General Education Course Information Sheet

Please submit this sheet for each proposed course

Department & Course Number	Math 98T
Course Title	Boundaries, Edges, and Singularities: Exploring Mathematical Image Segmentation
Indicate if Seminar and/or Writing II course	CUTF-Seminar

1 Check the recommended GE foundation area(s) and subgroups(s) for this course

Foundations of the Arts and Humanities	
• Literary and Cultural Analysis	
• Philosophic and Linguistic Analysis	X
• Visual and Performance Arts Analysis and Practice	X
Foundations of Society and Culture	
• Historical Analysis	X
• Social Analysis	
Foundations of Scientific Inquiry	
• Physical Science	X
With Laboratory or Demonstration Component must be 5 units (or more)	
• Life Science	X
With Laboratory or Demonstration Component must be 5 units (or more)	

2. Briefly describe the rationale for assignment to foundation area(s) and subgroup(s) chosen.

The segmentation problem is an open and difficult problem in image processing. Researchers use tools from physics, mathematics, art, and human perception to understand and to provide solutions to this problem. The goal of the course will be to examine and critically analyze the methods and their motivations from a scientific, mathematical, historical, and visual perceptive.

3. "List faculty member(s) who will serve as instructor (give academic rank):
Hayden Schaeffer, Teaching Fellow. Luminita Vese, Professor.

Do you intend to use graduate student instructors (TAs) in this course? Yes No X

If yes, please indicate the number of TAs

3. Indicate when do you anticipate teaching this course over the next three years:

2011-2012	Fall Enrollment		Winter Enrollment	X 12	Spring Enrollment	

3. GE Course Units

Is this an ***existing*** course that has been modified for inclusion in the new GE? Yes No X

If yes, provide a brief explanation of what has changed.

Present Number of Units:	Proposed Number of Units: 5

3. Please present concise arguments for the GE principles applicable to this course.

❑ General Knowledge	Students will learn to translate what they see in the world into the language of mathematics. For example, objects in an image can be thought of as geometric shapes in the plane. The course will unify theory, mathematics, intuition, and our perception of the visual world.
❑ Integrative Learning	Students will use theories from physics and methods from mathematics and statistics to describe art and images. They will also study applications in medicine, engineering, computer science, and biology.
❑ Ethical Implications	Students will have to critically analyze the role that automated methods play in medical decisions, defense strategies, etc.
❑ Cultural Diversity	The course will include historical perspectives on theory and research, including contributions from minority and non-western researchers.
❑ Critical Thinking	The course will have a strong emphasis on critical thinking to evaluate and analyze theories and methods.
❑ Rhetorical Effectiveness	The course will have a strong emphasis on both the presentation and discussion of technical concepts for a general audience --talking about mathematics rather than using symbols and numbers.
❑ Problem-solving	This will be addressed through class discussions and small writing assignments.
❑ Library & Information Literacy	Their final paper will involve both extensive library and internet research.

(A) STUDENT CONTACT PER WEEK (if not applicable write N/A)

1.	Lecture:	**3**	(hours)
2.	Discussion Section:	**N/A**	(hours)
3.	Labs:	**N/A**	(hours)
4.	Experiential (service learning, internships, other):	**N/A**	(hours)
5.	Field Trips:	**1 (one time)**	(hours)

(A) TOTAL Student Contact Per Week **3** **(HOURS)**

(B) OUT-OF-CLASS HOURS PER WEEK (if not applicable write N/A)

1.	General Review & Preparation:	**2**	(hours)
2.	Reading	**5**	(hours)
3.	Group Projects:	**N/A**	(hours)
4.	Preparation for Quizzes & Exams:	**N/A**	(hours)
5.	Information Literacy Exercises:	**.5**	(hours)
6.	Written Assignments:	**3**	(hours)
7.	Research Activity:	**1.5**	(hours)

(B) TOTAL Out-of-class time per week	**12**	**(HOURS)**
GRAND TOTAL (A) + (B) must equal at least 15 hours/week	15	**(HOURS)**

