; Characteristics of Agri-food drones.
4. **Drones for food industry**: Inspection: Leak detection and welding control, Cleaning Validation; Spraying of chemicals; Scouting drones for monitoring; Aerial Photography; Shipping and delivery of food material.
5. **Future trends**: Food delivery drones, Drone technology as a tool for improving food productivity, Drones-based sensor platforms.
6. **Applications**: Food industry surveillance, Drones to boost agricultural production and

   help maintain food security.

Text / Reference Books

1. Robotics and Automation in the Food Industry. Current and Future Technologies; Wood head Publishing Series in Food Science, Technology and Nutrition, (2013) Edited by Darwin G. Caldwell.
2. Food Processing Technology, Principles and Practice, Fourth Edition, By P.J. Fellows.
3. Unit Operations of Agricultural Processing, 2nd Edition, (2004) By Sahay K.M. & Singh K.K.
4. Agricultural Automations: Fundamentals and Practices, 1st Edition, (2013) By Qin Zhang and Francis J. Pierce; CRC Press.
5. Robotics and automation for improving agricultural By John Billingsley, Burleigh dodds, Science Publication (2019).

DFSRDA-AGDRO-207P: Major Project

The project work may conform to anyone of the below stated types of broad based work.

1. Detailed design of drone for any agriculture application system. This may comprise of sensors and various types of actuators to perform certain required function.
2. Detailed experimental / practical verification of Agricultural Drone systems.
3. Detailed study of the agricultural equipment/implement integrated with digital technology and artificial intelligence. This study may comprise of various aspects such as rapid prototyping, reverse engineering, Aerial robotic devices/vehicles and programming, data acquisition systems, plant layout, mechanical handling systems, assembly shop, quality control system, maintenance system, various service systems, design, development and planning functions, techno-economic studies etc., feasibility of small scale industry.
4. Software development for particular application / design / analysis etc.
5. Any other relevant area to agriculture.

Group of students shall be considered for the project work. Group of Student is expected to prepare a project report and shall present a seminar on it.

DFSRDA-AGDRO-208P: Agri-DRONE Hardware Lab

List of Experiments:

1. Study on Drone component identification and uses
2. Study on types of drones: Quadcopter, Hexa copter, Fixed Wing, Parachute drones
3. Study on types of drones: FPV Racer, DJI Phantom,
4. Study on types of drones: Spraying Drones
5. Study of drone applications: Spraying
6. Study of drone applications: Surveying and Mapping
7. Study on drone training software, simulation platform through remote control
8. Study of autonomous mission planning: remote control, mobile apps, calibration with GCP
9. Study on drone manufacturing process: 3 D Printer, CAE/CAM design

DFSRDA-AGDRO-209P: Agri-DRONE Software Lab

List of Experiments:

1. Study on introduction to drone operating system
2. Study on communication between drones and RC
3. Study of Telemetry and telegraphy of drones
4. Study of drone sensors and Camera
5. Study of multispectral cameras: Mica sense and Parrot
6. Study of basics of data capturing using drones
7. Experimental Study of Crop health monitoring using drones
8. Calculation of Vegetation indices (NDVI, VCI etc.) using drones
9. Hands on practical on PiX 4D software introduction tools
10. Drone data processing using PiX 4D software
11. Advanced features for crop scouting and mapping using drones

DFSRDA -AGDRO-210P: CAD/CAM/CAE Lab

List of Experiments:

1. Introduction to CAD software's
2. Performance on CAD software for 3D design modeling of agricultural equipment's
3. Introduction to CAM Software
4. Introduction to CAE software
5. Experiment of Structural Analysis
6. Experiment of Thermal Analysis
7. Experiment of Modal Analysis
8. Experiment of CFD Analysis
9. Experiment of Electromagnetic Analysis

DFSRDA-AGAGV: *FIRST SEMESTER* (COURSE STRUCTURE)

Course and Examination Scheme of Certificate course (DFSRDA-AGAGV)

Subject Code	Subject Name	Teaching Scheme			Examination Scheme								
		Hours per Week		No. of. Credits	Theory					Practical			
		Theory	Practical		Duration of Paper (Hrs.)	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min Passing Marks	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min Passing Marks
DFSRDA-AGAGV-101	Fundamentals of Agri-AGV	04	-	2	3 Hrs	80	100	20	100	40-	-	-	-
DFSRDA-AGAGV-102	CAD/CAM in Agri-AGV	04	-	2	3 Hrs	80	100	20	100	-	-	-	-
DFSRDA-AGAGV-103	Agri-AGV Mechatronics	04	-	2	3 Hrs	80	100	20	100	-	-	-	-
DFSRDA-AGAGV-104	Agri-AGV Computing	04	-	2	3 Hrs	80	100	20	100	-	-	-	-
DFSRDA-AGAGV-105	Agri-AGV Maintenance	04	-	2	3 Hrs	80	100	20	100	-	-	-	-
DFSRDA-AGAGV-107P	Mini Project	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGAGV-108P	Mechatronics Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGAGV-109P	Image Processing Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGAGV-110P	Sensors, Actuators and PLC Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25

DFSRDA-AGAGV: *SECOND SEMESTER* (COURSE STRUCTURE)

Course and Examination Scheme of Certificate course (DFSRDA-AGAGV)

Subject Code	Subject Name	Teaching Scheme			Examination Scheme								
		Hours per Week		No. of. Credits	Theory					Practical			
		Theory	Practical		Duration of Paper (Hrs.)	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min Passing Marks	Max. Marks University Assessment	Max. Marks Internal Assessment	Total Marks	Min Passing Marks
DFSRDA-AGAGV-201	Agri-AGV in CDKS	04	-	2	3 Hrs	80	20	100	40	40-	-	-	-
DFSRDA-AGAGV-202	Agri-AGV in SSPN	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGAGV-203	Agri-AGV in SPM	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGAGV-204	Agri-AGV in FPA	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGAGV-205	Elective-I	04	-	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGAGV-206	Elective-II	-	02	2	3 Hrs	80	20	100	40	-	-	-	-
DFSRDA-AGAGV-207P	Major Project	-	04	2	4 Hrs	-	-	-	-	50	50	50	50
DFSRDA-AGAGV-208P	Agri-AGV Hardware Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGAGV-209P	Agri-AGV Software Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25
DFSRDA-AGAGV-210P	CAD/CAM /CAE Lab	-	02	1	2 Hrs	-	-	-	-	25	25	50	25

DFSRDA- AGAGV-101: Fundamentals of Agri-AGV

THEORY

1. **Introduction**: Material Handling – Functions, Types, analysis, Importance & Scope, Principles, - Part feeding device – types of material handling system – Unit material movement & Unit loads – Receiving, Shipping, in process handling – bulk handling equipment & methods.
2. **Material Handling Equipment**: Industrial trucks, lifting device, monorails, manipulators, conveyors, storage systems, elevators, racks, bins, pallets, cranes – Automation of material handling – mechanization of part handling.
3. **Automated Guided Vehicle System**: Types of AGV's – Guidance techniques – Painted line, wire guided, vision guided method – Applications – Vehicle guidance & routing – Traffic control & safety – system management – Quantitative analysis of AGV system.
4. **Storage System Conveyor systems**: types, Quantitative relationship & analysis – Automated storage system, performance – AS/RS system – Basic components, types, controls, features, applications, Quantitative analysis – carousel storage system – applications.
5. **Robotics in Material Handling**: General considerations in robot material handling – material transfer application – pick & place operations – machine loading & unloading – characteristics of robot application.
6. Application Methods of protecting materials for packages - auxiliary equipment's **-automated**

Text / Reference Books

1. Principles and Techniques of Vibrations, Leonard Meirovich, Prentice Hall Inc.
2. Engineering Vibration, DJ Inman, Prentice Hall International Inc.
3. Mechanical Vibration and Shock Measurements, J. T. Broch, Bruel and Kjae Publication.
4. Applications of Random Vibrations, N. C. Nigam, S. Narayanan, Narosa Publishers
5. Reference book Introduction to a 7 Agri-2.0 smart precision agriculture, history of precision agriculture, application of digital technologies, introduction to IoT applications, smart irrigation, android applications in agriculture automation

DFSRDA-AGAGV-102: CAD/CAM/CAE in Agri-AGV

THEORY

1. Introduction to CAD, Criteria for selection of CAD workstations, Design Process, Geometric modeling, entities, 2D & 3D Primitives. Types of CAD file extension: Parasolid, IGES, STL, STEP. Capabilities of Modeling & Analysis Packages such as solid works, Unigraphics(NX), CREO, ANSYS.
2. 2D & 3D Feature Based Part Sketch, Modeling: Translation, Scaling, Rotation, Reflection and, concatenation. Boolean operations. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse, Cones. Layers concept. Synthetic curves – Cubic, Bezier, B-Spline, NURBS. Surfaces, Point, Plane, Ruled Surface, Surface of Revolution, Engineering Drafting, Conceptual Part Design, Assembly: Top & Down assembly. GD&T, Stack-up analysis.
3. Introduction of ANSYS, Basics of ANSYS workbench, Introduction to FEA, Engineering data, Material Properties, Basics of Meshing, named selection, meshing methods, element types, Boundary conditions setup, Cell zones – fluid/solid, General guidelines, Different boundary conditions.
4. Study solver and types of solver methods. Types of Analysis: Structural Analysis, Modal Analysis, Thermal analysis, Thermal-electric analysis, Natural Frequencies.
5. Introductions to Fluid flow, Basics of CFD Analysis, Fluent, Electromagnetic analysis, Post processing methods, Report preparation. Design Optimization.
6. Introduction to CAM: Basics of additive manufacturing, File Formats, Model Repair and Validation, Pre & Post-processing, Multiple Materials, Material Selection, and types of materials, Hybrids, Composite Materials current and future directions. Process & FDM, SLA, PLA methods, Prototyping fundamentals, Data Conversion, and transmission, Checking and preparing, Building, Post processing.

