S5 – Remote Sensing

Content

- This document is a high-level curriculum design which captures the key principles, competencies, learning outcomes and syllabus items proposed for the updated curriculum specific to S5 – “Remote Sensing”.

S5: REMOTE SENSING

LEARNING OBJECTIVES

- **Establish the foundational knowledge in remote sensing required to be a surveyor**
- **Support subsequent learning**

Key Principles	Motivation	Syllabus Items	Competencies/Learning Outcomes
Introduction to Remote Sensing	Surveyors need to understand remote sensing fundamentals as remote sensing is a frequently used tool for data collection	● The Electromagnetic Spectrum ○ Characteristics of electromagnetic waves ○ Atmospheric windows ○ Scattering ○ Reflection ○ Absorption/emission ● Data Models ○ Vector Data ○ Raster Data ○ IFOV and FOV ○ Vector vs Raster	**Competencies** ● Describe sensors, data collection processes and data manipulation to support decision making for survey projects ● Identify benefits and limitations of remotely sensed data ● Describe and explain characteristics of electromagnetic waves, and interaction with the atmosphere and objects on ground ● Describe the fundamental principles of remote sensing and review their application to surveying the advantages and disadvantages of the two data models ● Describe and explain the differences and concepts of vector and raster data **Learning Outcomes** ● Compare different type of sensors data. ● Explain fundamental concepts of remote sensing and data models ● Choose appropriate raster data for survey projects

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Remote Sensing **Platforms**	Remote sensing technology is used by surveyors to do their work; surveyors need to be familiar with the characteristics of available remote sensing platforms	● **Advantages, limitations, and applications of remotely sensed data** ● **Ground based platforms (Handheld devices, Vehicles, tripods, and towers)** ○ Use of ground-based platform ○ Setting up ground-based platforms ○ Advantages and disadvantages of all platforms ● **Airborne platforms (RPAS, and Aeroplanes)** ○ Mission planning ○ Calculating flight altitude ○ Calculating number of flight lines ○ Calculating number of images per flight line ○ Calculating platform speed ○ Calculating image scale ● **Space borne platforms (Satellites)** ○ Law of gravitation ○ Circular motion and satellites ○ Kepler's laws ○ Satellite orbit classification	**Competencies** ● Describe and explain characteristics and theory of remote sensing platforms ● Recognize the appropriate remote sensing solution for the survey ● Describe and explain the fundamentals of satellite motion **Learning Outcomes** ● Review appropriate platform and sensor to capture relevant data to specific projects ● Identify the data requirements for the specific project ● Practice airborne mission planning

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Key Principles	Motivation	Syllabus Items	Competencies/Learning Outcomes
Passive Remote Sensing: Sensors	Remote Sensing technology is used by surveyors to do their work; surveyors must understand basic technology and characteristics of passive imaging sensors	● **Cameras and Scanners** ○ Characteristics, geometry, benefits, and limitations of a digital image ○ Single and stereo image mode ● **Image Resolution** ○ Spatial resolution ○ Spectral resolution ○ Radiometric resolution ○ Temporal resolution	**Competencies** ● Describe, explain, and illustrate the geometry and characteristics of camera and scanner sensors. ● Describe the various types of resolutions and demonstrate their role in data quality captured by cameras and scanners **Learning Outcomes** ● Identify and review the right sensor/data to meet the survey requirements ● Demonstrate the role of resolution in data quality captured by cameras and scanners

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Passive Remote Sensing: Image Processing and Manipulation	Surveyors need to understand digital image processing and manipulation to understand what they are looking at. Used for 3D spatial data collection and 2/3D object reconstruction and mapping	● **Image Processing** ○ Atmospheric corrections ○ Geometric corrections ○ Radiometric corrections ○ Derivations of 3D object metric information from imagery ○ Measurement and correction of image coordinates ● **Image Enhancement** ○ Contrast stretch ○ Histogram equalization ○ Digital filtering ● **Band Composite** ○ Band combinations of satellite imageries and their applications ● **Image Manipulation** ○ Image rectification ○ DEM and orthoimage generation ○ Coordinate transformations ○ Mathematical models for sensor and for sensor to object relationships ● **Statistical Characteristics** ○ Resampling ○ Image matching ○ Close range photogrammetry	**Competencies** ● Describe concepts, limitations and benefits of basic image processing, enhancement, and data manipulation techniques ● Describe the mathematical models relating sensor space to object space ● Describe and apply DEM and orthoimage generation **Learning Outcomes** ● Demonstrate basic image corrections, image enhancement, and band composites ● apply the mathematical models relating sensor space to object space ● Test calculations to determine print scale, and size ● Apply DEM and orthoimage generation

		○ Digital photogrammetry, epipolar geometry, image matching and 3D reconstruction	