Math 98T

Boundaries, Edges, and Singularities: Exploring Mathematical Image Segmentation

Instructor: Hayden Schaeffer

Course Description

In this seminar we will focus on **segmentation** -- how to partition an image into its basic objects. One of the most challenging problems computationally, yet one of the easiest for humans: how to partition an image into its basic objects. For example, when we look at Georges Seurat's "A Sunday Afternoon on the Island of La Grande Jatte," we see different colored umbrellas, an assortment of hats, people of different shapes and sizes, boats of varying scales, trees in the foreground and background, etc. Our minds analyze all of this in fractions of a second. When wanting to automate a process to do this on a computer, what quantities distinguish these objects from one another without being specific to the image itself? Our intuition says contrast or shape, but these are not always the correct measures.

This course will answer these questions and more by using mathematical intuition to help define the problem and analyze ways to solve it, without going into the rigorous details. The students will learn the basics of the methods used today, through discussions and research. Since most of the methods we will discuss are measured using the "Eye-ball norm" (how they look to the human eye), the students will decide for themselves the pros and cons of the method by examining real world examples. Applications include but are certainly not limited to: Medical imaging (for location and diagnosis), satellite and aerial object detection (roads and buildings), fingerprint and face recognition, machine vision, etc. We will also investigate the connection of image segmentation to art, psychology, fracture mechanics, physics, and even human nature.

This course is self-contained, all necessary "tools" will be provided.

Objectives:

By the end of the course (or during), you will:

- Be able to express mathematical concepts in your writing
- "Translate" nature into mathematics (or quantitatively measurable terms)
- Be able to critically evaluate imaging techniques
- Give a formal presentation
- Organize/plan a project
- Investigate cutting-edge material
- Learn effective team-working skills

- Learn efficient editing skills

Grading:
This class is grade only. Your grade will be made up of the following:

Discussions	20
Presentation	10
Short Write Ups (4)	20
Final Project	50
TOTAL	100

Discussions: You will be graded on active listening, engaging with the various topics, and participation.

Presentation: During week 10 you will give a short (5-10 min) explanation of your model to the class. You will be graded on verbal and non-verbal effectiveness, completeness, organization, and visual aids.

Short Write Ups: You will be asked to write up some of your thoughts before class (1-2 pages). You will be graded on your organization, language, length, and content. (5 points for each of the 4 write ups = 20).

Final Project:
This is a big part of your grade! You will apply the methodology in class to a problem you make up. For example, modeling the path one would take to walk through a crowd of people (to be discussed in class). The model does not have to be perfect, but it has to be well justified using the theory from the course.
The final project will be made up of the following components:

Meet with me to discuss ideas	1
Write a research outline/schedule	5
Make a model	1
Paper Outline	5
Paper Draft	10
Final Paper	28
TOTAL	50

See attached rubrics for more detail.
The grades will be A=90-100%, B=80-89%, etc.

Course Outline:
The topics, activities, assignments, and reading are listed by week. The reading is due before the class, unless otherwise stated. Assignments are due by Thursday before class (by email).

Week 1: Introduction (January 10 and 12)

Topics	• Introduction to Imaging and The Segmentation Problem • Digital Imaging • Grey vs. Color Images • Psychology of Visual Perception • What is applied Math: Math vs. Physics vs. Experimental Mathematics?
Questions	• What is an edge, boundary, contour, etc? • What is the difference between edges and boundaries?
Experiment	By hand segmentation
Assignments	• **Short Write Up 1:** Take a photo using a digital camera (a phone is ok) and describe the differences you see in the photo from reality. • **Learning style Quiz** (for hw)
Readings	• "The Unreasonable effectiveness of mathematics" by RW Hamming • "Experimental Mathematics: A Discussion" by Borwein, Borwein, Girgensohn, Parnes. • Chapter 1 of "Digital Image Processing" by Gonzalez and Woods • Parts of "Vision: A Computational Investigation into the Human Representation and Processing of Visual Information" • Images from "La Grammaire Du Voir" by Kanizsa • Handout on Gestalt theory from psychology