Text / Reference Books

1. CAD/CAM: Computer-Aided Design and Manufacturing by M Groover and E. Zimmers, Pearson Education, 1983.
2. CAD/CAM in Practice by A J Medland, Springer science and media, 2012.
3. CAD/CAM Theory and Practice Ibrahim Zeid, McGraw-Hill, 1991
4. Computer Aided Manufacturing by P N Rao, Publisher: McGraw Hill Education (1 July 2017)

DFSRDA-AGAGV-103: Agri-AGV Mechatronics

THEORY

1. **Sensors:** Principles and classification of transducers, guidelines for selection and application of transducers, basic requirements of transducers. Different types of transducers, displacement, strain gauge, LVDT, potentiometer, capacitive & inductive, Piezoelectric, temperature, optical, Hall effect transducers.
2. **Measurement of parameter:** Measurement of length, angle, area, temperature, pressure flow, speed force, torque, vibration, level, concentration (conductivity and ph.) measurement- sensors in robotics-tactile sensors-proximity and range sensors- miscellaneous sensors and sensor based systems-use of sensors in robotics.
3. **Fundamentals of Electric drives** - Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, nature and classification of load torque, equivalent moment of inertia, modes of operation.
4. **Control** Speed control and drive classification, closed loop control, current limit control, speed control, position control, torque control, PLL control, multi-motor drive control, digital control. DC motor control, speed control, position control, proportional control, PID controllers. **Control system modeling:** System concept, differential equations and transfer functions. Modeling of electric systems, translational and rotational mechanical systems, and Simple electromechanical systems. Practical controllers - Introduction to P, PI and PID controllers.
5. **Pneumatic Drives:** Merits of Fluid power & its utility for increasing productivity through Low Cost Automation, Transmission of Fluid Power through various types of Cylinders), Symbolic representation of Pneumatic elements (CETOP), Compressors and Air supply system including airline installations, signaling & control system. Pneumatic control elements (control valves & remote control system), Basic pneumatic circuits for controlling single & double acting cylinder, Basic pneumatic circuits, Advanced pneumatic circuits for controlling multi-cylinders (operable). Advanced pneumatic circuits for controlling multi-cylinders (inoperable circuits), Electro pneumatics with relay logic, and Pneumatics system with PID controls, Application of fluidics a non-moving part logic.
6. **PLC:** Evolution of PLC's - Sequential and programmable controllers - Architecture- Programming of PLC - Relay logic - Ladder logic - Gates, Flip flops and Timers. **Communication in PLC's:** Requirement of communication networks of PLC - connecting PLC to computer -Interlocks and alarms - Case study of Tank level control system and Sequential switching of motors.
7. **Block diagram representation of systems** – Block diagram reduction methods – Closed loop transfer function, determination of signal flow graph. Mason's gain formula – Examples. Time domain analysis: Test signals- time response of first order and second order systems- time domain specifications-types and order of systems- generalized error coefficient-steady state errors- concepts of stability-root locus. Frequency domain analysis: Introduction – correlation between time and frequency response – stability analysis using Bode plots,

Polar plots. Compensators: Realization of basic compensators – cascade compensation in time domain and frequency domain and feedback compensation – design of lag, lead, lag-lead compensator using Bode plot and Root locus.

Text / Reference Books

1. W. Shepherd, and L. N. Hully, “Power Electronics and Motor control”, (2e), Cambridge University, 1995.
2. Gopal K. Dubbey,“Fundamentals of Electric Drives”, (2e), Narosa Publishers, 2001.
3. R. Krishnan, “Electric Motor Drives Modeling, Analysis, and Control”, (2e), Prentice Hall, 2001
4. Anthony Esposito, “Fluid power with applications”, Pearson Education, 2003.
5. Sadhu Singh. "Computer Aided Design and Manufacturing", Khanna Publishers, New Delhi, 1998
6. Applied Nonlinear Control, by Slotine and Li, Prentice-Hall, 1991, ISBN 0-13-040890-5.
7. Ogata, K., Modern Control Engineering, Prentice-Hall, [2002]
8. Gibson, J. E., Nonlinear AutomaticControl, McGraw-Hill, [1963]
9. Khalil, Hasan K., Nonlinear Systems, Macmillan Publishing, [1992]

DFSRDA-AGAGV-104: Agri-AGV Computing

THEORY

1. **Image acquisition:** Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.
2. **Image analysis :** image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, discrete cosine transform to images, image scaling, standard video formats.
3. **3D vision:** Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2D and 3D geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods,
4. **Stereo vision:** Epipolar geometry, triangulation**,** rotational matrix, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3d reconstruction.
5. **Motion estimation and tracking:** Optical flow estimation, object tracking with Kalman filtering, feature extraction & object recognition.
6. **Introduction to programming languages:** C, C++, Python programming, Robotic Operating Programing (ROS), raspberry pi, Arduino
7. **Case studies/application:** Face recognition, vehicle tracking, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

Text / Reference Books

1. Milan Sonka, Vaclav Hlavac, Roger Boyle, Image Processing, Analysis and Machine Vision", (2/e), 1998.
2. Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, (2/e), Pearson education, 2003.
3. Boguslaw Cyganek & J. Paul Siebert, An Introduction to 3D Computer Vision Techniques and Algorithms, Wiley, 2009.
4. E.R. Davies, Royal Holloway, Machine Vision: Theory, Algorithms and Practicalities, (3/e), University of London, December 2004.

   R. Jain, R. Kasturi, B. G. Schunck, Machine Vision, McGraw-Hill, New York, 1995

DFSRDA-AGAGV-105: Agri-AGV Safety & Maintenance

THEORY

1. **Introduction to Maintenance System:** Basic concept of industrial safety management. Definition, Scope, Objective, functions and Importance of maintenance system, Type of maintenance system, break down maintenance system, Preventive maintenance, Predictive maintenance, design out maintenance, corrective maintenance, planned maintenance, total productive maintenance, condition monitoring. Problems on selection of methods like preventive or breakdown maintenance.
2. **Electrical safety:** Safe limits of amperages, voltages, distance from lines, etc., Joints and connections, Overload and Short circuit protection, earthing standards and earth fault protection, Protection against voltage fluctuations, Effects of shock on human body Hazards from Borrowed neutrals, Electrical equipment in hazardous atmosphere, Criteria in their selection, installation, maintenance and use, Control of hazards due to static electricity.
3. **maintenance policies – preventive maintenance**
   Maintenance categories – Comparative merits of each category – Preventive maintenance, maintenance schedules, repair cycle - Principles and methods of lubrication.
4. **General safety consideration in material handling**: Ropes, Chains, Sling, Hoops, Clamps, Arresting gears, Prime movers. Ergonomic consideration in material handling, design, installation, operation and maintenance of Conveying equipment, hoisting, traveling and slewing mechanisms.
5. **Repair methods for material handling equipment**
   Repair methods for Material handling equipment - Equipment records –Job order systems -Use of computers in maintenance.
6. **Quality Control and Safety Standards:** Quality objectives, Quality control, Quality Assurance – Process variability, ISO 9000 and TQM concepts, **Quality management:** Quality circles, tools, Zero defect management, 6 sigma–Quality Function Deployment (QFD). The Components and benefits of safety management system. Occupational Health and Safety Management Systems Occupational Health and Safety Management Systems (OHSAS) 18001.
7. **Principles and practices of maintenance planning**
   Basic Principles of maintenance planning – Objectives and principles of planned maintenance activity – Importance and benefits of sound Maintenance systems – Reliability and machine availability – MTBF, MTTR and MWT – Factors of availability – Maintenance organization – Maintenance economics.

Text / Reference Books

1. Mishra R C and Pathak K, “Maintenance Engineering and Management”, Prentice Hall of India, 2002.
2. Srivastava S.K.,“Industrial Maintenance Management”, - S. Chand and Co.,

1981
3. hattacharya S.N.,“Installation, Servicing and Maintenance”, S.Chand and Co., 1995
4. Bhattacharya S.N., “Installation, Servicing and Maintenance”, S. Chand and Co., 1995
5. Mishra R C and Pathak K, “Maintenance Engineering and Management”, Prentice Hall of India, 2002.
6. White E.N., “Maintenance Planning”, I Documentation, Gower Press, 1979.
7. Garg M.R., “Industrial Maintenance”, S. Chand & Co., 1986.
8. Higgins L, “Maintenance Engineering Hand book”, Mc Graw Hill, 6th edition, 2003
9. Morrow L.C, “Maintenance Engineering Hand book”, Mc Graw Hill, Latest Edition

DFSRDA -AGAGV-107P: Mini Project

Student shall prepare a working model of AGV. Prepare a CAD model with CAE analysis report. Student shall submit a report with images of the model. A Guide shall be allotted for each batch and the workload shall be 2 hour / batch per week.

DFSRDA -AGAGV-108P: Practical on Hydraulic and Pneumatic application in AGV

List of Experiments :

1. Study of Basic pneumatic circuit for the working of single and double acting cylinder in AGV.
2. Study of Basic hydraulic circuit design for the working of double acting cylinder in AGV.
3. Study of Circuits for the Use of different direction control valves and valve actuation in single and double acting cylinder, solenoid and multi-actuation circuit.
4. Study electro-mechanical circuit design based on the agriculture application.
5. Study of Electro Pneumatics circuit, based on the agriculture application.
6. Study of Electro hydraulics circuit design, based on the agriculture application.
7. Write a PLC program to latch and unlatch an output by sealing.
8. Write a PLC program to latch and unlatch an output with time delay.
9. Write/Draw a PLC program to operate 4 outputs simultaneously with time delay.
10. Experimental study of pneumatically sorting station, conveyer belt and diversion mechanism.

DFSRDA-AGAGV- 109P: Practical on integration & Image Processing

List of Experiments :

1. Experiment on AGV Design assembly, testing and system integration analysis.
2. Experiment on Stereo Vision Camera & integration with AGV operations.
3. Experiment on Real Sense Cameras & integration with AGV operations.
4. Experiment on ZED 2 Camera & integration with AGV operations.
5. Experiment on Multi Spectral Camera & integration with AGV operations.
6. Experiment on Spectro-radiometer & integration with AGV operations.
7. Experimental Analysis on PIX 4D software & integration with AGV operations.1
8. Experimental Analysis python Programme Software & integration with AGV operations.

DFSRDA -AGAGV-110P: Mechatronics (Sensors, Actuators and Controllers)

List of Experiments :

1. Study of Agricultural sensors and actuators for AGV.
2. Study of Industrial sensors and actuators for AGV
3. Study and Experiment on Solar Kit to test the solar panel efficiency on AGV application.
4. Study of Industry 4.0 trainer Kit-1 on AGV application.
5. Study of Industry 4.0 trainer Kit-2 on AGV application.
6. Interpretation of Agricultural sensors, PLC and actuators hardware and programming on AGV application.
7. Automatic irrigation system based on soil moisture level on AGV application.
8. Testing of soil temperature and humidity on AGV application.