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Key Principles	Motivation	Syllabus Items	Critical Thinking (must be able to think through) Competency/Learning Outcomes
Passive Remote Sensing: Image Analysis and Interpretation	Surveyors need to understand the outcome of image classification to for product preparation	● **Visual Interpretation** ○ Defining objectives ○ Selecting data ○ Interpretation key ● **Digital Interpretation** ○ Unsupervised image classification ○ Supervised image classification ○ Object oriented image classification	**Competencies** ● Describe and discuss image analysis and interpretation concepts and techniques. ● Identify appropriate data **Learning Outcomes** ● Implement and compare visual and digital imager interpretation ● Apply and compare the different types of image classification ● Identify, describe, and apply common image analyses and interpretation techniques

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Passive Remote Sensing: Applications	Surveyors use remote sensing images and need to be able to leverage remote sensing data for various applications, including base mapping	● **Passive Remote Sensing Applications** ○ Vegetation analysis and mapping using NDVI (Normalized Difference Vegetation Index) and other vegetation indices ○ Land-use/Land-cover applications including built up area mapping, and surface water mapping ○ Forest fire detection and burn area mapping ○ Temporal analysis for change detection ○ Principal Component Analysis (PCA) ○ Topographic mapping	**Competencies** ● Identify and describe common remote sensing data applications ● Identify, describe, and apply common applications of passive remote sensed data ● Identify, differentiate, and apply temporal image analysis methods **Learning Outcomes** ● Apply and compare the various vegetation indices ● Implement and analyse land use/land cover mapping types

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Active Remote Sensing Sensors and Applications: LIDAR	Active remote sensing sensors like LIDAR are becoming increasingly popular in geomatics and surveying industry. Surveyors need to know these technologies and their application LIDAR is used by surveyors for a range of products	• **Fundamentals of LIDAR technology** ○ Components of LIDAR Systems ○ Determination of 3D Coordinates from LIDAR Systems ○ Calibration ○ Processing of point cloud data ○ 3D point cloud co-registration • **Ground based LIDAR Systems** ○ (Terrestrial Laser Scanners–TLS) technology ○ Mission planning and data acquisition using TLS ○ Applications of TLS (Scanning of buildings and structures) • **Airborne LIDAR Systems** ○ Airborne LIDAR Technology (GNSS, IMU, Laser Scanner) ○ Mission planning and flying operation ○ Geolocation Process ○ Sources of Data Errors ○ Applications of Airborne LIDAR systems (DEM, DSM, volume calculation, view shed and watershed area determination) • **Spaceborne LIDAR System** ○ ICESAT-2 ○ GEDI • **LIDAR Applications**	**Competencies** • Identify and describe common LIDAR systems, including their benefits and limitations • Describe and explain, LIDAR technology, and its applications • Describe and explain various coordinates systems involved and how the final object coordinates are determined from the LIDAR system • Describe beam reflection mechanisms • Identify and describe the different laser range finding methods **Learning Outcomes** • Review and Interpret point cloud data and calculate coordinate precision • Process point cloud data • prepare mission plan and data acquisition for a project • Generate a DTM for a project • Calculate open pit volumes for a project

		○ Use in Land Surveying ○ Generation of Digital Terrain Models (DTMs) ○ Open Pit Volume Calculations ○ Transportation Expansion	

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Active Remote Sensing Sensors and Applications: RADAR	RADAR remote sensing sensors offer a unique advantage of almost all weather, and day/night data acquisition. Surveyors need to know these technologies and their applications, for example in DTM generation using InSAR Ground Penetrating Radar (GPR) Increasingly being used for detecting and mapping of 3D underground utility infrastructure	• **RADAR Technology** ○ RADAR wavelengths (Bands) ○ Polarization ○ Interference ○ Advantages and Limitations of RADAR • **Side looking RADAR (SLAR)** ○ Viewing geometry ○ Spatial resolution (Slant range, cross track, and along track resolution) ○ Image characteristics (Shadow, foreshortening, layover effect, and speckle noise) • **Synthetic Aperture RADAR (SAR)** ○ SAR Technology ○ SAR Applications ○ SAR Interferometry (InSAR) • **Ground Penetrating Radar (GPR)** ○ Physical principles, components of GPR ○ Wavelengths/frequencies, penetration, and resolutions ○ Sources of error ○ Airwaves ○ Line scans ○ Grid scans ○ Data understanding and interpretation ○ Dielectric constant of materials	**Competencies** • Identify and explain basic principles of active imaging, including advantages and limitations • Describe and explain the fundamentals and impact of image geometry on image appearance • Describe the fundamentals of different sources of RADAR data • Describe the different characteristics of optical and RADAR data • Describe, explain, and demonstrate RADAR (SAR and SLAR) technology, and its applications • Describe the GPR fundamentals • Explain the localization of objects **Learning Outcomes** • List advantages and limitations of RADAR Technology as well as which projects this would be most beneficial • Inspect and interpret detected objects • List GPR applications • Apply and practice GPR surveys • Review and interpret GPR images

