Syllabus Proposed 2024 - 2025

Indian Institute of Space Science and Technology

Curriculum Revision for M Tech (Geoinformatics) - July 2024

(L-Lecture T-Tutorial P-Practical C-Credit)

Semester	I	II	III	IV
Credits	18	19	15	18
	Total Credits: 70			

Semester I

S. N	Course Code	Course title	L	T	P	C
1	ESG611	Principles of Remote Sensing and Digital Image Analysis	3	0	0	3
2	ESG612	Geographic Information System	3	0	0	3
3	ESG616	Scientific Computing for Geospatial Analysis	2	0	0	2
4	ESG711	Mathematical Methods for Geospatial Analysis	3	0	0	3
5	ESG EC	Elective 1 - Core Elective	3	0	0	3
6	ESG 631	Remote Sensing and Digital Image Analysis Lab	0	0	3	1
7	ESG632	Geographic Information System Lab	0	0	3	1
8	ESG633	Programming for Geoinformatics Lab	0	0	3	1
9	ESG EL	Elective Lab 1	0	0	3	1
		Semester credits				**18**

Semester II

S.No	Course Code	Course title	L	T	P	C
1	ESG721	Machine Learning for Geoinformatics	3	0	0	3
2	ESG625	Analysis and Modelling of Geospatial Data	3	0	0	3
3	ESG EC	Elective 2 - Core	3	0	0	3
4	ESG EC	Elective 3 - Core	3	0	0	3
5	IEC	Elective 4 - Institute Elective/ ONLINE Course	3	0	0	3
6	ESG643	Machine Learning lab	0	0	3	1
7	ESG644	Analysis and Modelling of Geospatial data lab	0	0	3	1
8	ESG EL	Elective Lab 2	0	0	3	1
9	ESG EL	Elective Lab 3	0	0	3	1
		Semester credits				**19**

Semester III

S. No		Course title	L	T	P	C
1	ESG651	Thesis – Phase I				12
2	ESG 751	Skill Development (ONLINE Course)	3	0	0	3
		Semester credits				**15**

Semester IV

S. No		Course title	L	T	P	C
1	ESG652	Thesis – Phase 2				15
2	ESG657	Comprehensive Viva	0	0	0	2
3	ESG 752	Seminar				1

	Semester credits	**18**

Sem I Electives

S.N	Course Code	Course title	L	T	P	C
1	ESG 761	Digital Photogrammetry and UAV Remote Sensing	3	0	0	3
2	ESG 762	Lab for Digital Photogrammetry and UAV Remote Sensing	0	0	3	1
3	ESG 763	Geodesy and Satellite Positioning	3	0	0	3
4	ESG 764	Lab for Geodesy and Satellite Positioning	0	0	3	1

Sem II Electives

S. N	Code	Course title	L	T	P	C
1	ESG 765	Computational GIS	3	0	0	3
2	ESG 767	LAB for Computational GIS	*0*	*0*	*3*	*1*
3	ESG 663	Quantitative Remote Sensing	3	0	3	3
4	ESG 667	Computer Vision and Advanced Image Processing	3	0	0	3
5	ESG 768	LAB for Computer Vision and Advanced Image Processing	*0*	*0*	*3*	*1*
6	ESG 769	Geospatial Standards and Web / Cloud GIS	3	0	0	3
7	ESG 770	Hyperspectral and Thermal Remote sensing	3	0	0	3
8	ESG 771	Active Remote Sensing	3	0	0	3
9	ESG 668	Remote Sensing and GIS For Environmental and Natural Resource Management	3	0	3	3
10	ESG 669	Remote Sensing and GIS for Atmospheric and Ocean Studies	3	0	3	3

SEMESTER – I

1. Principles of Remote Sensing and Digital Image Analysis (3 – 0 – 0) 3 credits

Electromagnetic radiation and its interaction with matter, Spectral signatures, image formation, remote sensors and platforms, resolutions, radiometric and geometric distortions, Introduction to multispectral, hyperspectral, thermal, microwave and laser remote sensing, spectral indices, classification techniques, image transformations, intensity transformations, spatial filtering, image formats, noise reduction, image segmentation.