Week 2 Part 1: Degradation (January 17)	
Topics	• How to read math papers! (a quick tutorial) • Noise, blur, and missing data • What causes them? • How do we model them?
Questions	• What makes up an image? • What effect does degradation have to the image and the edges? • What do we do to account for them in our own mind? • What do you think is done in our own mind to reconstruct a corrupted image?
Part 2: Regularity/Smoothing (January 19)	

Topics	• Piece-wise Constant (P) • Harmonic, Piece-wise Elliptic (H^1) • Bounded Variation (BV)
Questions	• What regularity level is appropriate for an image and why? (with actual data) • What are objects in the real world that reside in these spaces?
Experiment	Computer Lab Trip (1/2 class). See these spaces in action! No programming background needed.
Assignments	• **Short Write Up 2:** What effect does degradation have on the edges of an image?
Readings	• Chapter 2 of "Digital Image Processing" by Gonzalez and Woods • Corresponding Chapter in the Course Reader

Week 3 Part 1: Basic Edge Detection (January 24)	
Topics	• Geometrical structures in images: Points, Lines, Edge • Thresholding • Concavity • (Mathematical) Singularities
Questions	• What are quantitative ways to measure edges? • What is shadowing and its effect on edges? • How do noise and blur effect edges? • How does missing data effect edges?
Part 2: Curves (January 26)	
Topics	• Properties: Length, Curvature, Elasticity, • Weak notations, Fractals, Hausdorff Measure, Hausdorff Dimension • Geodesics • Level Set method
Questions	• How curvy is a curve? • What defines a curve? • What happens to a curve if you remove a finite number of points? • Connection to Edges: Classical Length vs. Hausdorff Measure
Assignments	• If you haven't meet with me, schedule a meeting or stop by during office hours • Outline of Schedule due

Readings	• Class Handout • Corresponding Chapter in the Course Reader

Week 4: Motion of Curves and Surfaces (January 31 and February 2)	
Topics	• Mean Curvature Flow • Heat Equation with Connections to Brownian motion, harmonics, minimal surfaces • Frequencies and Fourier Analysis
Questions	• What do you predict will be the minimal structures? • Do weak notations of geometry appear in real life?
Experiments	• Bubble Lab! • Hearing the shape of a drum
Assignments	• **Short Write Up 3:** Write about the differences between your predicted minimal shapes and the ones from class.
Readings	• Corresponding Chapter in the Course Reader

Week 5: Snakes and Chan-Vese (February 7 and 9)	
Topics	• Snakes model • K-means and Chan-Vese (Piece-wise Constant) • Geodesic Active Contours • Applications in Medical Imaging, Military, Astronomy
Questions	• Can you characterize the solutions? • What are the core differences between these models? • What could applications be and why? (we will go over many applications in class)
Assignments	• **Short Write Up 4:** Pick one application of segmentation and discuss the benefit of mathematical modeling.
Readings	• Corresponding Chapter in the Course Reader • Look over the papers: "Snakes: Active Contour Model," "Active Contours without edges," and "Geodesic Active Contours" • Introduction of Chapter 4 of "Mathematical Problem in Image Processing" by Aubert and Kornprobst.

Week 6 and 7: Mumford-Shah Functional (February 14, 16, 21 23)	
Topics	• The Energy functional itself • Ambrosio-Tortorelli approximation • Chan-Vese (Piece-wise smooth) • Schaeffer-Vese • The artist problem • Applications in Camouflage Detection
Questions	• What are the benefits of the various models? • Which models are appropriate for the various applications: Medical Imaging, Astronomy
Assignments	• A finalized Model and paper outline
Readings	• Look over: "A Multiphase Level Set Framework for Image Segmentation Using the Mumford and Shah Model" by Chan and Vese • Look over: "Open Curve Active Contours" by Schaeffer and Vese • Corresponding Chapter in Course Reader