DFSRDA-AGAGV-201: Agri-AGV in CDKS

THEORY

1. **Introduction to CDKS**: Climate change and its impact on Agriculture, Climate Smart Agriculture Technologies, Digital Farming Solutions.
2. **Introduction to AGV's**: Definition, Types of AGV's, System Component, Application of AGV's in Agriculture
3. **Introduction to Precision Agriculture Technologies:** Importance of Precision Agri- culture and mapping in farming for decision making, Benefits of PA, Economic of precision agriculture & determining equipment and software
4. **Introduction to Protected Cultivation:** Greenhouse Introduction, Types of Greenhouse, Greenhouse Environment, Crops management in greenhouse, equipment needed, Greenhouse automation
5. **AGV's in Land and soil management**: Climate resilient soil management technologies, Use of AGV's in soil and land management, Working examples
6. **AGV's application in Field Crops**: Vegetables and other field crops scouting using AGV's, Crop monitoring, vegetable spraying applications
7. **AGV's application in Protected Cultivation**: Greenhouse crop monitoring using AGV's, weed management in greenhouse using AGV's, spraying applications, harvesting of vegetables and flowers using AGV's

Text / Reference Books

1. Precision Farming B.L. Jana Agrotech publishing academy
2. Push Button Agriculture: Robotics, Drones, Satellite-Guided Soil and Crop Management K.R. Krishna, CRC Press
3. Operations Management in Agriculture by Dionysis Bochtis, Claus Aage Gron Sorensen, Dimitrios Kateris; Academic Press: An Imprint of Elsevier.
4. Handbook of Agricultural Engineering, ICAR Publication, 6th edition
5. www.fao.org/3/w7365e04.htm#1.3 agricultural systems classification and order hierarchy

DFSRDA-AGAGV-202: Agri-AGV in SSPN

THEORY

1. **AGV:** Agriculture Automation Introduction, Agriculture Automation systems sensor, Controllers Actuator, Regulators and servos
2. **Agricultural AGV**: Introduction; Overview of a Robot Farming System, Autonomous Navigation Control; Future trends; Conclusion.
3. **Agriculture Robot Vehicles or AGV's**: Introduction; Wheel type Robots Tractor, Crawler Type Robot Tractor, Orchid Type AGV
4. **Next Generation of Autonomous Field AGV's:** Introduction, Component and their Functions, Types of AGV's and their Utility,
5. **Sensor mounting on AGV's and their utility in SSPN:** Introduction of Sensor, Different types of sensor used in SSPN, Application.
6. **AGVs and automation in transportation and material handling:** Introduction; Principles, Types of transportation and material handlings; (Case study: AGVs Roll into Food and Bev Plants) Future trends; Conclusion.

Text / Reference Books

1. Unit Operations of Agricultural Processing, 2nd Edition, (2004) By Sahay K.M. & Singh K.K.
2. Agricultural Automations: Fundamentals and Practices, 1st Edition, (2013) By Qin Zhang and Francis J. Pierce; CRC Press.
3. Robotics and automation for improving agricultural By John Billingsley, Burleigh dodds, Science Publication (2019).

DFSRDA-AGAGV-203: Agri-AGV in SPM

THEORY

1. **Introduction to farm production system and operations:** Evolution of Operations and System Management in Agriculture; Agricultural Operations; Management of Agricultural Operations; Energy Inputs and Outputs in Agricultural Operations.
2. **Introduction to farm machinery:** Introduction; Types of Farm Machinery; Choosing a Machinery System; Effectiveness and Efficiency of Agricultural Machinery; Cost calculation; Advances and Future Trends in Agricultural Machinery.
3. **Agricultural Vehicle Robot/ Agri-AGVs:** Introduction, Navigation Sensors and Autonomous Navigation control, Autonomous Vehicle guidance, Wheel type robot tractor, Crawler Type robot tractor, current trends- unmanned field machinery; First generation unmanned machines; next generation of autonomous field machinery.
4. **Agri-AGVs in land development and soil related activities**: Introduction; Objectives of land development; Principle of operation; advanced machines/ AGVs for land development operation, (Ploughing, Zero tillage system), Automation in soil analysis and soil fertility mapping.
5. **Agri-AGVs in sowing and planting**: Introduction; Objectives of Sowing/Planting; Principle of operation; Advanced Machines/Robots/AGVs for Sowing or Planting of Crops, vegetables and Orchards (Robots and potted plants in greenhouses, Harvey); Rice transplanting Robot/AGVs
6. **Agri-AGVs in intercultural, plant protection and allied activities:** Introduction; Objectives of Intercultural operation; Principle of operation; advanced machines/ Robots for weeding, precision spraying, challenges in current robotic sprayers, Satellite Guided weed detection and eradication.
7. **Agri-AGVs in harvesting:** Introduction; Objectives of harvesting operation; Principle of operation; Classification of mechanical harvesters, advanced machines/ AGVs for harvesting, field crop harvesting, Cotton Harvesting, Mechanical Mass harvesting of fruits, Nuts and vegetables.
8. **Economics of Agri-**AGVs: Agricultural Robots and their influence on Human Farm Labour, Agricultural automation and economic aspects of farming.

Text / Reference Books

1. Handbook of Agricultural Engineering, ICAR Publication, 6th edition
2. Operations Management in Agriculture by Dionysis Bochtis, Claus Aage Gron Sorensen, Dimitrios Kateris; Academic Press: An Imprint of Elsevier
3. Push Button Agriculture by K. R. Krishna; CRC Press.
4. Agricultural Automation: Fundamentals and Practices by Qin Zhang and Francis J Pierce; CRC Press.
5. www.fao.org/3/w7365e04.htm#1.3 agricultural systems classification and order hierarchy
6. Agricultural Robotics: The Future of Robotic Agriculture
7. Robotics and automation for improving agriculture by John Billingsley; Burleigh Dodds Science Publishing.

DFSRDA-AGAGV-204: Agri-AGV in FPA

THEORY

1. **Food Processing:** Introduction; Post Harvest and Food Processing Unit Operations; Material Handling, Packaging and Transportation; Novel Food processing techniques.
2. **Agricultural AGV in FPA**: Introduction; Current manufacturing procedures; Automation in food sector; Specification for a food sector AGV; Future trends; Conclusion.
3. **AGVs and automation in the fresh produce**: Introduction; Machine vision system as a key technology; Vegetable preprocessing and grading systems; Information flow for food traceability and farming guidance; Future trends; Conclusion.
4. **AGVs and automation in Unit Operations Food Processing:** Introduction; Types of unit operations and machines; Working principle, Automation in primary food processing operations in different food industries; (Case study: In field grading of harvested crops) Future trends; Conclusion.
5. **AGVs and automation for packaging**: Introduction; Principles; Types of packaging; Automation in packaging of different agricultural fresh produce and food products; Case study of a reconfigurable system for carton folding; Future trends; Conclusion.
6. **AGVs and automation in transportation and material handling:** Introduction; Principles, Types of transportation and material handlings; (Case study: AGVs Roll into Food and Bev Plants) Future trends; Conclusion.
7. **Automation for a sustainable food industry: computer aided analysis and control engineering methods:** Introduction; Definition of sustainability and links with the food industry; Automation and sustainability in food manufacturing; Tools for automated sustainable design and operation in food engineering; Advanced tools and methods for sustainable food engineering with potential applications; Software technologies for automated sustainable design; Conclusion and future trends; Sources of further information and advice.

Text / Reference Books

1. Robotics and Automation in the Food Industry. Current and Future Technologies; Woodhead Publishing Series in Food Science, Technology and Nutrition, (2013) Edited by Darwin G. Caldwell.
2. Food Processing Technology, Principles and Practice, Fourth Edition, By **P.J. Fellows.**
3. Unit Operations of Agricultural Processing, 2nd Edition, (2004) By Sahay **K.M. & Singh K.K.**
4. Agricultural Automations: Fundamentals and Practices, 1st Edition, (2013) By Qin Zhang and Francis J. Pierce; CRC Press.
5. Robotics and automation for improving agricultural By John Billingsley, Burleigh dodds, Science Publication (2019).

DFSRDA-AGAGV-207P: Major Project

The project work may conform to anyone of the below stated types of broad based work.

1. Detailed design of Agricultural AGV system. This may integration of machines, hydraulics/ pneumatic system, design of some small industrial product developments.
2. Detailed experimental / practical verification of Agricultural AGV system.
3. Detailed study of Agricultural AGV system by incorporating with digital technologies and Artificial Intelligence. This study may integration of various aspects such as rapid prototyping, reverse engineering, Agricultural AGV system and programming, data acquisition systems, plant layout, mechanical handling systems, assembly, testing, quality control system, trouble shooting, schedule maintenance, planning functions, techno-economic studies etc., feasibility of small scale industry.
4. Software programming development for particular applications requirements, operations etc.
5. Any other relevant area to agriculture AGVs.

   Group of students (max 4 members) shall be considered for the project work. Group of Student is expected to prepare a project report and shall present a seminar on it.

DFSRDA-AGAGV-208P: Agri-AGV hardware Lab

List of Experiments :

1. Experiment on primary raw material identification and preparation for AGV.
2. Experiment on fabrication and testing of AGV
3. Experiment on welding of AGV components
4. Experiment on AGV
5. Experiment on AGV Jackal J 100
6. Experiment on AGV Husky A200
7. Experimental study of innovative AGV applications
8. Experimental study of AGV application in Horticulture.
9. Experimental study of AGV application in nursery.
10. Experimental Study of AGV application for inter-culture operations.

DFSRDA -AGAGV-209P: Practical on Agri-AGV software lab

List of Experiments :

1. Introduction to C language & python programming.
2. Prepare a python Programme for plant type recognition.
3. Prepare a python Programme for disease recognition.
4. Prepare a python Programme for fruits recognition.
5. Prepare a python Programme for weed recognition.
6. Prepare a python Programme for AGV operations.
7. Prepare a python Programme for colour based cotton boll picking operation.
8. Prepare a python Programme for selective spraying.
9. Prepare a python Programme for multipurpose AGV applications operations.
10. Prepare a python Programme for disease recognition auto selective spraying.

DFSRDA -AGAGV-210P: Practical on CAD/CAM/CAE

List of Experiments :

1. Introduction to CAD software's
2. Application of CAD/CAE software tool for 3D design & development of agricultural AGV's
3. Introduction to Additive manufacturing Software (3D printer).
4. Introduction to CAE software
5. Experiment of Structural Analysis of AGV
6. Experiment of Thermal Analysis of AGV
7. Experiment of Modal Analysis of AGV
8. Experiment of CFD Analysis of AGV
9. Experiment of Electromagnetic Analysis of AGV
10. Experiment of 3D printing of AGV components.

1. PRODUCT DESIGN AND DEVELOPMENT

THEORY

Unit I: Introduction- Significance of product design, product design and development process, sequential engineering design method, the challenges of product development, Estimation and costing.

Unit II: Product Planning and Project Selection- Identifying opportunities evaluate and prioritize projects, allocation of resources Identifying Customer Needs: Interpret raw data in terms of customers need, organize needs in hierarchy and establish the relative importance of needs.

Unit III: Product Specifications- Establish target specifications, setting final specifications, Concept Generation: Activities of concept generation, clarifying problem, search both internally and externally, explore the output.

Unit IV: Industrial Design-Assessing need for industrial design, industrial design process, management, assessing quality of industrial design, Concept Selection: Overview, concept screening and concept scoring, methods of selection, Ergonomics.

Unit V: Theory of inventive problem solving (TRIZ)- Fundamentals, methods and techniques,

General Theory of Innovation and TRIZ, Value engineering Applications in Product development and design, Model-based technology for generating innovative ideas.

