

ECEN 161: Information, Quantum Computing and Complexity: The Beauty of Nature and the Nature of Beauty

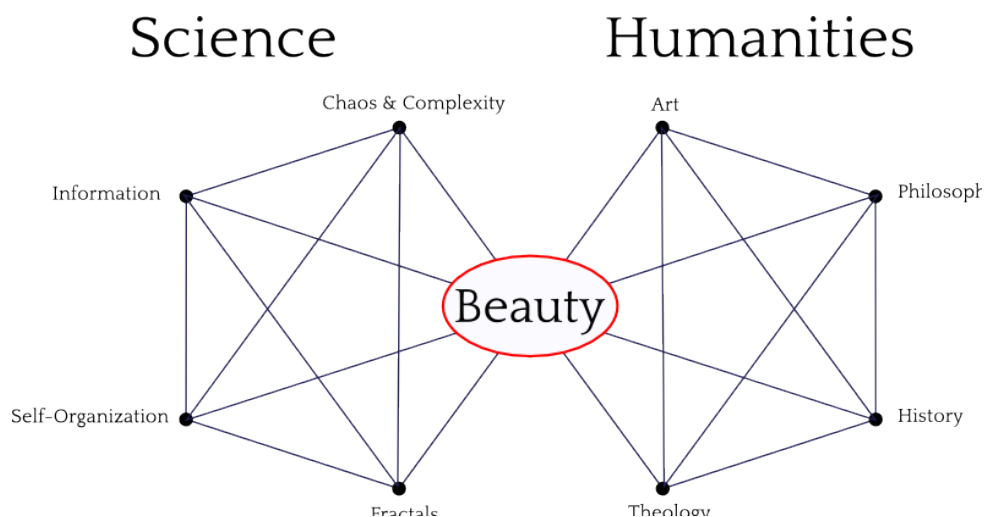
REQUIRED READING:

1. Aleksandar I. Zecevic, *The Beauty of Nature and the Nature of Beauty* (TBN), Amazon CSP, 2018. ISBN: 978-1987653045
2. Aleksandar I. Zecevic, *Ten Dialogues about Art and Beauty* (TDA), Amazon CSP, 2018. ISBN: 978-1987653144
3. Aleksandar I. Zecevic, *The Many Faces of Complexity: An Interdisciplinary Approach to Beauty* (MFC), Amazon CSP, 2018. ISBN: 978-1987652963

Note: In the following, these three books will be referred to by their abbreviations: TBN, TDA and MFC.

COURSE OBJECTIVES AND SCOPE

Aesthetics is usually seen as a topic that is of interest to philosophers, artists and theologians, but relatively few people associate it with science, engineering and mathematics. One could legitimately argue, however, that such an outlook is rather narrow, since humans tend to enjoy natural beauty, complex structures and elaborate geometric forms just as much as they enjoy good literature, music or painting. If we take that into account, it follows that a proper examination of beauty requires a *broad interdisciplinary approach*, which incorporates many different points of view. The diagram shown below illustrates what such an approach might entail, and provides a schematic description of how this course is organized.



Connecting all the “dots” in this diagram is, of course, a very ambitious goal, whose realization is by no means easy. Perhaps the most serious challenge stems from the fact that each discipline has its own vocabulary and unique methods of investigation. As a result, any attempt to combine insights from philosophy, history and theology with the findings of physics, psychology and neuroscience is bound to encounter multiple “language barriers”. These barriers are not insurmountable, however, particularly if one is sufficiently familiar with certain recent developments in mathematics and science. It is largely for this reason that the course includes a considerable amount of technical material, much of which is of the advanced variety.

Understanding this material properly will require a non-trivial effort, since the topics that we will be dealing with involve some rather sophisticated mathematics. I believe, however, that the effort will be worth your while, since developing an interdisciplinary understanding of aesthetics helps us make connections between seemingly unrelated fields of human inquiry. There is much to be gained from this, both practically and philosophically. I find it fascinating, for example, that our sense of beauty has been a remarkably effective tool for scientific research, although its origins appear to be entirely biological. Indeed, it is hard to explain how certain preferences that emerged in the course of evolution eventually led to the discovery of black holes, infinite sets or the Higgs boson (which have nothing whatsoever to do with the survival of our species).

Science alone cannot answer this question, nor can it tell us why certain works of art have such a powerful effect on us. Although we have learned a great deal about how the human brain responds to different visual and auditory stimuli, the essence of such profound aesthetic experiences remains as elusive as it ever was. This is the point where philosophy, history and theology need to enter the picture, and provide a different perspective.

Bearing that in mind, I organized the course in such a way that each technical topic is accompanied by a related topic from the humanities. It is my hope that this highly interdisciplinary “mix” will broaden the scope of your knowledge, and will lead to new insights about the nature of beauty and the role that it plays in our lives.

LEARNING OBJECTIVES FOR CULTURES AND IDEAS 3

1. Demonstrate an understanding of Asian, African, Middle Eastern, Eastern European and/or Latin American cultures in their global and/or diasporic contexts.
2. Identify, analyze and evaluate the challenges and complexities as cultures interact and influence one another.