Week 8: Continuation of Week 8 with Related models (February 28 and March 1)	
Topics	• Continuation • Goat Model • Geodesic Goat
Questions	• Continuation of last week • Why goats?
Assignments	• Draft of the paper by the beginning of 9th week (if not earlier)
Readings	• Look over: "Open Curve Active Contours" by Schaeffer and Vese

Week 9 and 10: Additional topics (March 6,8, 13 and 15)	
Topics	• TV-MS • Texture • Non-locality • High-order Curve evolution • Connections to Fracture Mechanics and Fluid Interfaces
Questions	TBA

Assignments	• Final Paper due by end of the 10th week (March 16th) • Prepare Presentations (pick someone to practice with)
Readings	TBA
In Class Activity	• Writing workshop: You will be put in groups to read and edit your drafts. Attach all comments to the final paper. • Presentations

Reading List:
Many of these readings will be on the website:

1. The course reader
2. "The Unreasonable effectiveness of mathematics" by RW Hamming
3. "Experimental Mathematics: A Discussion" by Borwein Borwein, Girgensohn, Parnes.
4. "Digital Image Processing" by Gonzalez and Woods
5. Mathematical Problem in Image Processing" by Aubert and Kornprobst. (Online)
6. "Vision: A Computational Investigation into the Human Representation and Processing of Visual Information"
7. Images from "La Grammaire Du Voir" by Kanizsa
8. "Open Curve Active Contours" by Schaeffer and Vese
9. "Snakes: Active Contour Model"
10. "Active Contours without edges"
11. "Geodesic Active Contours"
12. "A Multiphase Level Set Framework for Image Segmentation Using the Mumford and Shah Model" by Chan and Vese

and more.

Course Revision Proposal

Mathematics 98T
Boundaries, Edges, and Singularities: Exploring Mathematical Image Segmentation

Requested revisions that apply:

☐ Renumbering ☐ Title ☐ Format ☐ Requisites ☐ Units ☐ Grading ☐ Description

Multiple Listing: ☐ Add New ☐ Change Number ☐ Delete

Concurrent Listing: ☐ Add New ☐ Change Number ☐ Delete

	CURRENT	PROPOSED
Course Number	**Mathematics 0**	**Mathematics 98T**
Title	**Boundaries, Edges, and Singularities: Exploring Mathematical Image Segmentation**	**Boundaries, Edges, and Singularities: Exploring Mathematical Image Segmentation**
Short Title	**IMAGE PROCESSING**	**IMAGE PROCESSING**
Units	Fixed: **5**	Fixed: **5**
Grading Basis	**Letter grade only**	**Letter grade only**
Instructional Format	Primary Format **Seminar - 3 hours per week**	Primary Format **Seminar - 3 hours per week**
	Secondary Format **None**	Secondary Format **None - 0 hours per week**
TIE Code	**SEMT - Seminar (Topical) [T]**	**SEMT - Seminar (Topical) [T]**
GE	**Yes**	**Yes**
Major or Minor Requirement	**No**	**No**
Requisites	**Satisfaction of entry-level Writing requirement. Freshmen and sophomores preferred.**	**Satisfaction of entry-level Writing requirement. Freshmen and sophomores preferred.**
Description	Seminar, three hours. Enforced requisite: satisfaction of Entry-Level Writing requirement. Freshmen/sophomores preferred. Exploration of modern segmentation techniques in image processing from perspective of mathematical intuition and our own visual experience. Applications in medical imaging, satellite and aerial object detection, fingerprint and face recognition, machine learning, and more. Letter grading.	**Seminar, three hours. Enforced requisite: satisfaction of Entry-Level Writing requirement. Freshmen/sophomores preferred. Exploration of modern segmentation techniques in image processing from**