Textbook

1. Introduction to Remote Sensing by James B. Campbell, 4th Edition, Guilford Press
2. Remote Sensing and Image Interpretation (5 th Ed.) by Thomas M. Lillesand, and Ralph W. Kiefer, John Wiley & Sons Ltd.
3. Fundamentals of Remote Sensing (3rd edition) 2018 by George Joseph and C Jegannathan, Universities Press

References

1. Remote Sensing Digital Image analysis by John A. Richards and XiupingJia, Springer, 2006.
2. Digital Image Processing by R. C. Gonzalez and R. E. Woods, (3 rd Ed.) Prentice Hall.
3. Digital Image processing: A Remote Sensing Perspective by John R. Jensen, Prentice- Hall, 2004.

2. Geographic Information System (3 - 0 - 0) 3 credits

Introduction to Geographic Information System (GIS) - Hardware, Software, Data types and models-Spatial data quality, Thematic maps, Symbolization, Scale and generalization - Co-ordinate systems, Map projections and visualization - Input / output techniques in GIS (spatial and non-spatial), Editing, Topology, Database structure - Analysis: spatial, network analysis, optimization of path, time and cost, Routing and events, Facility location, Interpolation methods, Digital elevation model, Surface analysis -Geovisualization - Decision support systems, OpenGIS, WebGIS, Enterprise GIS - Planning, Designing and Implementation, National Spatial Data Infrastructure (NSDI),Future trends.

Textbook

1. Concepts and Techniques of Geographic Information Systems by Lo C.P. and Yeung A.K.W., (2nd Ed.), Prentice Hall, 2006.
2. Introduction to Geographic Information Systems by Kang-Tsung Chang, McGraw Hill Publishers.
3. Principles of Geographical Information Systems by Burrough P.A. and McDonnell R.A., Oxford University Press, 1998.
4. Geographic Information Systems and Science by Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, John Wiley & Sons Ltd.
5. The Handbook of Geographic Information Science, Wilson J. (Ed), Wiley-Blackwell, 2007.

3. **Scientific Computing for Geospatial Analysis (2-0-0) 2 credits**

Programming in the context of processing of raster, vector and tabular geospatial data. Basic principles of programming, including languages and syntax, paradigms, variables, control flow and functions. python, and R. - Image spatial data structures - ADT, spatial ADTs and their operations, Spatial data structures and spatial indexing - Spatial databases – Structured query language- Creation, updation and editing databases., database normalisation, normal queries , spatial queries.

References

1. Lutz, M., 2013. Learning Python, 5 edition. ed. O'Reilly Media, Beijing.
2. Data Structures and Program Design in C by Robert L Cruise, (2nd Ed.), Pearson Education.
3. Fundamentals of Database Systems byElmasri and Navathe, (6thEd.), Addison-Wesley, 2011.
4. Design and analysis of spatial data structures. H. Samet.
5. Applications of spatial data structures: Computer Graphics, Image Processing and GIS. H. Samet.
6. An Introduction to Database Systems byC.J.Date, A. Kannan S. Swamynathan (8thEd.), Pearson Education, 2009.
7. Spatial databases: A tour. S. Shekhar, S. Chawla

4. **Mathematical Methods for Geospatial Analysis (3-0-0) 3**

Probability and statistics: Introduction, Conditional probability, Baye's theorem: Probability Distributions: Continuous and discrete random variables - density and mass function: Expectation, Variance, properties and examples - Binomial, Poisson. Continuous distributions: Normal; Determination of Mean, Variance and standard deviation of the distributions, fuzzy sets, fuzzy and multivalued logic.

Optimization Techniques: Maxima and Minima of functions of several variables, Lagrange Multipliers, Constrained and Intelligent techniques,

Sampling theory : Central Limit Theorem, Difference Between Two Sample Proportions, Sample Mean and Variance, Sample Proportion, Sampling Distributions, Sampling Procedures, Statistics for Normal Random Variables Confidence interval, Testing of Hypothesis, Goodness of fit.

Linear Algebra: n- dimensional Euclidean spaces, linear transformation, scalar and vector products, Matrices and determinants, Eigen values and Eigen vectors, Generalised inverses.

