UNIVERSITY OF WATERLOO | FACULTY OF ENVIRONMENT
Department of Geography and Environmental Management

GEOG-371 Advanced Remote Sensing Techniques (0.5 CU)
Fall 2019
(version 20190901)

Instructor	**Course Assistant**	**Teaching Assistants**
Dr. Richard Kelly Room: EV1-320, ext 35451 E-mail: rejkelly@uwaterloo.ca ***Office Hours***: Tues. 4:30-6pm Location - EV1-320	Mike Lackner (MAD) Mapping Analysis and Design E-mail: mlackner@uwaterloo.ca ***Office Hours***: by appointment	Sheryl Chau Email: shmchau@uwaterloo.ca ***Office Hours:*** Justin Murfitt ***Office Hours***: Email: jmurfitt@uwaterloo.ca

Lectures	**Labs**	
Wednesday 12:30-2:20 pm RCH 302	Fri. 10:30am-12:20pm (101) Tues. 2:30-4:20pm (102)	Fri. 1:30-3:20pm (103) Tues. 12:30-2:20pm (104)

Course Outline

Overview

Remote sensing is an important technique for environmental monitoring and scientific analysis. Remote sensing is used for global change studies (e.g. environmental change) and for more local scale applications such as urban landscape mapping, precision farming and many other day-to-day activities. This course introduces and develops advanced remote sensing information extraction techniques that are increasingly used by municipalities, environmental consultancies, federal agencies and industry. It builds on the fundamentals of remote sensing science and Earth observation systems (e.g. optical and microwave systems) introduced in GEOG271. It focuses on current information extraction processes used by government and non-government organizations and by professional Earth and Environmental system science researchers to provide information about human and physical environments.

Course Description

This course focuses on the use of remote sensing to map key environmental states. Emphasis is placed on the application of remote sensing methods and data processing for analysis of physical and human environments. The course presents advanced techniques for further remote sensing and Earth observation work and gives the student a strong basis from which to develop their analytical skills.

Course Learning Goals:

- Build upon material introduced in GEOG 271 and GEOG 181/187/165.
- Deepen understanding of the physical principles underlying remote sensing system measurements.
- Develop expertise in applying appropriate image processing and data modeling techniques for selected applications (land cover classification, urban form mapping, Earth system mapping).
- Be able to understand the uncertainties throughout the information extraction process.
- Develop an awareness of current remote sensing themes through directed readings.

- Understand how a remote sensing product can be integrated in a GIS project framework.
- Gain and develop a strong working knowledge of standard image processing software for remote sensing applications.

Learning Outcomes

At the end of the course, students will have a stronger understanding of the remote sensing approach to monitoring and mapping the Earth surface. Students will understand and be able to apply judiciously a range of information extraction methods and be able to quantify the error/uncertainty in the methods used. Students will also be ready to undertake GEOG471, the Remote Sensing Project.

Pre-requisite knowledge

It is essential that you can recall your knowledge from GEOG165/GEOG181/GEOG187 and GEOG271 as these courses form the foundations for GEOG371.

Weekly lectures

Each week, a lecture will be delivered that presents new material to students. Where appropriate you will be encouraged to participate in what should be a supportive learning environment. You may use a laptop or device to make notes *only* if you have documented permission from AccessAbility Services. Otherwise, laptops and devices must be shut down during the course of the lecture. Recent research indicates that students retain knowledge better if they write notes with pen and paper rather than note taking on a computer[1].

Weekly Labs

- Access to the Geddes computer lab is restricted by code (1 3 2 4) to those enrolled in particular courses including this one. Food and/or drink are NOT permitted in the Geddes lab (EV2-1002A).
- *Students are responsible for maintaining their own backups of their work.* There are a number of options available for backing up your work, including the network drive for FE students and Office 365 OneDrive cloud storage. It is suggested that you keep two copies of your work in separate locations. Remember that you are only as far ahead as your latest backup!