Unit VI: Concept Testing- Elements of testing: qualitative and quantitative methods including survey, measurement of customers' response. Intellectual Property- Elements and outline, patenting procedures, claim procedure, Design for Environment- Impact, regulations from government, ISO system.

Text / Reference Books

1. Ulrich K. T, and Eppinger S.D, Product Design and Development, Tata McGraw Hill
2. Otto K, and Wood K, Product Design, Pearson
3. Engineering of creativity: introduction to TRIZ methodology of inventive Problem Solving, By Semyon D. Savransky, CRC Press.
4. Inventive thinking through TRIZ: a practical guide, By Michael A. Orloff, Springer
5. Systematic innovation: an introduction to TRIZ ; (theory of inventive Problem Solving), By John Terninko, Alla Zusman, CRC Press.

2. TRIBOLOGY FOR DESIGN

THEORY

Unit I: Introduction-Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket - Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining Bearing, Terminology - Sliding contact bearings -Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings.

Unit II: Friction and Wear-Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention.

Unit III: Lubrication of Bearings-Mechanics of Fluid Flow - Theory of hydrodynamic lubrication -Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing-Somerfield number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise-Length to diameter ratio - Radial clearance - Minimum oil-film thickness.

Unit IV: Hydrodynamic Thrust Bearing-Introduction - Flat plate thrust bearing - Tilting pad thrust bearing, Pressure Equation - Flat plate thrust bearing - Tilting pad thrust bearing, Load - Flat plate thrust bearing - Tilting pad thrust bearing, Center of Pressure - Flat plate thrust bearing - Tilting pad thrust bearing, Friction - Flat plate thrust bearing - Tilting pad thrust bearing

Unit V: Hydrostatic and Squeeze Film Lubrication-Hydrostatic Lubrication - Basic concept - Advantages and limitations - Viscous flow through rectangular slot – Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications.

Unit VI: Elasto-Hydrodynamic Lubrication-Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings.

Unit VII: Gas (Air) Lubricated Bearings-Introduction, Merits, Demerits and Applications, Tilting pad bearings, Magnetic recording, discs with flying head, Hydrostatic bearings with air lubrication, Hydrodynamic bearings with air lubrication, Thrust bearings with air lubrication.

Unit VIII: Tribological Aspects of Rolling Motion-The mechanics of tyre-road interactions, Road grip and rolling resistance, Tribological aspects of wheel on rail contact. Finite Bearings-Hydrostatic bearings, Hydrodynamic bearings, Thrust oil bearings, Porous Bearings, Foil bearings, Heat in bearings.

Text / Reference Books

1. Harnoy , Bearing Design in Machinery, Marcel Dekker Inc, NewYork, 2003.
2. M. M. Khonsari & E. R. Booser, Applied Tribology, John Willey &Sons, New York, 2001.
3. E.P.Bowden and Tabor.D., Friction and Lubrication, Heinemann Educational Books Ltd., 1974.
4. A.Cameron, Basic Lubrication theory, Longman, U.K.., 1981.
5. M.J.Neale (Editor),Tribology Handbook , Newnes. Butter worth, Heinemann, U.K., 1995.

3. ADVANCED MATERIALS AND PROCESSING

THEORY

Unit I: Introduction of advanced materials and its manufacturing processes for engineering applications.
Piezoelectric materials (PZT)- Piezoelectric effect, Di-electric hysteresis, piezoelectric constants, piezoelectric charge constants, dynamic behavior of PZT transducers, piezoelectric materials and manufacturing techniques (stability, poling and depolarization).

Unit II: Shape memory alloys (SMA)- Shape memory effect and the metallurgical phenomenon of SMA, Temperature assisted shape memory effect, Visco-elastic behavior, magnetic shape memory effect. Various shape memory alloys. Manufacturing technology of SMAs.

Unit III: Electro rheological (ER) and magneto-rheological (MR) materials- Characteristics of ER and EM fluids. ER and EM materials.

Unit IV: Composite materials- Design and manufacturing of polymer matrix, metal matrix and ceramic matrix composites. Various forms and type of reinforcements, fillers and additives. Design of composites for structural, wear resistance and high temperature applications.

Unit V: Micro-electro-mechanical (MEMS) systems- Introduction, characteristics of silicon wafers and other materials for MEMS applications. Various manufacturing techniques of MEMS components Materials for high temperature applications - Ni-Cr alloys, ODS materials, Ni base and Co based super alloys, carbon-carbon composites.

Unit VI: Powder metallurgy- Introduction and feature of powder metallurgy processes. Advanced solidification techniques: directional solidification, single crystal growth and levitation melting.

Unit VII: Advanced Material processing techniques- Thermal spraying, Ion beam machining, Laser and Electron beam processing, Friction Stir Welding, Special alloys machining, Superplastic forming, Flow forming, Explosive forming, Thin films and their deposition, Diamond coating techniques-tribological applications, Diffusion bond coating of high temperature materials.

Text / Reference Books

1. Gandhi, M.V. and Thompson, B.S., Smart materials & Structures, Chapman & Hall, 1992.
2. Otsuka, K. and Wayman, C. M., Shape memory materials, C.U.P, 1998
3. Taylor, W., Pizoelectricity, George Gorden and Breach Sc. Pub., 1985
4. Mallick, P.K., Fiber Reinforced Composites Materials, Manufacturing and Design Marcel Dekker Inc, New York, 1993.
5. William D Callister: Materials Science and Engineering: An Introduction, 6th Edition, Wiley Publication.
6. S. Kalpakjian and S. Schmid: Manufacturing Engineering and Technology, 4th Edition,
7. Pearson Education.
8. M. P. Grover: Fundamentals of Modern Manufacturing: Materials, Processes & Systems , Prentice Hall.

4. DESIGN FOR MANUFACTURABILITY

THEORY

Unit I: Manufacturing Considerations in Design- Design for manufacture, Tolerance and tolerancing analysis. Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components. Finishing, surface coatings and surface modifications of materials.

Unit II: Engineering Design- Design of cast, forged sheet metal parts and welded constructions. Design for assembly and dismantling, modular constructions. Erection, operation, inspection and maintenance considerations, Costing and Ergonomics.

Unit III: Machining considerations- Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment. Examples illustrating the various principles. Available design variants for some of the common basic functional requirements.

Text / Reference Books

1. Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.
2. Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.
3. Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
4. Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5. Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7. Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.

5. DESIGN OPTIMIZATION

THEORY

Unit I: Introduction-Design Characteristics of Mechanical Elements - Adequate and Optimum design - Principles of optimization - Conventional Vs Optimal design process - Design variables - Formulation of objective function – Design constraints - Variable bounds - Classification of Engineering optimization problem.

Unit II: Single Variable Optimization Techniques-Optimality Criteria - Bracketing Methods - Exhaustive search method - Bounding phase method – Region Elimination Methods - Interval halving method - Fibonacci search method - Golden section search method - Gradient based Methods - Newton - Raphson method - Bisection method - Secant method - Cubic search method.

Unit III: Multi Variable and Constrained Optimization Techniques-Optimality criteria - Direct search Method - Simplex search methods - Hooke-Jeeve's pattern search method - Powell's conjugate direction method - Gradient based method - Cauchy's method - Newton's method - Conjugate gradient method. Kuhn - Tucker conditions - Penalty Function - Concept of Lagrangian multiplier - Complex search method - Random search method

Unit IV: Intelligent Optimization Techniques-Introduction to Intelligent Optimization - Soft Computing - Working principles of Genetic Algorithm Types of reproduction operators, crossover & mutation, - Simulated Annealing Algorithm - Particle Swarm Optimization (PSO) - Graph Grammar Approach - Example Problems

Unit V: Engineering Applications-Structural applications - Design of simple truss members. Design applications - Optimum design of simple axial, transverse loaded members - Optimum design of shafts - Optimum design of springs. Dynamic applications - Optimum design of single, two degree of freedom systems and gear vibration absorbers. Mechanisms applications- Optimum design of simple linkage mechanisms

Text / Reference Books

1. Jasbir S Arora, *Introduction to Optimum design,* Mechrawhill International, 2011.
2. S. S.Rao, *Engineering Optimization: Theory and Practice*, Wiley- Inter-science, 2008.
3. K. Deb, *Optimization for Engineering design algorithms and Examples*, Prentice Hall of India Pvt. 2005.
4. C.J. Ray, *Optimum Design of Mechanical Elements,* Wiley, John & Sons, 2007.
5. R. Saravanan, *Manufacturing optimization through intelligent techniques*, Taylor & Francis Publications.

6. GEO-INFORMATICS IN AGRI-DRONE NAVIGATION

THEORY

Objectives

The Post Graduate Certificate in Geo-informatics Programme is proposed with the following objectives:

1. To provide conceptual knowledge and hands-on training in the basics of geoinformatics technologies.
2. To acquaint the learners with the use of technology in analyzing the spatial data.
3. To acquaint the learners with the use of technology and applications in irrigation, drainage, Agricultural farm management.
4. To promote and to dissipate the application of Agri-drone based Navigation system techniques in Precision Agriculture.
5. To widen opportunities of learners for study and developing a career in different Agricultural sectors of employment involving fields related to geoinformatics.

This course introduces two important components of geoinformatics i.e. Drone (UAV) based GNSS and the GIS. GNSS have become essential part of all applications where mobility plays an important role such as in transportation systems i.e., navigation and aviation, weather forecasting, environment management, natural resource management etc. Drone (UAV) based GNSS Technology has not only enhanced the ease and flexibility of spatial data acquisition but has also diversified the approaches.

Part 1: Introduction to Geoinformatics

Introduction of the basic concepts of geospatial data and data processing tools. in order to understanding of basic concepts of geospatial data, sources of data, data products and formats and data analysis tools. Deals with the basics of maps, mapping, interpretation of topographical maps and also with how to choose a suitable map projection.

Part 2: Application of Geoinformatics in Agriculture

An overview of the scope and applications of geoinformatics in different fields of Agriculture such as natural resources studies and management, land use and planning, climate, agriculture, crop health, environment and disaster related studies.

Part 3: Remote Sensing and Image Interpretation

Remote sensing, defined as a science and art of acquiring information about Earth materials without coming in direct contact with them is carried out with the help of cameras/ sensors mounted in the drone, UAV, aircrafts or satellites.The concept and historical development of remote sensing and describes electromagnetic spectrum, properties of EMR and radiation laws. The basic understanding of interaction of EMR with common Earth materials and spectral signature.

Outcomes:

1. Familiarize the learners /researcher with the physical principles of remote sensing, characteristics of sensors and digital images, and basic concepts of visual and digital modes of image interpretation and application in Agriculture.
2. Create awareness and opportunities for application of geoinformatics techniques in Precision Agriculture.
3. Hands on training and technology transfer to end user for enhancing the productivity

7. GROUNDWATER DIGITIZATION BY GEOSPATIAL TECHNIQUES

THEORY

Objectives:

1. To digitize the watershed boundary and study the geo-morphological characteristics of watersheds.
2. To generate the various thematic maps using digitized satellite images.
3. To generate ground truth data on well yields, pre and post monsoon groundwater levels and existing groundwater recharge potential.
4. To identify the groundwater potential zones and suggesting suitable recharging techniques for enhancing groundwater potential.