		○ Construction of 3D images/tomographic images ○ Object detection and locations ○ GPR data interpretation ○ GPR applications ● **Interpretation of RADAR Imagery** ● **Applications** ○ Agriculture ○ Forestry ○ Mining	

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Active Remote Sensing Sensors: SONAR Technology and Hydrography	Hydrography provides up-to-date nautical charts for safe navigation and the protection of the marine environment. It focuses on the measurements of physical characteristics of water bodies and adjoining coastal areas Surveys that involve water bodies and offshore require knowledge of SONAR, which is actively used in bathymetric surveys	• **Principles and Processes of Hydrographic Surveying and SONAR Technology** ○ Sound waves and their characteristics ○ Refraction of sound waves ○ Propagation of sound waves in water ○ Tidal fundamentals, measurements, streams, and currents ○ Non-tidal water variations ○ Vertical Datum, elevation, and soundings, MLW, MLLW, MHW • **SONAR Systems** ○ Single Beam Echo Sounders (SBES) ○ Narrow Beam and Wide Beam Sounders ○ Multibeam Echo Sounders (MBES) ○ Side Scan Sonars (SSS) ○ Sonar Data Processing • **Elements of Hydrographic Surveys** ○ SONAR survey requirements ○ Mission planning ○ Surveys in support of river crossings and engineering ○ Surveys in support of port management and coastal engineering	**Competencies** • Describe and explain the principles and processes of hydrographic surveying • Describe and explain the concepts of sound wave propagation, acoustic system parameters, the physical properties of water and its impact on the speed of sound • Describe and explain hydro-acoustics concepts • Describe and explain tidal fundamentals • Describe and explain the ellipsoid-based water depth determination • Describe and explain the concepts of tides' generation, how they are measured and parameters affecting non-tidal water level variations • Describe and explain of sonar sensors, single beam and multibeam echo sounders and relevant calibration processes • Describe, explain side scan sonars technology, and its applications • Describe and explain ellipsoidally referenced hydrographic surveys **Learning Outcomes** • Apply the principles of horizontal and vertical positioning, datums, methods used for depth measurements, heave compensation systems and principles of motion sensors • Plan and manage hydrographic surveys and evaluate hydrographic data • Calculate water depths

		○ Ellipsoidally referenced hydrographic surveys ○ Nautical charting and marine navigation ○ SONAR data applications ○ Data quality, errors, uncertainty ○ Mapping	

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Information from optical and range data: **-Photogrammetric Computer Vision**	● Used for 3D spatial data collection and 2/3D object reconstruction and mapping ● Used in UAV and mobile mapping applications	● **Camera calibration, measurement, and correction of image coordinates** ○ Coordinate transformations ○ Mathematical models for sensor and for sensor to object relationships collinearity, epipolar geometry, coplanarity, space resection, space intersection ● **Sensor poses estimation, photogrammetric bundle block adjustments, structure from motion, visual odometry**	**Competencies** ● Describe and explain the use of optical and range data for 3D reconstructions and modelling ● Identify, describe, and apply the proper mathematical models ● Identify and apply the proper approach for sensor pose estimation ● Explain geometric and mathematical photogrammetric principles and the theory and procedures of photogrammetric orientations. ● Explain and apply the principles and mathematical models for DEM and orthoimage generation ● Explain and apply photogrammetric planning and identify control requirements. ● Identify and apply the use of photogrammetric principles for various applications ● Identify and explain the different camera calibration procedures **Learning Outcomes** ● Explain the concepts and uses of optical data for spatial data collection (3D position) and the 2/3D object reconstruction from optical and range measurements. ● Explain and apply the mathematical photogrammetric theory and procedures of photogrammetric triangulation (indirect, integrated sensor, direct, orientations). ● Examine the camera calibration parameters required for a photogrammetric project ● Calculate approximate coordinate precision from aerial imagery

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Mobile Mapping Systems Applications	Used for 3D spatial data collection and 2/3D object reconstruction and mapping Used in UAV and mobile mapping applications	• Mobile mapping, Direct georeferencing, Simultaneous Localization and Mapping (SLAM) ○ 3D reconstruction from optical and range ○ Image rectification ○ DEM and orthoimage generation • Close range photogrammetry, Vanishing geometry • Mobile mapping systems • Navigation and mapping sensors • Reference coordinate systems and transformations of navigation and mapping sensors used for mobile mapping systems • Sensor co-registration including bore sighting and lever arm calibration	**Competencies** • Describe and explain the mobile mapping systems and their role and uses in geomatics. • Describe and explain calibration of mobile mapping systems • Explain and apply the navigation and mapping sensors used on-board mobile platforms. • Identify and describe the coordinate systems and properly apply the coordinate transformations for mobile mapping applications. **Learning Outcomes** • Apply and analyze methods for platform and sensor localization (position and orientation) • Apply and analyze methods and computational algorithms for processing data captured by mobile platforms. • Design, plan and evaluate mobile mapping missions