		perspective of mathematical intuition and our own visual experience. Applications in medical imaging, satellite and aerial object detection, fingerprint and face recognition, machine learning, and more. Letter grading.
Justification	Part of the series of seminars offered through the Collegium of University Teaching Fellows.	**Part of the series of seminars offered through the Collegium of University Teaching Fellows.**
Syllabus	File *Math 98T syllabus.doc* was previously uploaded. You may view the file by clicking on the file name.	File *Math 98T syllabus.doc* was previously uploaded. You may view the file by clicking on the file name.
Supplemental Information	**Professor Luminita Vese is the faculty mentor for this seminar.**	**Professor Luminita Vese is the faculty mentor for this seminar.**
Grading Structure	**In class discussion 20% 5 short write-ups (about 2 pages) 5% each Term paper (about 15 pages) 40% Presentation 15%**	**In class discussion 20% 5 short write-ups (about 2 pages) 5% each Term paper (about 15 pages) 40% Presentation 15%**
Effective Date	**Winter 2012**	**Winter 2012**
[redacted]	[redacted]	[redacted]
Department	**Mathematics**	**Mathematics**
Contact	Name **CATHERINE GENTILE**	Name **CATHERINE GENTILE**
Routing Help	E-mail **cgentile@oid.ucla.edu**	E-mail **cgentile@oid.ucla.edu**

ROUTING STATUS

Role: Registrar's Office

Status: Processing Completed

Role: Registrar's Publications Office - Hennig, Leann Jean (lhennig@registrar.ucla.edu) - 56704

Status: Added to SRS on 6/28/2011 10:26:57 AM

Changes: TIE Code

Comments: Corrected title -- this is a NEW course, not a revision!

Role: Registrar's Scheduling Office - Hennig, Leann Jean (lhennig@registrar.ucla.edu) - 56704

Status: Added to SRS on 6/28/2011 10:25:46 AM

Changes: TIE Code
Comments: Corrected title.

Role: Registrar's Office - Hennig, Leann Jean (lhennig@registrar.ucla.edu) - 56704
Status: Returned for Additional Info on 6/28/2011 10:24:15 AM
Changes: Title, TIE Code, Discontinue Date
Comments: Corrected title per Cathie 6-28-11

Role: Registrar's Scheduling Office - Hennig, Leann Jean (lhennig@registrar.ucla.edu) - 56704
Status: Added to SRS on 6/28/2011 10:18:03 AM
Changes: No Changes Made
Comments: Reroute to Leann to correct title.

Role: Registrar's Publications Office - Hennig, Leann Jean (lhennig@registrar.ucla.edu) - 56704
Status: Added to SRS on 5/25/2011 11:24:58 AM
Changes: Title, Description
Comments: Edited course description into official version; corrected title.

Role: Registrar's Scheduling Office - Bartholomew, Janet Gosser (jbartholomew@registrar.ucla.edu) - 51441
Status: Added to SRS on 5/20/2011 11:21:07 AM
Changes: Short Title
Comments: Added a short title.

Role: FEC School Coordinator - Soh, Michael Young (msoh@college.ucla.edu) - 65282
Status: Returned for Additional Info on 5/19/2011 11:06:27 AM
Changes: No Changes Made
Comments: Routing to Registrar's Office

Role: FEC Chair or Designee - Knapp, Raymond L (knapp@humnet.ucla.edu) - 62278
Status: Approved on 5/19/2011 7:41:42 AM
Changes: No Changes Made
Comments: No Comments

Role: L&S FEC Coordinator - Soh, Michael Young (msoh@college.ucla.edu) - 65282
Status: Returned for Additional Info on 5/18/2011 5:00:48 PM
Changes: No Changes Made
Comments: Routing to FEC Chair Ray Knapp for approval

Role: CUTF Coordinator - Gentile, Catherine (cgentile@oid.ucla.edu) - 68998
Status: Approved on 5/13/2011 4:09:21 PM
Changes: No Changes Made
Comments: on behalf of Professor Kathleen Komar, chair, CUTF Faculty Advisory Committee

Role: Initiator/Submitter - Gentile, Catherine (cgentile@oid.ucla.edu) - 68998
Status: Submitted on 5/13/2011 4:08:31 PM

Comments: Initiated a New Course Proposal

Back to Course List

Comments or questions? Contact the Registrar's Office at
cims@registrar.ucla.edu or (310) 206-7045