Student Evaluation and Progress

(1) Major lab assignments (4)	65%
(3) Minor lab practicals (3)	15%
(3) Mid-term test	20%
Total	**100%**

(1) Four major lab assignments, A1-A4 (65%)

- Major graded lab assignments will form 65% of the final grade. Each assignment builds on the exercises in the previous 2-3 weeks. The shading in the course outline below indicates the substantive components of each lab.
- *Each lab assignment is to be completed and handed in hardcopy form at the start of their lab in the following week. Students must also submit their digital copy via the drop box on LEARN*. It will be graded and returned to the student within two weeks of submission. Late student submissions will take longer to grade and return.

[1] Mueller and Oppenheimer (2014) The Pen Is Mightier Than the Keyboard: Advantages of Longhand Over Laptop Note Taking, *Psychological Science,* https://doi.org/10.1177%2F0956797614524581.

- A cover sheet must be completed with all assignment hardcopy submissions (see below).

Assignment sanctions. It is in your interest to keep to the deadlines for assignment submission. Late work will be sanctioned with 10% deducted from the assignment for each week or part thereof for which the work is late. Sanctioned work will receive no feedback. Authorized medical notes, or requests that have been granted by the instructor ***prior to the deadline*** are the only valid way of obtaining an extension.

(2) Three minor lab practicals. MLP1-MLP3 (15%)

- There will be three minor lab practicals that you will need to complete in lab that will be assessed either in the lab (week 1) or using a short answer format (weeks 10 and 11).

Unseen written mid-term test (20%)

- An unseen written mid-term test is set for 2 November *in class*. Students will choose to answer two essay questions out of five in 1.5 hours. Questions will be based on material and readings covered in the first five weeks of the course.

Students are **required** to attend a five-minute meeting with the instructor in the third and fourth weeks of the course to discuss progress and any issues that might have arisen. Office hours or lab times can be used for this purpose. Any more in-depth issues may be dealt with through an appointment with the TAs or the instructor.

Academic Integrity

Please make sure that you are familiar with what constitutes academic integrity from the University's excellent web site http://www.lib.uwaterloo.ca/ait/. You should familiarize yourself with this web site. Sanctions may be applied to submitted work where the rules are not followed.

University of Waterloo LEARN Course Environment:

This course uses the LEARN course environment for course material dissemination and information exchange. It will also be used for submitting coursework. LEARN is a web-based course management system that enables instructors to manage course materials (posting of lecture notes etc.), interact with their students (drop boxes for student submissions, on-line quizzes, discussion boards, course e-mail etc.), and provide feedback (grades, assignment comments etc.).

Logging Into LEARN

Since LEARN is a web-based system, you will need a browser. Once you have started up your browser, type in the following URL: http://uwaterloo.ca/learn-help Please note that announcements regarding LEARN (service outages etc.) are posted; it is a good idea to check these regularly.

Getting Help

A LEARN student guide can be found at **http://uwaterloo.ca/learn-help**.

Course Readings

Recommended Text:

Jensen, J.R., 2015. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Fourth Edition. Prentice Hall, Toronto, Canada, 623pp. Online book is available to rent at a more cost effective price.

Other Useful Remote Sensing Textbooks:

Campbell, J.B., 2011 *Introduction to Remote Sensing* (Fifth Edition), The Guilford Press, 626pp.

Jensen, J.A. 2006 *Remote Sensing of the Environment: An Earth Resource Perspective*, Second

Edition, Prentice Hall, Toronto, Canada, 592pp
Lillesand, T.M., R.W. Kiefer, and J.W. Chipman. 2015, *Remote Sensing and Image Interpretation* (Seventh Edition), John Wiley & Sons, Canada, 736pp.
Mather, P.M. and M. Koch, 2011 *Computer Processing of Remotely-sensed Images*, (Fourth Edition). John Wiley & Sons Canada.
Mather, P.M. and B. Tso. 2009 *Classification Methods for Remotely Sensed Data*, Second Edition, CRC Press 376pp.
Richards, J.A. 2013 Remote Sensing Digital Image Analysis An Introduction (5th Edition). Springer. *Available Online through UW Library Service.*

This course deals with advanced remote sensing and digital information extraction methods. The recommended text (Jensen, 2015) covers many image processing aspects in the course with others covered by the other texts. For students planning to take GEOG 471, it is recommended that you obtain a copy of this text, as it will be a useful reference in this project course.