Numerical Methods: Numerical Solution of nonlinear equations, Direct and iterative methods to solve system of linear equations, Numerical integration – Trapezoidal and Simpson's rule, Ordinary and partial Differential equations, Interpolation, Splines and curve fitting

Text Books

1. Stewart, J., Calculus: Early Transcendental, 5th ed., Brooks/Cole (2007).
2. Kreyszig, E., Advanced Engineering Mathematics, 9th ed., John Wiley (2005).

Suggested Reference Books

3. K B Datta: Matrix and Linear Algebra.
4. S.S Rao, Optimization Theory and Applications, Wiley eastern, 1984.
5. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, 6th edition, 2016

SEMESTER- II

1. Machine Learning for Geoinformatics (3-0-0) 3 credits

Basic concepts of machine learning and Pattern recognition concept: Application and importance in Geoinformatics - Supervised learning : Bayes concept, Supervised learning techniques including decision tree, artificial neural networks, support vector machines, Convolution neural network - Features : spectral, spatial , textural feature, feature space , 3D features - Feature reduction , feature selection, (PCA, LDA, etc) - Accuracy assessment : Different assessment methods - Unsupervised learning : Different types : Partitioning based technique, Density based technique - Semi-supervised learning techniques, object based classification, - Introduction to Deep learning: Deep learning architectures

Text books:

1. Pattern Classification Duda, Richard O, Hart Peter, David G Strok, 2000
2. Pattern Recognition and Machine learning Christopher M Bishop 2006
3. Deep learning by Ian Goodfellow, Yoshua Bengio,Aaron Courville, MIT Press, 2016.

References

1. Machine Learning, Tom Mitchell, McGraw Hill, 1997
2. Machine Learning for Spatial Environmental Data: Theory, Applications, and Software (Environmental Sciences: Environmental Engineering) 1st Edition Mikhail Kanevski,VadimTimonin,Alexi Pozdnukhov

2. Analysis and Modelling of Geospatial Data (3-0-0) 3 credits

Spatial data representation – discrete Euclidean plane/ geometric domain/ discretisation of arcs – spatial object domain: vector data models: spaghetti, arc – node , DCEL – field based model: tasselled representation, triangulation, Voronoi, Delaunay triangulation – geometric algorithms, topological and set based algorithms – network analysis, traveling salesperson algorithm – spatial analysis: interpolation methods, deterministic, stochastic, geostatistics, spatial autocorrelation, semi-variogram, kriging, types of kriging – uncertainty and its assessment.

References:

1. GIS : A computing perspectives, Second edition by MichealWorboys and Matt Duckham CRC Press 2004

2. Geospatial analysis, 5th Edition – de Smith, Goodchild, Longley http://www.spatial analysisonline.com/html
3. Geostatistics for Environmental Scientists, Second Edition by Richard Webster and MargaratA . Oliver, John Wiley and Sons Ltd.

Elective Courses

1. Digital Photogrammetry and UAV Remote Sensing (3-0-0) 3 credits

Photogrammetry: Basics of geometric Optics, Camera calibration , CCD cameras, time delay integration, flight planning, Vertical aerial photographs: image measurement and correction, Parallax, Stereo model, Tilted photos - Rectification, Mathematical photogrammetric principles, Analog vs Analytical vs Digital models, Concepts of Orientation - Collinearity and Coplanarity -Image matching, Aerotriangulation, Photogrammetric outputs- ortho image - digital elevation model, SAR Interferometry, LASER mapping, virtual reality modelling
UAV RS: Concepts, Rules and Regulations, configuration of Sensor and platform, sensor calibration, UAV operation and Data acquisition methods, pre-processing techniques, mosaicking, ortho rectification and DEM, data quality, standards and accuracy assessment

Textbooks

1. Elements of Photogrammetry with Application in GIS, Fourth Edition -2014 by Paul R Wolf, Bon A. Dewitt, McGraw-Hill.
2. Kraus K.: Photogrammetry. Berlin: de Gruyter, 2007. ISBN 978-3-11-019007-6. (EN)
3. Introduction to Modern Photogrammetry by Edward M.Mikhail, JananS.Bethel& Chris McGlone, Wiley & Sons Inc,2000.
4. UAV-Based Remote Sensing Volume 1 &2 Edited by Felipe Gonzalez Toro & Antonios Tsourdos

2. Geodesy and Satellite Positioning (3-0-0) 3 credits

Introduction to geodesy, introduction to observational techniques, potential theory, interpretation of observed gravity anomalies, satellite equations of motion, reference frames, time systems, satellite orbital perturbations due to the gravity field, space-based geodetic methods, earth rotation variations, tidal variations, non-tidal variations of the gravity field.

