Digital Image Processing in the Geosciences

GEOS F622: fall 2022

Course information

Time: Tuesdays and Thursdays 9:00-10:30
Place: WRRB 004 or online
Instructor: Simon Zwieback, szwieback@alaska.edu
Office hours: Tuesdays and Thursdays, 10:30–11:30

Course type

Online synchronous

Course description

Image processing and analysis techniques to monitor and understand the Earth system. Geoscience applications to be addressed include thin-section analysis, remote sensing of geohazards and geomorphometry. Apart from lectures and demonstrations, the advantages and drawbacks of image processing techniques will be evaluated through exercises and a course project.

Course goals

The overarching goal is for the student to be able to select, design, and scrutinize image processing techniques in the geosciences. The student will analyze and apply image processing techniques for image enhancement (e.g., filtering, contrast manipulation) and information extraction (e.g., segmentation, classification); interpret image statistics and frequency spectra; and design and appraise multi-component image processing workflows. While the focus is on geoscience applications, examples from cognate scientific fields such as engineering and ecology will also be included.

Learning outcomes

At the end of the course, the student will be able to

- Characterize a digital image in regard to: spatial sampling, intensity statistics, resolution
- Design spatial filters for smoothing, sharpening, and edge detection
- Select an appropriate image processing workflow for a given input image and task at hand (e.g., segmentation, noise removal)
- Interpret the frequency components of digital images and linear filters
- Build an image processing workflow to extract geoscientific information from an image

Instructional Methods

Lecture with demonstrations and labs, graded assignments, discussion, independent project

Evaluation

Quizzes: 25%
Assignments 1-3: 30%
Discussion: 10%
Independent project: 35%

Grading criteria

A (A+: > 94%, A-: > 90%)
B (B+: > 80%, B-: > 70%)
C (C+: > 60%, C-: > 50%)
D (D+: > 45%, D-: > 40%)

Reading

Gonzalez and Woods, Digital Image Processing, 4th Edition, Pearson, 2018.
Papers and additional readings will be provided by the instructor.

Software and technology requirements

Two multiplatform applications will be used in the labs and assignments: FIJI, a free multiplatform image processing suite, and Google Colaboratory, an online platform.

Course policy

Students are expected to attend and participate in the lectures.

Late assignments will be accepted with a 5% penalty per day late.

Course calendar

The course consists of five units:

Unit	Applications
1 Digital images Digital representation of images Intensity transformations and statistics	Contrast enhancement, thresholding
2 Spatial filtering Spatial filtering of graylevel images Morphological filtering of binary images	Smoothing and sharpening, edge detection, noise removal, template matching
3 Frequency domain Interpreting images in the frequency domain Linear filtering in the frequency domain	Image restoration, computationally efficient image processing
4 Information extraction	Image segmentation, object detection, semantic segmentation with convolutional neural networks
5 Project	Higher-level geoscientific applications: remote sensing, topographic analysis, thin sections, etc.

Tentative schedule:

Week	Unit	Evaluation	Additional information
1	1		Lab 1: Digital images
2	1		Lab 2: Contrast enhancement
3	1, 2		HW1 ass.; P1
4	2		P2
5	2	HW1 due	HW2 ass.; Lab 3: Morphology
6	3	Quiz 1	P3
7	3	HW2 due	Lab 4: Frequency domain
8	3	Project outline due	HW 3 ass.; P4
9	4		P5
10	4	HW3 due	Lab 5: Geomorphometry
11	4	Quiz 2	P6
12	5	Project work	Lab 6: Clustering
13	5	Thanksgiving	

14	5	Project work	
15	5	Project presentations	

Papers:
P1: Asmussen et al.: Semi-automatic segmentation of petrographic thin section images using a “seeded-region growing algorithm” with an application to characterize weathered subarkose sandstone.
P2: Lindsay et al.: Scale-Optimized Surface Roughness for Topographic Analysis.
P3: Debella-Gilo and Kaab: Sub-pixel precision image matching for measuring surface displacements on mass movements using normalized cross-correlation.
P4: Brombrun et al. An algorithm for the detection and characterisation of volcanic plumes using thermal camera imagery.
P5: Ramo and Chuvieco: Developing a Random Forest Algorithm for MODIS Global Burned Area Classification

Student protections and services

Every qualified student is welcome in my classroom. As needed, I am happy to work with you, disability services, veterans' services, rural student services, etc to find reasonable accommodations. Students at this university are protected against sexual harassment and discrimination (Title IX), and minors have additional protections. For more information on your rights as a student and the resources available to you to resolve problems, please go the following site: www.uaf.edu/handbook/.