Lecture Outline

Week (date)	Lecture	Lab (101,102,103,104)	Grade
1(4/9/2019)	Course Introductions. RS observations: spatial and temporal resolution.	**Minor Lab Practical #1** Introduction to ENVI: image contrast enhancement, spatial filters.	MLP1 (3%)
	Readings: Jensen (2015), Chapters 1 & 2. Grecchi, R.C. *et al.* (2017). An integrated remote sensing and GIS approach for monitoring areas affected by selective logging: A case study in northern Mato Grosso, Brazilian Amazon. *Int J Appl Earth Obs Geoinformation*, 61, 70-80. dx.doi.org/10.1016/j.jag.2017.05.001. Wang, K., Franklin, S. E., Guo, X., He, Y., & McDermid, G. J. (2009). Problems in remote sensing of landscapes and habitats. *Progress in Physical Geography*, *33*(6), 747–768. doi:10.1177/0309133309350121 Anderson, K. (2016) Integrating multiple scales of remote sensing measurement – from satellites to kites, Progress in Physical Geography, 40(2) 187-95. DOI: 10.1177/0309133316639175		
2(11/9/2019)	Image quality, geometric and radiometric correction.	Analyzing image quality, re-projecting data, and radiometric correction	A1 10%
	Readings: Jensen, (2015) Chapters 4 - 7 Smith, D.P. and S.F. Atkinson (2001) Accuracy of rectification using topographic map versus GPS ground control points. *Photogrammetric Engineering and Remote Sensing*, 67(5): 565-570. (TA593.A2 P5) Song, C., Woodcock, C., Seto, K., Lenney, M., & Macomber, S. (2001). Classification and change detection using Landsat TM data: when and how to correct atmospheric effects? *Remote sensing of Environment*, *75*(00), 230–244.		
3(18/9/2019)	Image enhancements and image transformations	TC, PCA, pan-sharpening	
	Readings: Jensen (2015) Chapters 5 & 8 Huete, A., Liu, H., Batchily, K., & van Leeuwen, W. (1997). A comparison of vegetation indices over a global set of TM images for EOS-MODIS. *Remote sensing of Environment, 59*, 440–451. Zhao, G. and Maclean, A.L. (2000) A comparison of canonical discriminant analysis and principal component analysis for spectral transformation, *Photogrammetric Engineering and Remote Sensing*, 66(7): 841-847. (TA593.A2 P5)		
4(25/9/2019)	Per pixel classification (supervised [MLC,RF,SVM])	Classification (MLC/RF/SVM)	A2 25%

	Readings: Jensen (2015) Chapter 9 Xie, Y., Sha, Z., & Yu, M. (2008). Remote sensing imagery in vegetation mapping: a review. *J. Plant Ecology* , *1:* 9–23. doi:10.1093/jpe/rtm005 Wu, W. and Shao, G. (2002) Optimal combinations of data, classifiers, and sampling methods for accurate characterizations of deforestation, *Canadian Journal of Remote Sensing*, 28(4): 593-600.	