Development of global surveying techniques, positioning and navigation with satellites, Reference systems: coordinate systems, time systems, satellite orbits: orbit description, orbit determination, orbit dissemination, satellite signalsGPS – reference systems, GPS services, GPS segments, GPS signal structure. GPS errors, DGPS concept, other Global/ regional positioning systems: GLONASS, GALILEO, Beidou, IRNSS, QZSS,etc -signal structure, segment ;satellite based augmentation systems (SBAS) - GAGAN, WAAS, EGNOS, MSAS ; CORS network , application of GPS

Textbooks

1. Geodesy for Geomatics and GIS Professionals by Elithorp and Findorff available from http://xanedu.proquest.com/originalworks/elithorp, 1-800-218-5971, ISBN 1-59399-087-1
2. Anderson, A. J., and A. Cazenave, Eds., Space Geodesy and Geodynamics, Academic Press, 1986.
3. Kaula, W. M., Theory of Satellite Geodesy, Dover, 2000.
4. Seeber, G., Satellite Geodesy: Foundations, Methods, and Applications, De Gruyter, 2nd Edition, 2003.
5. Introduction to GPS: The Global Positioning System, by Ahmed El-Rabbany, ARTECH House.
6. Understanding GPS: Principles and Applications by Elliott D.Kaplan, Artech House, 2005.
7. GPS: Theory, Algorithms and Applications by GuochangXu,Artech House, 2009.

3. Computational GIS (3-0-0) 3 credits

Data types and models – spatial and non- spatial data techniques in GIS – editing –Topology – database structure – Spatial analysis of vector and raster data models – Network analysis, optimization of path and events, facility location, simulation, prediction and modeling, hydrological analysis – Simple, Complex and Spatial regression interpolation methods – multidimensional (MD) data - spatial representation of data, visualization, and algorithms related to spatial processing – statistics vs machine learning

3D geospatial data - topology of 3D data – interpolation and transformation algorithms - 3D attribute data acquisition, source of data: field base, airborne, satellite, microwave and LiDAR - data input, editing, management – surface analysis - 4D / 5D multidimensional representation - Geovisualization - applications: virtual cities, emergency response, urban development, infrastructure management, transportation, Utilities modelling - Decision support systems, expert systems

Text Books

1. Introduction to Geographic Information Systems by Chang, K. (5th Ed.), McGraw Hill.
2. Geographic Information Systems and Science by Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, John Wiley & Sons Ltd.
3. GIS: A Computational Perspective 3rd Edition by Matt Duckham, Qian (Chayn) Sun, Michael F. Worboys, CRC Press,2024
4. Spatial Data Modelling for 3D GIS, Abdul-Rahman, Alias, Pilouk, and Morakot, Springer,2008.
5. Multi Dimensional Geographic Information Science, Raper, J. Taylor and Francis, 2000.
6. Spatial Tesselations – Concepts and Applications of Voronoi Diagrams (2ndEd.) by Okabe, A., Boots, B., Sugihara, K. and Chiu, S. N., John Wiley and Sons, 2000.

4. Geospatial standards and Web / Cloud GIS (3-0-0) 3 credits

Types of Geospatial data: based on scale, spatial data and database model, Data Quality – components of data quality – Interoperability – Data sharing – National Geospatial Data Infrastructure - Standards of data, geospatial data, data models, data formats - Quality Assessment and reporting

Web GIS, its Elements and architecture- Types of WebGIS services, map/data services and task oriented services – Geoportal architecture - Data/GIS/ application server, GIS Cloud, Cloud interface – MapServer/ GeoServer/ MapBender/ Open layers - Open Geospatial Consortium (OGC), OGC Geoserver standards – WMS, WFS, WMPS, metadata standards, standard data models – JSON, GeoJSON, KML, GML, SensorML, Location service - Protocols: HTTP, FTP, SMTP- Frontend & Backend programming : HTML, CSS, Javascript, python, PHP - Cloud data –Google Earth Engine, crowd sourcing, mobile mapping and applications.