Brief contents:

The course will highlight the use of remote sensing and GIS techniques for digitization of satellite images for ground water potential zone identification. The course will enable the students to collect the ground truth data on well yield data, recording pre and post monsoon groundwater level data base and its analysis with respect to aquifer characteristics. The course will provide the practical knowledge of identification of suitable groundwater potential zones in an area using digitization through Remote Sensing & GIS and also the implementation of groundwater recharging techniques for enhancing ground water potential which in turn helps to sustain the crop productivity.

Part-1

Assessment and analysis of rainfall and runoff potential related to soil, topography, slope etc., Collection of ground truth data on groundwater levels, conduction of pumping tests on selected / distributed wells in an area, analysis of well characteristics like specific yield and transmisivity, identification of opportunities and constraints faced by the farmers.

Part-2

Introduction to application of Remote Sensing and GIS techniques for digitization of watersheds, Hands on training to digital processing of satellite images, Generation of thematic maps and its applications, Practical approach to identification of suitable sites for ground water potential and prospects zones.

Part-3

Study on scientific methods of open well and bore well recharge techniques, Practical training and demonstrations on implementation of recharge techniques, measurements and analysis of groundwater recharge and its assessment with respect to groundwater enhancement, water budgeting and advanced techniques of providing protective irrigation to rainfed crops for sustaining crop productivity.

Expected outcome:

By the end of the course students / participants will acquire the knowledge of;

1. Identification of ground water potential and prospects zones in an area through satellite image digitization using remote sensing and GIS.
2. Execution of open well and bore well recharging following scientific techniques using rainwater
3. Helps in enhancing ground water potential and thereby achieving the goal of doubling farmer's income through sustaining crop productivity by providing protective irrigation on larger area during frequent dry spell periods.

8. MATHEMATICAL MODELLING AND SYSTEM ANALYSIS

THEORY

Brief Introduction of Course:

This course introduces mathematical applications to obtain a decision tools for different agricultural cropping systems and Machineries in agriculture.

Objectives:

The learner's perception and historic practices can be tabulated or incorporated to make an advancement

Unit I: Mathematical Modelling: Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques

Unit II: Modelling Techniques: Dimensional analysis: Concept behind dimensional approach, Buckingham Pi theorem, Models using dimensional approach - Continuous approach: Models based on physical laws

Unit III: Discrete Approach: Models based on discrete approach. Prey - Predator models - Combat Modelling: Modelling the Lanchester laws with System Dynamics.

Unit IV: System Analysis: The state of a system, mathematical models of continuous linear lumped parameter, time invariant systems, Discrete time systems, Linear approximation of non-linear systems, Topological models of system, Block diagram representation, Signal flow graph, and Mason 's rule. A generalized approach to modelling. Principles of conservation and continuity and Applications. Basics of simulator technology.

Outcome:

The mathematical modelling in agricultural robotics, drones and AGVs is an outcome from course learner .It is expected to develop a case studies and applications oriented IOT tools for digital information system applications particularly extended ability in developing a crop based calculative, modelling.

9. DATABASE TECHNIQUES FOR UAV

THEORY

Objectives:

1. To get acquainted with Unmanned Arial System (UAV), Database concepts and Soft Computing Techniques.
2. To understand Digitization techniques and interpretation.
3. To provide hands on training on Unmanned Arial System (UAV), database and Soft Computing Techniques for enhancing productivity in rain fed agriculture.

Brief content of course:

The module course will include fundamental concepts about Computer, Representation of data in different forms, Database concepts, Working of UAV, Different soft computing techniques for analysis of collected data. Use/integration of these techniques for development of Website / Blogs /Apps. Applications of UAV's (Drone) for precision in agriculture.

Part-1.

Computer Fundamentals – A short review, actual representation of data in different forms like text (alphanumeric), images, Pictures and audio-visual (Video). Database concepts and its relevance for agriculture information system with specific reference to GIS, Remote sensing and UAV applications. Soft computing techniques for agriculture – review. History and system view of Drones. Case studies on use of UAV's (Drones) in agriculture.

Part-2

UAV – Critical techniques and requirements. Technical performance, regulatory framework. Case study on implementation of Soft computing technique (ANN, Fuzzy & Neural-Fuzzy- Hybrid). IoT concepts. Design of database for UAV application in agriculture. Digitization and ground truthing. Use of Drone Mapping software. Components of existing ERP system for Drone applications in agriculture.

Part-3

Hands on sessions for designing, implementing database. Development of Soft computing technique for generation/interpretation of data produced by UAV (Drones). Configuration setup of drones on field. Use of Open source tools for UAV application. Integration of generated data/interpretations with tools for development of Adaptive technologies.

Expected outcomes:

1. By the end of module course the students/ participants will acquire the knowledge of
2. Data Representation/storage formats, Digitization of Maps.
3. Drone system and its applications in Agriculture Drone Mapping Software & related ERP concepts.
4. Database concepts. Awareness about Soft computing techniques
5. Hands on training/Execution of on field Drone System use
6. Technology transfer to end user for enhancing the Precision and Productivity.

10. INTERNET OF THINGS (IOT) IN PRECISION AGRICULTURE

THEORY

Objectives:

Various beneficiary applications can be developed based on the proposed model. Some of the benefits of IOT and cloud computing applications in agriculture are as mentioned below:

1. Improvement in the efficient usage of inputs like soil, water, fertilizers, pesticides, etc.
2. Livestock monitoring
3. Indoor farming – greenhouses
4. Storage monitoring – water tanks, fuel tanks
5. Disease and pest monitoring

Brief contents:

IOT and cloud computing is a technology which tends to connect various objects in the world to the Internet. Internet of Things (IOT) gives a new dimension in the area of smart farming and agriculture domain. With the use of fog computing and WiFi-based long distance network in IOT, it is possible to connect the agriculture and farming bases situated in rural areas efficiently. To focus on the specific requirements, we propose scalable network architecture for monitoring and controlling agriculture and farms in rural areas. Compared to the existing IOT-based agriculture and farming solutions, the proposed solution reduces network latency up to a certain extent. In this, a cross-layer-based channel access and routing solution for sensing and actuating is proposed. It involves the use of RFID, wireless and other sensors with Internet stack inbuilt into the device.

The proposed syllabus is as follows:

Part 1: Introduction to IOT, Sensing, Actuation, Basics of Networking, Communication protocols, Sensor networks, Machine-to-machine communication

Part 2: Interoperability in IOT, Introduction to Arduino programming

Integration of Sensor and Actuators with Arduino, Introduction to Python programming

Part 3: Introduction to Raspberry Pi, Implementation of IOT with Raspberry, Data handling and Analytics, Cloud Computing, Smart Home/ Green House/ Farm.

Expected outcome:

By the end of the course students / participants will acquire the knowledge of;

1. After six month training programme the student should perform, operate and identifies different IOT enabled system/application in agricultural field such as Precision Farming, Livestock Monitoring, and Agricultural Drones etc. for farmers to maximize yields using minimal resources such as water, fertilizer and seeds.
2. Selects various types of sensors as per requirement. Positions appropriate sensors and collects necessary data like various types of soil properties including compaction, structure, pH and nutrient levels etc.

3. Soil moisture, temperature at various depths, rainfall etc. at predetermined intervals.
4. Identifies and selects different wireless communication modules and topology such as ZigBee, Bluetooth, GSM module, Wi-Fi, Ethernet,
5. Identifies and install the appropriate devices such as Location Sensors, GPS & GPS integrated circuits, Wearable sensors to cattle for livestock monitoring by collecting data regarding the location, wellbeing and health of cattle.
6. Installs the devices used in green house such as Carbon dioxide, Oxygen, Air temperature sensors etc

11. ROBOTICS IN SMART GREENHOUSE

THEORY

Objectives:

1. To design and construct digital Greenhouse /Poly house for smart agriculture.
2. To impart technical skills for establishment digital Greenhouse /Poly house for smart agriculture.
3. Hands on training to students or end user for installation of digitized greenhouse, playhouses for enhancing productivity

Brief content

The course will be useful for enhancing productivity under control condition by adoption of smart greenhouse/ poly house / technologies. The course is useful for students for planning, design, site selection and orientation of greenhouse/ poly house. The course will enable the student to collect basic sensory data to monitor atmospheric temperature, humidity and carbon dioxide. Technical knowledge on Greenhouse monitoring using different software's and its execution (climatic manager, irrigation and misting programme etc).

Part I

Types of greenhouses based on Glazing material, shape, construction etc. Planning and designing and construction of smart greenhouse orientation and site selection. Physical and chemical properties of Growth media.

Part II

High value crop suitable for smart greenhouse / poly house. Plant response in green house, cooling, advance irrigation and fertigation system in smart greenhouse.. Sensors used in Green house, playhouses for moisture detection, Equipment monitoring, Access control, Power supply monitoring, CO_2 levels, Air circulation monitoring, Water pH levels. Controlled temperature, humidity, CO_2 through use of different monitoring software such as climatic manager, irrigation and Misting programme. Plant protection measures in smart green house trough robotic applications.

Part III

Robotic applications used for Harvesting and material handling. Achieving real time status of all controlled condition by monitoring system on cloud based that can access sensor data from internet connected devise such as tablets or smart phone.

Expected outcomes:

By the end of course student / participants will acquire knowledge of

1. Awareness and skill development required for execution of smart Green house /Poly house.
2. Technology transfer to the end user for enhancing the production

12. DRONE TECHNOLOGY IN PLANT HEALTH MANAGEMENT

THEORY

Objectives:

1. To impart conceptual knowledge among agricultural graduates for user friendly operation of drone technology.
2. To develop skill entrepreneurs cum artisans for revolutionizing business ideas of digital farming.
3. To identify suitability of existing agricultural drones for pesticide application and other agricultural operations through adaptive research trials.

Brief contents:

The major applications of drone in agriculture are pesticide application, irrigation, crop monitoring, soil and field analysis. Drone technology in farming and agriculture represents a huge opportunity for those with an entrepreneurial spirit. Unmanned aerial systems (UAV) equipped with several sensors and microcontrollers, multispectral cameras, GPS receivers and many more, supports farmer in the efficient use of plant protection products, providing important data on the type of soil and protecting crops from diseases.

Accurate and timely estimates or prediction of crop production in regional scale is critical for many applications such as food security warning system, agricultural lands management, crop insurance, food trade policy and carbon cycle research. This project module will to get acquaint about technical know-how of drone technology.