Week (date)	Lecture	Lab (101,102,103,104)	Grade
5(2/10/2019)	Object-based image analysis (OBIA)	OBIA *PCI Geomatica* example	
	Readings: Jensen Chapter 9 Blaschke, T. (2010). Object based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing*, *65*(1), 2–16. doi:10.1016/j.isprsjprs.2009.06.004 Myint, S. W., Gober, P., Brazel, A., Grossman-Clarke, S., & Weng, Q. (2011). Per-pixel vs. object-based classification of urban land cover extraction using high spatial resolution imagery. *Remote Sensing of Environment*, *115*(5), 1145–1161. doi:10.1016/j.rse.2010.12.017		
6(9/10/2019)	**MID-TERM (1.5 hour)**	Accuracy Assessment	
	Readings: Jensen (2015) Chapter 13 Congalton, R. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37: 35–46. Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201. doi:10.1016/S0034-4257(01)00295-4		
7(16/10/2019)	**THANKSGIVING – NO LECTURES OR LABS**		
8(23/10/2019)	Lidar I Introduction to lidar RS	Bare Earth models, height comparisons & classification	
	Readings: Jensen (**2007**) Chapter 10. Lidar Remote Sensing		
9(30/10/2019)	Lidar II Lidar data processing	Field data collection (traditional and modern methods)	
	Readings: Jensen (**2007**) Chapter 10. Lidar Remote Sensing Weltz, M., Ritchie, J., & Fox, H. (1994). Comparison of laser and field measurements of vegetation height and canopy cover. *Water Resources Research*, *30*(5), 1311–1319. St-Onge, B., & Jumelet, J. (2004). Measuring individual tree height using a combination of stereo photogrammetry and lidar. *Canadian Journal of Forest Research*, 34(10), 2122–2130. doi:10.1139/X04-093 Special Issue: Photogrammetric Engineering and Remote Sensing March 2011 (Vol 77, No. 3) Various papers on lidar RS for forest biomass. Hellesen, T., & Matikainen, L. (2013). An Object-Based Approach for Mapping Shrub and Tree Cover on Grassland Habitats by Use of LiDAR and CIR Orthoimages. *Remote Sensing*, *5*(2), 558–583. doi:10.3390/rs5020558		A3 20%
10(6/11/2019)	Cloud-based processing **Reading**: Gorelick *et al.* (2017) Google Earth Engine: Planetary-scale geospatial analysis for everyone, *Remote Sensing of Environment, 202:18-27. http://dx.doi.org/10.1016/j.rse.2017.06.031*	**Minor Lab Practical #2** Cloud-based processing – the Google Earth Engine environment	MLP2 6%
11(13/11/2019)	Remote sensing with Open Source Systems - Python Notebooks **Reading**: TBA	**Minor Lab Practical #3** Image processing using scripting in Python.	MLP3 6%

Week (date)	Lecture	Lab (101,102,103,104)	Grade
12(20/11/2019)	Radar 12 Radar application	Radar lab 1	A4 10%
	Readings: Jensen (2007) Chapter 9 Rosenqvist, A., & Shimada, M. (2007). ALOS PALSAR: A pathfinder mission for global-scale monitoring of the environment. *IEEE Transactions on Geoscience and Remote Sensing*, *45*(11), 3307–3316. Kovacs, J. M., Vandenberg, C. V., Wang, J. and F. Flores-Verdugo (2008) The use of multipolarized spaceborne SAR backscatter for monitoring the health of a degraded mangrove forest. *Journal of Coastal Research* 24: 248-254. (doi:10.2112/06-0660.1)		
13(27/11/2015)	Roundup: change analysis	Radar lab 2 *1/12/2015 & 4/12/2015*	
	Readings: TBD		

*(Grey shaded labs indicate the labs that contribute to the **four major (A1-A4) and three minor (Mi1-Mi3) lab assignments.** Lectures are shaded in light blue)*

PLEASE NOTE: The course instructor and TAs will respond to e-mail queries within 3 business days. ***Only University of Waterloo-derived email address requests will be answered.***

Assignment Checklist (To be completed and submitted with ALL assignments)

Please read the checklist below following the completion of your assignment. Once you have verified these points, hand in this signed checklist with your assignment.

1. I have referenced and footnoted all ideas, words or other intellectual property from other sources used in the completion of this assignment.

2. I have included a proper bibliography, which includes acknowledgement of all sources used to complete this assignment.

3. This assignment was completed by my own efforts and I did not collaborate with any other person for ideas or answers.

4. This is the first time I have submitted this assignment or essay (either partially or entirely) for academic evaluation.

Signed:_____ Date:_____
Print Name: _____ UW-ID# _____

From the Associate Dean, Undergraduate Studies

♦ **Intellectual Property:**

Students should be aware that this course contains the intellectual property of their instructor, TA, and/or the University of Waterloo. Intellectual property includes items such as:

-Lecture content, spoken and written (and any audio/video recording thereof);
-Lecture handouts, presentations, and other materials prepared for the course (e.g., PowerPoint slides);
-Questions or solution sets from various types of assessments (e.g., assignments, quizzes, tests, final exams); and
-Work protected by copyright (e.g., any work authored by the instructor or TA or used by the instructor or TA with permission of the copyright owner).