References:

1. https://www.ogc.org/standards/
2. https://www.giscloud.com/
3. Pinde Fu, Jiulin Sun, Web GIS: Principles and Applications, 2011
4. Pinde Fu, Getting to Know Web GIS 5th Edition, 2022
5. Steven Holzner, "PHP: The Complete Reference" 1st Edition TATA McGraw Hill ,2008 ISBN: 9780070223622
6. Stefano Iacovella, Brian Youngblood "GeoServer Beginner's Guide" Packt Publishing , 2nd Revised Edition, 2017, ISBN-13: 978-1849516686
7. Scott Davis, GIS for Web Developers, Pragmatic Bookshell, 2007, ISBN: 0974514098
8. Anuj Tiwari, Kamal Jain, Concepts and Applications of WEBGIS, Nova Science Publishers,2017, ISBN-1536127795.

5. Quantitative Methods in Remote Sensing (3-0-0) 3 credits

Remote sensing data calibration, reflectance, radiance conversion, spectral reflectance and materials properties, deterministic methods, statistical, empirical methods, physically based methods, estimation of geophysical variables, forest growing stock, LST / SST, soil moisture, snow melt and runoff prediction, crop yield, rainfall, ocean chlorophyll and productivity, validation and spatial scaling.

Textbook

1. Quantitative Remote Sensing of Land Surfaces by Liang S., Wiley-Interscience Publishers, 2003

6. Active Remote Sensing (3-0-0) 3 credits

Electromagnetic radiation, waves and antenna systems - phase, coherence - emission laws, microwave radiometry - interaction of microwave with atmosphere and earth features - Passive and active microwave sensing, sensors - Passive Remote sensing - atmospheric sounding and imaging, Active remote sensing - concept of Synthetic Aperture Radar (SAR), radar equation, range and azimuth resolutions, radar image interpretation, SAR image distortions- Geometric,

Speckle, Multilook, Doppler effects. Microwave scattering of land surface, SAR interferometry (InSAR), Polarimetric and Differential – Applications
LIDAR system components, characteristics of LIDAR data, LIDAR remote sensing platforms- airborne platforms, spaceborne platforms, ground-based platforms, bathymetric mapping systems, registration of LIDAR data,LIDAR filtering, DTM generation, point cloud processing, building extraction, forestry- LIDAR and forests, measuring forests with LIDAR, basic forest metrics, 3D urban modelling, mobile LIDAR mapping, fusion with other sensors, Applications

References:

1. Introduction to Microwave Remote Sensing by Iain H. Woodhouse, CRC, 2004.
2. Polarimetric Radar Imaging. From Basics to Applications by Lee, J.-S. andPottier, E., CRC Press, 2009.
3. Topographic Laser Ranging and Scanning, Principles and Processing, Shan, J. and C. Toth, Taylor & Francis, 2nd edition. 2018.
4. LiDAR Remote Sensing and Applications Pinliang and Qi Chen 2018 CRC Press

7. Hyperspectral and Thermal Remote Sensing (3-0-0) 3 credits

Reflectance spectroscopy, dimensionality reduction, feature selection, subspace modelling, endmember extraction, hyperspectral band ratios and vegetation indices, hyperspectral classification methods, target detection, spectral unmixing, spectral libraries, applications of hyperspectral remote sensing

Thermal Properties: Conductivity, specific heat, Heat capacity, thermal diffusivity and thermal inertia – Energy transformation - Radiant and Kinertic Temperature – Black body - Planck law, the Stefan-Boltzmann law, Wein's displacement law Kirchhoff's law – Radiative transfer model – emissivity – causes of emissivity

Textbooks

1. Hyperspectral Remote Sensing by Michael T Eismann, SPIE, 2012

2. Hyperspectral Data Exploitation: Theory and Applications by Chein-I Chang, Wiley& Sons Ltd. 2007

3. Techniques and Applications of Hyperspectral Image Analysis by Hans F. Grahn and Paul Geladi, Wiley & Sons Ltd.

8. Computer Vision and Advanced Image Processing (3-0-0) 3 credits (offered by Department of Avionics)

Image Formation Models, Monocular imaging system, Orthographic & Perspective Projection, Camera model and Camera calibration , 3D scanning, 3D from RGBD data, Binocular imaging systems Image Processing and Feature Extraction, point cloud processing, Triangulation and partitioning, range search, Structure from motion, Shape Representation and