Secondly, agricultural graduates will get hands on training on use, repair and maintenance of various Unmanned Aerial Vehicle (UAV) systems which will lead as one of revolutionizing business operation.

Part - 1 assembling of Drone and its working

This part consists of hands on training related to introduction of various types of Drones used in industrial sector, Application of drones in agriculture, Government rules and regulations on use of drone technology, Accessories and technical specification of drones, General components or parts (Battery, Motors, Propellers, Flight Controller, Electronic Speed Controller (ESC) and their function. Multispectral Sensor, Thermal Sensor, Visual Sensors etc., Software's and Programming, GPS module, Working, repair and maintenance of drones.

Part - 2 Entrepreneurship developments

Job opportunities in drone industry, Market price summary of agricultural drones, role of agroprenures, Identification of farmers or agricultural graduates who can run start up or business related to commercialization and popularization of drone technology. Linking of entrepreneurs with industry, establishment of drone custom hiring centers

Part-1 Demonstration of drone technology

Research trials on efficiency of majorly available drones of market will be taken at different locations in the Marathwada region of Maharashtra. The minor changes required in drone as per the cropping pattern and pesticide application rates of different crops will be undertaken in the laboratory. Efficacy of insecticide or chemical applied through drone will be tested and compared with the regular plant protection methods and techniques. Crop yield parameters such as plant standing, estimated grain yield, biomass yield and any damage of plants per unit area will be counted though high spectral camera images and data recorded in drone. The data

obtained in above trials will be helpful for popularizing drone technology confidently and with sound proof in the region.

Expected outcome:

By the conclusion of the course, students / participants will gain the knowledge on:

1. The technology will give scope for e-powering people who live in rural India as well as those who work for their welfare and can generate interest about digital farming in the farmers and others working at the grassroots.
2. This certificate course on precision machinery such as drones, agricultural robots will result in imparting skills among agricultural graduates to establish custom hiring centers and other business opportunities.
3. The cost on pesticide application can be reduced largely and the considerable water, time and other agricultural inputs will be saved in dry land region. Thus, it will result in minimizing cost of cultivation.
4. The crop yield parameters such as uniformity in plant standing, grain yield and biomass yield etc. can be predicted for future strategic planning in the area.

13. AUTOMATION IN FRUITS AND VEGETABLE PROCESSING PLANT

THEORY

Objectives

1. To introduce students/entrepreneurs/ farmers for theoretical and practical practices of advanced techniques of fruit and vegetable processing in food industries.
2. To build capacities of student/ entrepreneurs of handling of software practices in Fruit and vegetable processing.

Brief Content

This course highlights the modern concepts of processing of fruits and vegetables in relation to precision of processing techniques for product developments. The course provides practical knowledge of fruit and vegetable processing using robotic hands in processing. The demonstrations of preparations of different fruit and vegetable processed products

Introduction

The processing of fruits and vegetables for different value added products using different unit operations and processes viz. handling, sorting, grading, processing, filling, packaging, stacking etc. and use of software technology i.e. robotics in processing practices in the need of modern era of processing.

Part-I

The different processing techniques of fruits and vegetables, the present challenges of food processing and possible solutions to the present challenges.

Part-II

The consideration of existing facilities for processing of fruits and vegetables and potential for the digital processing practices. The modern fruit and vegetable processing practices coordinated with existing facilities in ELP plant. The use of robotic handling in unit operations and unit processes are coordinated.

Outcome

Course at its end will achieve

Critical understanding of fruit and vegetable processes using robotics practices. Highly trained skilled professionals for handling and processing of fruits and vegetables for modern food processing industry sector.

14. SMART FOOD PROCESS CONDITION MONITORING

THEORY

Objectives:

1. To upgrade the quality of food products.
2. To process the food material into value added food products in the aesthetic and hygienic condition.
3. To assess the qualitative and quantitative bioactive, nutritional and functional components in the food products.

Brief contents:

The course will help in fast, reliable and effective identification and understanding of sophisticated instruments and process control devices for food processing and value addition. Secondly, students will get hands on training on equipment handling and demonstration for estimation of nutritional component and processing profile of different food products.

Part-1

Instrument terminology and performance system accuracy, flow sheet symbols, instrument evaluation, electrical, mechanical, magnetic and optical transducers for measurement of process variables like temperature, pressure, flow, level, consistency and humidity, indicating and recording devices: direct acting and servo operated systems, digital indicators, strip and circular chart recorders, electronic data loggers, principles of automatic process control.

Part-2

Process characteristics, controller characteristics, closed loop system, pneumatic and electric controllers, final controlling elements, control valves, valve sizing, electronic actuators, motor drives and controls, introduction to programmable logic controllers (PLC): internal structure, inter facing with sensors and actuators, binary logic diagrams and ladder diagrams, choosing a PLC system.

Part-3

Applications of MS Excel to solve the problems of food technology: Statistical quality control, Sensory evaluation of food, and Chemical kinetics in food processing; Use of word processing software for creating reports and presentation; Familiarization with the application of computer in food industries -Milk plant, Bakery Units, Fruit & Vegetable processing Unit; Familiarization with software related to food industry; Ergonomics application in the same; Visit to Industry and case study problems on computer.

Expected outcome:

By the end of the course students / participants will acquire the knowledge of;

1. Introduce the role of computerization in food processing, particularly for communication, process and quality optimization, automation, simulation, designing and manufacture
2. Demonstrate in-depth knowledge of the scientific foundations of the

disciplines in engineering and the natural sciences that constitute the field of food technology

3. Demonstrate an ability to analyze both complete systems and the constituent parts of the industrial manufacture of food products
4. Demonstrate an insight into how different sub-systems co-operate with each other
5. Demonstrate an insight into current research and development in the field
6. Demonstrate enterprising skills
7. Compete in the global food industry scenario

15. DIGITAL SYSTEM MANAGEMENT IN SEED PRODUCTION, PROCESSING AND QUALITY ASSURANCE

THEORY

Seed quality plays an important role in the production of agronomic and horticultural crops. Characteristics such as trueness to variety, germination percentage, purity, vigor, and appearance are important to farmers planting crops. Achieving and maintaining high seed quality is the goal of every professional seed producer. Seed processing is a vital part of the seed production needed to move the improved genetic materials of the plant breeder into commercial channels for feeding the rapidly expanding world population. The farmer must get the quality seed that is free from all undesired materials because farmer's entire crop depends on it. Seed certification is a process designed to maintain and make available to the general public continuous supply of high quality seeds and propagating materials of notified kinds and varieties of crops, so grown and distributed to ensure the physical identity and genetic purity. Seed certification is a legally sanctioned system for quality control of seed multiplication and production. The course covers a wide range of seed science and technology issues related to production of high quality seeds, processing, testing, certification, quality control, seed storage, field and laboratory techniques in seed quality assurance

Objectives of the Program

1. To build capacity of students, officers & professionals in the area of quality Seed production.
2. Application of digital tools for post-harvest handling and management of seeds.
3. To know the importance of seed testing by digital tools.
4. To create awareness about the opportunities in digital seed certification & quality control.

Key component of the programme:

The programme is designed around the following themes:-

Quality Seed Production: Seed Formation and Development, Principles of Seed Production in self and cross pollinated crop, Seed production technology in field crops, Planning and management of seed production programme.

Post-harvest and handling and management of seeds: Harvesting and maturity indices, Post-harvest techniques of seed storage, In store drying, Store losses, Assessment of losses, Post-harvest quality assessment techniques, Quality and safety

Seed Testing: The use of seed sampling and digital testing equipment, Maintenance of equipment, Sampling and physical purity analysis for quality testing, Seed viability and vigour testing, Reporting the results of tests, Storage of test samples, The role of the seed testing laboratories under the seed law.

Seed Certification and Quality Control: Seed certification standards for Millets, Pulses, Oilseeds, Fiber crops, Forage, Vegetables and for Spices.

Outcome:

The sessions will be delivered through lectures, group discussions, case studies, and field visits. The program design will be highly participatory. Each participant will be expected to contribute ideas and take part in group activities. The participants will work in small groups to undertake various assignments allotted to them. Experiential learning methodology is effectively incorporated in the program. The participants will learn through group interaction, field visits and the trainers. Each delegate will have the opportunity to share and present the current system of seed production.

16. CLIMATE RESILIENT TECHNOLOGIES IN DRY LAND FARMING FOR ENHANCING PRODUCTIVITY THROUGH DIGITIZATION

THEORY

Objectives:

1. To get acquainted with the climate change and its effect on rainfed Agriculture
2. To understand about the climate resilient digital technologies in rainfed Agriculture.
3. To provide hands on training on adoption of climate resilient digital technologies for enhancing productivity in rainfed agriculture.

Brief content of course:

The module course will includes climate change and variability, monsoon behavior, occurrence of drought, types of drought, rain water management, harvesting and its reutilization, climate resilient technologies, stress management in dry spell, In-situ and ex-situ rain water conservation, mulching practices, protective irrigation, rainfed integrated farming system, soil health management in dry land agriculture, mechanization in rainfed agriculture, which helps in enhancing productivity of rainfed agriculture etc. These technical information is to be digitized with adaptive techniques.

Part-1.

Risks and vulnerability in the context of climate change, challenges and constraints, Analysis of long term meteorological data for assessing climate variability, introduction of climate resilient crop varieties, introduction of in-situ rain water conservation techniques, introduction of dry spell management techniques, introduction of advance water saving techniques.

Part-2

Hands on training and application of digital software's for analysis of meteorological data, Practical demonstrations to implement climate resilient technologies, rain water management through in-situ and ex-situ approach. Practical's on farm implements operations and maintenance.

Expected outcome:

By the end of module course the students/ participants will acquire the knowledge of

1. Climate change and its impact on rainfed agriculture by digital solutions.
2. Awareness of monsoon behavior by adaptive technologies.
3. Skill development in climate resilient digital technologies.
4. Hands on training/Execution of climate resilient digital technologies
5. Technology transfer to end user for enhancing the Productivity.

17. DIGITAL AGRICULTURE THROUGH SMART FARMING

THEORY

Objectives

1. To develop skills of students / farmers (end users) about handling software and data processing, AGVs and robots on farm for Smart Farming/Digital Farming.
2. To build capacities of students / farmers (end users) for enhancing productivity with drudgery reduction.

Brief Content

This course highlights the modern concepts of agronomy in relation to precision farming and digital farming. This course will enable students to conduct research on precision farming, variable resource techniques, and data processing. The course will provide practical knowledge of handling Drones, AGVs and Agribots useful in agronomic operations.

Introduction

Agronomy of major crops including package of modern practices followed in smart farming like sowing, weed management, Irrigation Management, Plant protection, special operations and harvesting using AGVs and Agribots.

Part – I

Exiting farming practices and potentials of digital farming practices. Characteristics of present global and national agriculture, solutions to present challenges in agriculture using Digital Farming technology, AGVs and Agribots.