Course materials and the intellectual property contained therein, are used to enhance a student's educational experience. However, sharing this intellectual property without the intellectual property owner's permission is a violation of intellectual property rights. For this reason, it is necessary to ask the instructor, TA and/or the University of Waterloo for permission before uploading and sharing the intellectual property of others online (e.g., to an online repository).

Permission from an instructor, TA or the University is also necessary before sharing the intellectual property of others from completed courses with students taking the same/similar courses in subsequent terms/years. In many cases, instructors might be happy to allow distribution of certain materials. However, doing so without expressed permission is considered a violation of intellectual property rights.

Please alert the instructor if you become aware of intellectual property belonging to others (past or present) circulating, either through the student body or online. The intellectual property rights owner deserves to know (and may have already given their consent).

♦ **Academic Integrity:**

In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. The University's guiding principles on academic integrity can be found here: **http://uwaterloo.ca/academicintegrity**. ENV students are strongly encouraged to review the material provided by the university's Academic Integrity office specifically for students: **http://uwaterloo.ca/academicintegrity/Students/index.html**

Students are also expected to know what constitutes academic integrity, to avoid committing academic offenses, and to take responsibility for their actions. Students who are unsure whether an action constitutes an offense, or who need help in learning how to avoid offenses (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. Students may also complete the following tutorial:
https://uwaterloo.ca/library/get-assignment-and-research-help/academic-integrity/academic-integrity-tutorial

When misconduct has been found to have occurred, disciplinary penalties will be imposed under Policy 71 – Student Discipline. For information on categories of offenses and types of penalties, students should refer to Policy 71 - Student Discipline: **https://uwaterloo.ca/secretariat-general-counsel/policies-procedures-guidelines/policy-71**. Students who believe that they have been wrongfully or unjustly penalized have the right to grieve; refer to Policy #70, Student Grievance:
https://uwaterloo.ca/secretariat-general-counsel/policies-procedures-guidelines/policy-70

♦ **Note for students with disabilities:** AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

♦ **Mental Health:** The University of Waterloo, the Faculty of Environment and our Departments/Schools consider students' well-being to be extremely important. We recognize that throughout the term students may face health challenges - physical and / or emotional. **Please note that help is available**. Mental health is a serious issue for everyone and can affect your ability to do your best work. Counselling Services

www.uwaterloo.ca/counselling-services is an inclusive, non-judgmental, and confidential space for anyone to seek support. They offer confidential counselling for a variety of areas including anxiety, stress management, depression, grief, substance use, sexuality, relationship issues, and much more.

♦ **Religious Observances:** Students need to inform the instructor at the beginning of term if special accommodation needs to be made for religious observances that are not otherwise accounted for in the scheduling of classes and assignments.

♦ **Grievance:** A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. See Policy 70 - Student Petitions and Grievances, Section 4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt please contact your Undergraduate Advisor for details.

♦ **Appeals:** A decision made or penalty imposed under Policy 70 - Student Petitions and Grievances (other than a petition) or Policy 71 – (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) www.adm.uwaterloo.ca/infosec/Policies/policy72.htm

♦ **Unclaimed assignments:**
Unclaimed assignments will be retained for … [period of time*; or: "until one month after term grades become official in quest"]. After that time, they will be destroyed in compliance with UW's confidential shredding procedures.

♦ **Communications with Instructor and Teaching Assistants:**
All communication with students must be through either the student's University of Waterloo email account or via Learn. If a student emails the instructor or TA from a personal account they will be requested to resend the email using their personal University of Waterloo email account.

♦ **Turnitin.com:** Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin® in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit the alternate assignment.

https://uwaterloo.ca/environment/undergraduate-teaching-resources

Associate Dean, Undergraduate Studies, 5 January, 2018