Segmentation , Deformable curves and surfaces , Snakes and active contours , Fourier and wavelet descriptors, , Multiresolution analysis (wavelets, curvelets, countourlets, shearlets), Object recognition, Hough transforms and other simple object recognition methods , Shape correspondence and shape matching, Shape priors for recognition, simultaneous localization and mapping, digital watermarking, content based image retrieval, image compression, image matching

References:

1. Richard Szeliski , Computer Vision: Algorithms and Applications , Springer, 2010
2. Computer Vision - A modern approach, D. Forsyth and J. Ponce, Prentice Hall ,2002
3. Introductory Techniques for 3D Computer Vision, by E. Trucco and A. Verri, Publisher: Prentice Hall,1998.
4. Robot Vision, by B. K. P. Horn, McGraw - Hill,1986.

8. Remote sensing and GIS for Environmental and Natural Resource Management (3- 0- 0) 3 credits

Role of remote sensing in agriculture, soil, water resources, geology and geomorphology studies. Spectral Signatures of vegetation soil, minerals - vegetation/soil/ mineral indices - application in agriculture: Crop production forecasting, assessment and monitoring of crop growth, - estimation of soil quality, mineral and nutrient contents, soil moisture content, pollution mapping - passive and active remote sensing methods -

Forest inventory and monitoring – species composition - forest fire forecasting - Environmental and Climate Change on of forest/ ecological system. Retrieval and modeling of biophysical, biochemical parameters - Biomass/ carbon accounting - environment impact assessment, environment degradation and pollution - Planetary studies- National missions on agriculture, forest, water bodies, soil and land use, geology.

References:

1. Remote sensing of vegetation: principles, techniques and applications. Hamlyn G. Jones and Robin A Vaughan, Oxford University Press, Oxford
2. Advances in Remote Sensing for Natural Resource Monitoring, Prem C. Pandey, Laxmi K. Sharma, 2021

9. Remote sensing and GIS for Atmospheric and Ocean Studies (3- 0- 0) 3 credits

State of the atmosphere; Main constituents of dry air, Vertical thermal structure of the atmosphere; Standard atmosphere; Hydrostatic equilibrium; Weather and its phenomena – Winds, cyclones, precipitation, hydrologic cycle; Surface weather and vertical structure; Elements of radiative transfer in atmosphere- Basic quantities, Blackbody radiation – basic

laws - Radiative transfer equation, Physics of Gaseous absorption, emission, Scattering, Solar radiation and surface reflection; Radiation balance;

Satellite and radar meteorology; Meteorological satellite instrumentation - Operational polar orbiting and geostationary satellites, weather sensors – passive radiometry, spectroscopy and occultation; active - Radar basics, conventional, radar and satellite rainfall measurements, , NEXRAD system, Image interpretation; Visible infrared and water vapor imagery, Spectral properties, inversion methods and Image processing techniques for atmosphere and ocean: calibration, validation and quality control for weather data products - applications of ground-based and satellite remote sensing for studies of e.g. temperature, composition, aerosol and cloud properties, precipitation, as well as the properties of sea surface and sea ice : chlorophyll, sea surface temperature, carbon sequestration.

References

1. Atmospheric science – An introductory Survey – John M Wallace and Peter V Hobbs. 2nd edn, 2006
2. Satellite meteorology: an introduction -Kidder, Stanley Q., Thomas H. VonderHaar. (1995). San Diego, CA: Academic Press.
3. Satellite meteorology: online remote sensing guide. Prepared by WW2010, Urbana Champaign: University of Illinois. Online access: http://ww2010.atmos.uiuc.edu/(Gh)/guides/rs/sat/home.rxml
4. Burrows J.P., Borell P., and Platt U., The Remote Sensing of Tropospheric Composition from Space, Springer
5. Satellite Oceanography: An Introduction for Oceanographers and Remote Sensing Scientists, By I. S. Robinson. (Chichester: Ellis Horwood Ltd, 1984).\

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