Part-II

Co- coordinating modern agronomic practices with precision agriculture by using sensor applications, drones, AVGs and Agribots. Use of digital data for soil and crop management. Application of AGVs and Drones for solution of specific problems like picking of Cotton, harvesting of sorghum, bajra, soybean and sugarcane, trash and residue management ,reducing the labour expenses for reducing cost of cultivation.

Outcome

Course at its end will achieve Skill development in handling Drones, AGVs, Agribots, through hands on training required for smart agriculture. Enhanced productivity through digitization of agriculture.

18. BIO SENSORS FOR RAPID DETECTION OF INSECT RESISTANCE AND PARENTAL IDENTIFICATION IN CROP PLANTS

THEORY

Objectives:

1. To detect Pink bollworm resistance in Bt. cotton using immunological assay.
2. To develop enzyme based molecular kit for identification of Bollworm complex.
3. To test hybrid purity and identify spurious seeds in crop plants by using DNA based biosensors.

Brief contents:

The course will help in fast, reliable and effective identification four significant pest species in the cotton bollworm complex (*Helicoverpa armigera, Helicoverpa assulta, Pectinophora gossypiella and Earias vittella*) irrespective of their life stages and will offer support to conventional taxonomic differentiation based on morphological characters. Similarly, in recent years *Pectinophora gossypiella (*Pink bollworm) become resistant to first generation transgenic Bt cotton, which threatened the cotton growers and brain workers in area of biotechnology. This project will help in developing of immunological assay to analyze *Bt* gene expression.

Secondly, students will get hands on training on DNA based identification of spurious seeds in crop plant. This will help in developing entrepreneurs in field of biotechnology for detecting insect resistance and pure seed identification at initial level

Part-1

Assessment and analysis of cotton bollworms from Bt cotton and non Bt. Cotton fields for developing DNA based diagnostic tool in early identification. The primary work of standardizing mitochondrial DNA isolation protocol followed by amplification of two partial regions of the mitochondrial DNA (mtDNA), the cytochrome oxidase subunit I (COI) and the cytochrome b (Cyt b) genes by PCR and digested with restriction endonucleases. This will leads in generation of DNA patterns for differentiation of the four pest species.

Part-2

Development of Immuno-biosensors for analysis to study intra-plant and in-seasonal variability in Cry1Ac expression in *Bt* cotton. The gene expression in plant parts will be correlated with survival of pink bollworm on different plant parts so as to quantify the variation of gene expression and infestation of pink bollworm.

Part-3

The different molecular markers will be used to develop PCR based biosensors in crop plants. The PCR based biosensors will help in parental identification, detection of spurious seeds and verification of hybrid purity in crop plants. This technique is fast, reliable and effective at distinguishing specimens irrespective of their life stages.

Expected outcome:

By the end of the course students / participants will acquire the knowledge of;

1. Development of molecular diagnostic kit for identification of cotton bollworms at early stage.
2. Help in addressing farmers complaints related to bollworm survival on *Bt*-cotton plants as study makes a systematic attempt to correlate the Cry1Ac expression in *Bt* cotton tissues with *pink bollworm* mortality, thus identifying a critical expression level for Cry1Ac in tissues, below which insect would be able to survive.
3. Development of new entrepreneurs in area of biotechnology which may become a part of agricultural clinic as PCR biosensors will help in fast, reliable and effective detection of insect pest irrespective of their life stages and seed purity.

19. HI-TECH NURSERY MANAGEMENT FOR ENTREPRENEURAL SKILL DEVELOPMENT

THEORY

Objectives:

1. To help students t get acquainted with horticulture based hi-tech nursery.
2. To provide an opportunity to the students or practical learning learning in nursery based industries through work experience.
3. To acquaint the students and rural youths ongoing thrust programmes and related new technology (use of Agribots, AVG and Drones) in the relevant field.
4. To develop confidence and competence amongst the aspirants for solving problems in related nursery management based enterprises as their carrier.

Brief content:

Nursery is a place where plants are cultivated and grown to usable size. The nursery management gained a status of commercial venture where retailer nurseries sell planting materials to the general public, wholesale nurseries which sell only to other nurseries and to commercial landscape gardeners and private nurseries which supply the needs of institutions or private estates. The course content includes, the digitalization in all the related activities of nursery which includes proper care and management for rising healthy, vigorous and disease free seedlings for production of quality planting materials. Imparting the training the knowledge and skills in this area will help the stakeholders essentially providing direction to think and act eventually creating self-confidence. In short the holistic development in the stakeholders can be achieved through creating competence, capability, capacity building, skills and expertise in the field.

Part 1

Application of Agribots, AVG and Drones maintenance of mother orchards. Procurement of scion material of commercial importance. Selection and raising of rootstock. Commercial production of saplings (cuttings, budded, grafts, tissue cultured plantlets).

Part 2

After care of nursery plants, viz. watering, shade, nutrient management, use of plant growth regulators. Labeling and packaging of nursery plant. Use of sensors in identification and control of pests and diseases. Nutrient management using GPS technology.

Part 3

Labour management in nursery. Estimation of cost of production of nursery plants. Supply chain management in nursery. Marketing of nursery plants. Entrepreneurship development in nursery.

Expected outcome

1. At the end of the project following outcome is expected
2. It helps in creating competence, capability, capacity building, skills and expertise in the field of handling of Agribots, AVG and Drones in nursery management.

20. DIGITAL PLANT HEALTH CLINIC: MOLECULAR DIAGNOSTICS OF PLANT PATHOGENS

THEORY

Objectives

1. To introduce students to theory and practice of development with respect to various molecular methods of detection and diagnosis of plant diseases for production of disease free planting material of Horticultural crops.
2. To explore critically the issue of access and management of molecular methods of detection and diagnosis of plant diseases,
3. To build capacities of students with respect to molecular detection and diagnosis of plant pathogens.
4. Drone application in pesticide spraying.

Brief Contents

This course highlights molecular detection and diagnosis of Plant Pathogens perspectives for climate smart precision agriculture. This course will enable students to undertake research on Molecular methods of detection and diagnosis of Plant Pathogens. The course provides practical knowledge of popular tools and strategies such as ELISA, PCR, RPA, biosensors and Point of Care diagnostics and precise application of pesticide by drone to the students

Part-1

Many species of fungi can cause disease in plants. Accurate detection and quantification of fungi is essential for diagnosis, modeling and surveillance. Detection of fungi enables a understanding of natural microorganisms. In recent past good amplification platforms, probe development and various quantitative PCR technologies have revolutionized research on Plant Pathogen detection and identification. Early detection of plant disease and precise application of pesticide are the major constrains as far as farmers are concern.

Part-2

Introduction: Enzyme-linked immune-sorbent assay and DNA-based technologies like polymerase chain reaction have been the basis for molecular detection in modern plant pathology. Genomics and biosystematics research are generating fast-growing databases that can be used to design molecular assays for simultaneous detection of a large number of pathogens. The medical research field is creating novel platforms with improved capabilities for multiplexing, high throughput and portability, which will provide new opportunities for plant pathology. As new molecular testing devices gain wide acceptance in medical diagnostics, tools for routine monitoring of pathogens and beneficial organisms should become more commonly used in plant pathology if we successfully manage to adapt these technologies to a wide range of microorganisms. Students can use this techniques in there research programmes.

Part-3

Agricultural extension has been undergoing major changes. Changing policies, declining public funding, new thinking and approaches, climate change and other environmental factors pose major challenges to public sector extension services. Pre-packaged, crop and region- biased extension approaches often failed to help remote and resource poor farmers to cope with rapidly changing realities. This has necessitated the search for alternative approaches. One such alternative, plant health

clinics operated by local students of the University in locations that are easily accessible to farmers. Plant health clinics accept any crop problem. They provide regular, relevant and practical advisory services on plant health management. Clinic records generate useful information on priority problems and changing status of pests and diseases.

Expected Outcomes

By the end of the course students will:

1. Have a critical understanding of molecular methods of detection and diagnosis of plant pathogens to adopt of Climate smart precision farming
2. Students will develop skills to run Plant Heath Clinic commercially.
3. Digitalization of Plant clinic
4. Drone application in precise pesticide spraying.

21. GEO-INFORMATICS FOR CLIMATE SMART AGRICULTURE

THEORY

Objectives

The program is proposed with following objectives:

1. To provide the basic knowledge and hands-on training in the basics of geoinformatics and crop simulation modeling
2. To acclimatize to the learners with the use of technology in climate smart agriculture
3. To execute the agro advisory services more efficiently by using real time data.

Brief content of course:

1. Role of remote sensing and geo-special technologies n climate smart agriculture
2. Abiotic stress in agriculture
3. Crop modeling under climate change situations
4. Protected cultivation under green house
5. Precision farming for resource use efficiency, reduced emission of GHG's and with special reference to small and marginal farmers.
6. Climate change study using open top chambers
7. Micrometeorological studies using the Eddy Covariance, Bowen ratio and empirical methods.

Part 1: Introduction to Geoinformatics

This module course will introduces the some basic components of geoinformatics applications in the agriculture field such as to identify the crop health, soil moisture status, biotic and abiotic stress etc. The information generated from drone is important for preparation of precious agro met advisory services on real time basis. Spatial data is having large scale application in the agriculture field.

Part 2: Climate change studies

The existing filed crop cultivars performance under the elevated carbon dioxide (CO_2) and temperature. The screening of the best cultivars under projected CO_2 and temperature as per Intergovernmental Panel on Climate Change (IPCC).

Part 3: Remote Sensing and Image analysis

Use of satellite data and Drone data for agriculture field and the conversion of image data in the operational mode using the image processing software. Development of different spectral signature of field crops and orchards for unsupervised classification of image data.

Outcomes:

1. The real time information is used for agro advisory services.
2. The elevated CO_2 and temperature studies will help to find suitable germplasm.
3. The use of drone and satellite data will help to monitor the crop health, soil moisture status and real time management.
4. Micrometeorological studies will helpful for microclimate management under the climate change scenario.

22. DIGITIZATION IN SOIL, WATER AND PLANT ANALYSIS

THEORY

Objectives:

1. Digitization and Geo-referring of village-wise soil maps in GIS environment.
2. To generate the various thematic maps using digitized satellite images.
3. To promote professional skill, entrepreneurship and knowledge skills through meaningful hands on experience and working in soil, water, plant and fertilizer analysis.

Brief contents:

The course will highlight the use of remote sensing and GIS techniques for digitization of satellite images for identification of different types of soil. The course will enable the students to collect the soil data and its analysis with respect to morphological, physical and chemical characteristics and diagnosis of nutrient deficiency through plant analysis. The course will provide the practical knowledge of identification of soil types and diagnosis of nutrient deficiency of an area using digitization through Remote Sensing and GIS which in turn helps to sustain soil fertility and crop productivity.

