RANGING TECHNIQUES
ENGE 354

Lecture : 4 **Year : III**
Tutorial : 0 **Part : II**
Practical : 3/2

Course Objectives:
The objective of this course is to introduce the fundamental principles of active remote sensing techniques, including LiDAR and RADAR imaging, used in geomatics applications. The course emphasizes airborne laser scanning (ALS) data acquisition and processing, along with their practical applications in real-world mapping, terrain modeling, and engineering problem-solving within the field of geomatics.

1 Introduction (2 hours)

1.1 Basic ranging techniques
 1.1.1 LiDAR
 1.1.2 RADAR
 1.1.3 Other techniques (SONAR, SLR, LADAR, VLBI)
1.2 Comparison among various techniques
1.3 Importance of ranging technique

2 LiDAR (3 hours)

2.1 LiDAR and its platform
2.2 LiDAR terminologies
2.3 Laser scanning systems
2.4 LiDAR supported file formats

3 Airborne Laser Scanning (ALS) Technology (8 hours)

3.1 Operating principles
 3.1.1 Electromagnetic spectrum: Light spectrum; Laser emission; Absorption and reflectance
 3.1.2 Features of laser beam: Laser pulse characteristics; Laser pulse repetition frequency; Laser beam divergence; Laser pulse energy distribution
 3.1.3 Laser Ranging: Laser beam, target interaction
3.2 Key elements of ALS technology: Laser, LIDAR, and working principle (Laser, LIDAR, ALS)
3.3 Full-waveform LIDAR: History and background, applications, wave form processing

4 Visualization of ALS Data (4 hours)

4.1 Visualization of laser scanner data
  4.1.1 Imaging height data: Imaging point clouds, shading, coloring, perspective views
  4.1.2 Imaging reflectance data
  4.1.3 Point cloud viewing
4.2 Visualization for error analysis
  4.2.1 Visual inspection: Data completeness, systematic height errors, scanner artifacts, systematic reflectance errors, quality of filtering, quality of extracted features
  4.2.2 Measurements in strip overlap
  4.2.3 Comparison to reference height data
  4.2.4 Comparison to maps

5 Mobile and Terrestrial Laser Scanning (MLS and TLS) (4 hours)

5.1 Principles
5.2 Properties of TLS/MLS
5.3 Point cloud properties
5.4 Devices and platforms
5.5 MLS and TLS registration
5.6 Applications

6 Segmentation of Point Clouds (3 hours)

6.1 Extraction of information from point clouds
6.2 Segmentation algorithms
6.3 Extraction of smooth surfaces: Scan line segmentation, surface growing, surface merging, voxel space analysis
6.4 Extraction of parameterized surfaces: Planes, cylinders, spheres

7 Applications of LIDAR (5 hours)

7.1 Digital elevation model
7.2 Forestry: Laser interaction with tree canopies; Forestry measurements obtainable with LiDAR; Forest inventory parameters; Biomass / carbon parameters; Leaf-on versus leaf-off; Change detection for forestry applications
7.3 Building extraction and reconstruction
7.4 Natural hazards: Flood; Earthquakes; Soil erosion and landslide

8 Radar Imaging Technology (8 hours)

8.1 Transmitting and receiving polarized radiations
8.2 Radar imaging system
  8.2.1 Pulse compression radar

- 8.2.2 Range resolution and resolution along track direction
- 8.2.3 Synthetic aperture radar (SAR) and its governing equation
- 8.2.4 Swath width and bounds on pulse repetition frequency
- 8.2.5 The radar resolution cell
- 8.2.6 Squint and spotlight operating mode

8.3 Radar target interaction

- 8.3.1 Radar equation
- 8.3.2 Radar cross section: Theoretical expression, cross section in dB
- 8.3.3 Distributed targets, scattering coefficient in dB and polarization dependence
- 8.3.4 Scattering matrix
- 8.3.5 Target vectors
- 8.3.6 Covariance and coherency matrices
- 8.3.7 Measuring the scattering matrix and relating to stokes vector
- 8.3.8 Polarization synthesis and compact polarimetry

9 Radar Image Interpretation (8 hours)

9.1 Analytical complexity

9.2 Visual Interpretation: Role of incidence angle, wavelength and polarization

9.3 Quantitative analysis of radar image data

- 9.3.1 Overviews of methods
- 9.3.2 Features available for radar quantitative analysis
- 9.3.3 Application of standard classification techniques
- 9.3.4 Classification based on radar Image statistics: Maximum likelihood approach; Handling multi-look data; Relating scattering and covariance matrices; Stokes scattering operator

9.4 Interpretation based on structural models

- 9.4.1 Polarization phase difference
- 9.4.2 Structural decomposition: Scattering matrix, Freeman- Durden approach, Cloude- Pottier approach

Practical (22.5 hours)

1. Visualization and error analysis of ALS, MLS and TLS Data
2. Building facades extraction
3. Forest inventory parameters estimation
4. Post-disaster damage assessment i.e., flood, earthquake
5. Radar image visualization
6. Radar image classifications

Final Exam

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

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

* There may be minor deviation in marks distribution.

References

1. Wang, C., Yang, X., Xi, X., Nie, S., Dong, P. (2024). Introduction to LiDAR remote sensing. CRC Press.
2. Richards, J. A. (2009). Remote sensing with imaging radar. Springer.
3. Srivastava, P. K., Gupta, D. K., Prasad, R. (Eds.). (2022). Radar remote sensing: Applications and challenges. Elsevier.
4. Renslow, M. S. (Ed.). (2012). Manual of airborne topographic LiDAR. Bethesda, MD: American Society for Photogrammetry and Remote Sensing.
5. Vosselman, G., Maas, H.-G. (Eds.). (2010). Airborne and terrestrial laser scanning. CRC Press.