Part -1

Collection of soil and water samples by using GIS techniques and analysis of soil and water characteristics like PH, EC, organic carbon content, calcium carbonate content ,macro, micro nutrient and heavy metal content in soil content and plant analysis for diagnosing the nutrient deficiency in field and horticultural crops of the region.

Part-2

Introduction to application of Remote Sensing and GIS techniques for digitization of village wise soil maps. Hands on training on to digital processing of satellite images. Generation of thematic maps and its application. Practical approach to identification of suitable sites for growing of field and fruit crops.

Expected outcome

By the end of course students/ participants will acquire the knowledge of;

1. Identification of types of soil in an area through satellite image digitization using remote sensing and GIS.
2. Helps in enhancing soil and water potential and thereby achieving the goal of doubling farmers income through sustaining crop productivity.

23. DECISION SUPPORT SYSTEM (DSS) BY GEOSPATIAL TECHNIQUES

THEORY

Objective:

1. To evaluate soil site suitability for major crop production systems in study area.
2. To identify the soil boundary by using hyper spectral remote sensing ,Drones and GIS technique for development of soil site suitability map.
3. To identify the nutrients deficiency symptoms by using Drones technique for site specific nutrients management.
4. Development of DSS for doubling farmer income.
5. To educative the real user through trainings.

Brief contents:

The decision support system is the powerful tool for doubling the farmer income. This module mainly focuses on to evaluate the soil site suitability for commonly grown crop in study area and development of soil site suitability map by using hyper spectral remote sensing, Drones and GIS technique for popper selection of site for specific crop in study area . This is the new concept of land evaluation and land use information through Geographical Information System. Geospatial soil data is the key for land development program. Identify nutrient deficiency symptoms by Drones technique and check the ground trough through laboratory analysis for proper diagnosis.

Part 1 :

Evaluate the soil site suitability for communal grown crop by using already available data set and analysis of morphological, physical and chemical and mineralogical characteristics of remaining part of Marathwada region.

Part 2 :

Identify the studied soil boundary by using new technique hyper spectral imaginary data set and its confirmation through Drones technique and ground troughs. The soil site suitability map will be prepared by using GIS technique.

Part 3 :

The Nutrient deficiency symptoms will be identify through Drones technique and verified through plant chemical analysis for proper and timely diagnosis.

Expected outcome :

1. Provide soil resource inventory of Marathwada region. This can helpful to land use planner, students, researcher and farmers.
2. Soil site suitability map can helpful to farmers for proper selection of soil site as per its suitability it could helpful to doubling the farmer income.
3. Promotes the awareness of farmer and real user regarding soil site suitability and nutrient deficiency for proper management.

24. ROBOTICS AND AGVS IN AGRICULTURE PEST MANAGEMENT

THEORY

Objectives:

1. To introduce students to important pests of crops grown in Marathwada region of Maharashtra
2. To impart knowledge on various aspects of pest management
3. To demonstrate use robotics and AGVs in pest management

Brief Contents:

Pest refers to any agent insects, microbes, plants and animals and that cause damage to our crops. Depending on the situation, insects can be considered as pests and harmful at certain periods of time and beneficial at another. Farming is labour intensive and often occupied with manual infuriating hard work. Agriculture could perhaps be one of the latest industries that can use robotic technology and automation machines. Farmers have been keenly interested in ways to make their work easier. Many of the labour saving devices and simple-operated machines in agriculture have been developed by farmers themselves Cultivation of crops for optimum yield and quality produce is highly methodical but can be improved by the aid of technological support. Technology plays an ever increasing role in agriculture. Data collection for surveys as well as accessing and obtaining vitalinformation regarding crop pests. The aim of the project is to promote awareness among students and young scientist on relative technological advancement in farming and use of robotic technology in agriculture pest management.

Part I

Theory and practice of identification of useful and harmful insects.Ecological aspects of insect pest abundance and role of biotic and abiotic factors on insect growth.Study on insect behaviour, biology, life table and other basic principles of insect life cycle.

Part II

Theory and practice of pest monitoring and survey and surveillance.Invasive pests.Intelligent selection and use of pest control tactics that will ascertain favourable economic, ecological and sociological consequences.Judicious application of pesticideswhile providing protection against hazards to humans, plants, animals and environment.Use of multiple actions in a compatible manner to maintain pest damage below the economic injury level.Insecticide resistance, resurgence and residue management. Insecticide formulations, spraying techniques.

Part III

Theory and practice of using robotics and AGVs in pest management practices including pest identifation, monitoring and surveillance. Use of robotics in deciding economic thresholds of important crop pests.Use of robotics in handling hazardous pesticides in field.Sensors that will detect the resistance monitoring in pests and to ascertain pesticide residues in food commodities.

25. FARM WOMEN SKILL DEVELOPMENT BY DIGITAL SYSTEM

THEORY

Objectives:

1. To acquaint farm women to digital farming for management of various selected crops.
2. To develop skills among farm women for handling selected digital devices such as Drones, AGV and Agribots for management of selected crops.
3. To build capacity of farm women in handling digital devices or technologies for enhancing productivity

Brief Content:

This course will enable farm women to acquaint with digital farming management. The course will provide them practical knowledge of handling Drones, AGV and Agribots useful for agronomic operations.

Introduction

Women are involved in most of the operations in agriculture right from sowing to harvesting with package of practices of crops (eg. Cotton, Soybean, Sorghum, and sugarcane). Various digital devices or technologies for enhancing productivity

Part – I

Digitalization in management of agricultural practices . Present challenges in agriculture management and possible solutions to the present challenges through digitalization. Use of sensor applications i.e. drones, AVGs and Agribots.

Part-II

Exiting farming practices and potentials of digital farming practices. Coordinating modern agronomic practices for reducing the labor expenses for reducing cost of cultivation and other specific problems.

Outcome

1. Course at its end will achieve
2. Critical understanding of digital agriculture through hands on training of handling Drones, AGVs, Agribots.
3. Trained, skilled farm women capable of handling for digitization of agricultural operations. Eligibility: Any Science graduate

26. INTERACTIVE HUMANOID ROBOT (ROBOVIE) IN CHILD DEVELOPMENT

THEORY

Objectives:

1. To orient students to communicative & humanoid robot
2. To develop interdisciplinary approach in cognitive science, communicative & humanoid robot
3. To build capacity of students in utilization of humanoid robot in various areas of child development

Brief Contents:

This course will enable students to utility of robots in child development. The course will provide them practical knowledge and insight of use of robots in language, communication and cognitive development.

Introduction

Various digital devices or technologies are used now days in child development and education. Through human and robot interaction, more advanced and supportive environment can be provided in child development.

Part – I

Acquaintance to various types of robots, utility in human development, humanoid robots, communicative robots, social and physical support of robots for human development.

Part-II

Inter disciplinary approach in utility of advanced technologies, cognitive science, mental therapy, language , conversation, communication, retrieval of information, relationship development, cognitive development

Outcome

Course at its end will achieve Orientation to students through hands on training of handling robots for enhancing cognitive development in children. Trained, skilled professional capable of handling robots for advanced child development.

27. WOMEN IN DIGITAL FARMING

THEORY

Objectives:

1. To introduce students about role of women farmers in traditional farming and need of adoption of technologies, digital farming for farm women.
2. To build capacities of students to help farm women for developing skills for use of hardware, software and data processing in digital farm management of selected crops.

Brief Content:

This course will enable students to acquaint with role of women farmers in traditional farming and need of adoption of technologies to reduce their drudgery, digital farming for women, with digital farming, techniques and data processing. The course will provide practical knowledge to students of handling Drones, AGV and Agribots and its digitalization in agronomic operations for farm women.

Introduction

Adoption of digitalization in farming has become essential part of progress in farming. It is necessary to orient students to know traditional farm practices and adoption of technologies in various agriculture operations like sowing, weed management, Irrigation Management, Pest and Disease management etc.

Part – I

Global and national digitalization in agriculture. Present challenges for women in Indian agriculture, possible solutions to the present challenges. Use of digital farming,

Part-II

Exiting farming practices and potentials of digital farming practices , agriculture management by using sensor applications i.e. drones, AVGs and Agribots. Use of digital data for crop and soil management. Application of AGVs and Drones for specific challenges

Outcome

Course at its end will achieve Critical understanding of digital agriculture for farm women through hands on training of handling Drones, AGVs, and Agribots. Trained, skilled professionals capable of handling and processing required for digitization of agriculture.

28. DIGITAL EXTENSION FOR INFORMATION MANAGEMENT IN AGRICULTURE

THEORY

Objectives:

1. To understand the concepts of ICTs and use of ICT tools for Agril. Extension.
2. To develop ICT based agricultural information management platform for strengthening agricultural extension.
3. To study the usages of robotics, drones, AGVs & Smart Devices in agriculture.

Brief Contents:

Part-I

1. ICTs – Concept, definition, tools and application in extension education. Reorganizing the extension efforts using ICTs, advantages, limitations and opportunities.
2. ICTs projects, National and International case studies of Extension Projects using ICTs. Different models / approaches of ICTs.
3. Expert systems in agriculture. Agricultural web sites and portals. IoT in Agriculture.
4. Agricultural content analysis of ICT projects. Handling of ICT tools. Designing extension content. Online extension service. Visit to ICT extension project

Part-II

1. Community Radio, Web, Tele and Video Conferencing. Computer aided extension. Information Kioks, Multimedia, Emerging issues in ICT.
2. Use of Social media and mobile apps for Transfer of Technology, Market Led extension. Creation of accounts on social media.
3. National e-Agricultural Initiatives and Extension
4. Farmers Call Centres in India
5. Agricultural knowledge management and dissemination through digital libraries and participatory videos.
6. Linking farmer to markets – e-NAM, AGMARKNET, e-Choupal
7. Agricultural MOOCs

Part-III:

Use of Robotics, drones, AGVs and Smart Portable Device in agriculture

Expected outcome:

1. Students will acquire knowledge and skills in understanding the concepts of ICTs and how ICT tools can be used for Agricultural Extension.
2. Student studies various ICT projects which are successful in delivering the services to the clientele fulfilling the objectives of ToT (Reaching to unreached).
3. Develop expertise in handling of robotics, drones, AGVs and smart portable device in agriculture.

29. DESIGN OF EXPERIMENT

THEORY

Unit I:
Overview and Basic Principles, Simple Designs and Analysis of Variance,

Unit II:
Block Designs, Latin Squares and Related Designs, Full Factorial Designs, 2- level Full Factorial and Fractional Factorial Designs.

Unit III:
Response surface methods and designs, Designs with Random Factors, Nested Designs, and split-plot Designs.

Text / Reference Books

1. Clewer, A.G. and D.H. Scarisbrick. 2001. Practical Statistics and Experimental Design for Plant and Crop Science. John Wiley and Sons, LTD. New York Morris, T.R. 1999.
2. Experimental Design and Analysis in Animal Sciences. CABI Publishing, New York