COURSE LEARNING OUTCOMES

Students who successfully complete this course should be able to:

1. Distinguish between conventional information, quantum information and biological information, and understand the operation of quantum gates.
2. Calculate information entropy for simple systems and understand its various interpretations.
3. Understand the distinction between different types of fractal dimensions, and use this knowledge to characterize attractors in nonlinear dynamic systems.
4. Describe how perturbations and parametric variations affect the behavior of nonlinear systems, and distinguish between chaotic dynamics and catastrophes.

5. Identify limit cycles and their basins of attraction for cellular automata and Boolean networks.
6. Understand the notion of beauty from a philosophical and theological perspective, and identify the similarities and differences between these two outlooks.
7. Identify the role that aesthetic considerations play in mathematics and the natural sciences.
8. Describe and discuss the biological, neuropsychological and evolutionary roots of the “aesthetic drive” in humans.
9. Compare the aesthetic standards of different cultures, and provide a historical context for how these standards developed.
10. Reflect on the similarities and differences in the ways the natural sciences and the humanities approach beauty (in the spirit of C. P. Snow’s famous essay *The Two Cultures*).

Outcomes 1 – 5 will be evaluated through homework assignments and the three projects. Items 6 – 10 will be assessed through weekly class discussions, and through the two research papers.

GRADING

Projects: 30%

Homework: 20%

Research paper 1: 15%

Research paper 2: 20%

Class participation 15%

PROJECTS. Three projects will be assigned, covering the following topics:

1. Fractals, the Mandelbrot Set and Julia Sets
2. Strange Attractors, Chaos and Catastrophes
3. Cellular Automata and Boolean Networks

Since each of these projects involves a considerable amount of simulation in Matlab, it is important for you to be sufficiently familiar with basic Matlab functions and m-files. You can work in pairs (a single report is required for each group).

HOMEWORK. The main purpose of the homework assignments is to reinforce certain key concepts that will be introduced in the lectures. These assignments should be done *individually*.

RESEARCH PAPERS. Two research papers will be assigned, each of which should be 6-8 pages long. Before you start writing them, you must first read Chapter 7 of *The Beauty of Nature and the Nature of Beauty*. You will also need to do some preliminary research and identify three (or more) external sources that are relevant to the topic. I will need to approve these readings at least 3 weeks before the assignment is due.

Research Paper 1. Compare two cultures that have interacted historically, and describe how they have influenced each other. Your analysis should focus on the differences and similarities between their aesthetic values, taking into account socio-political, philosophical and religious

factors. Your discussion should not be limited to art, and should include attitudes toward natural beauty as well.

When selecting your external sources, make sure that they take an in-depth look at each of the two cultures that you selected. This background information should be included in the paper. You should also use at least one source that deals with the way these cultures have interacted and influenced each other.

Research Paper 2. Consider the two cultures that you compared in Research Paper 1, and examine how they have been impacted by modern technology and the emergence of the internet. Use this as a framework for a general discussion about the pros and cons of globalization when it comes to art and cultural distinctiveness. As you do so, I would like you to focus on the following three questions:

- Does the possibility of freely exchanging ideas with other cultures pose a threat to established artistic traditions, or do you think it could perhaps transform and enrich them? Provide examples that support your position.
- Can the internet and digital art act as “global equalizers” which will gradually erase differences between different cultures? If so, would this be a good thing?
- Do you think that cross-cultural aesthetics is likely to become a viable discipline, given that much of our “conceptual vocabulary” is defined by the tradition in which we grew up?

Note: In addition to the three external references that you identified, you are required to read Chapter 8 of *Ten Dialogues about Art and Beauty*, since it discusses various aspects of cross-cultural aesthetics.

The first paper will be due at the beginning of week 6 and the second one on the first day of finals week. Since both papers require identifying appropriate sources and a considerable amount of reading, make sure you start early! The specific claims and opinions that you choose to express in these papers are entirely up to you. You will be graded on the quality of your arguments, your understanding of the material and your writing skills (such as clarity, grammar, and style).

CLASS PARTICIPATION. Each of the weekly “companion topics” will require some preliminary reading on your part (the relevant sections of the textbooks are indicated below). Although I will review these topics and clarify the main concepts, I will expect you to come prepared. The emphasis will be on class discussions, and your participation is essential.

LECTURES

Week 1	Overview of classical information theory (Chapter 1, MFC)
	<i>Companion Topic:</i> The nature of beauty (Reading: Chapters 1, 2 and 6 in TDA)

Week 2	<p>Biological information and quantum information (Chapters 2, 3, MFC)</p> <p><i>Companion Topic:</i> The beauty of nature (Reading: Chapter 1, TBN)</p>
Week 3	<p>Quantum computing (Chapter 3, MFC)</p> <p><i>Companion Topic:</i> The beauty of nature (ctd.) (Reading: Chapter 1, TBN)</p>
Week 4	<p>Quantum computing (ctd.) (Chapter 3, MFC)</p> <p><i>Companion Topic:</i> Beauty in science and mathematics (Reading: Chapter 2, TBN)</p>
Week 5	<p>Nonlinearity, chaos and catastrophes (Chapter 8, MFC)</p> <p><i>Companion Topic:</i> Beauty in science and mathematics (ctd.) (Reading: Chapter 3, TBN)</p>
Week 6	<p>Nonlinearity, chaos and catastrophes (ctd.) (Chapter 8, MFC)</p> <p><i>Companion Topic:</i> Beauty, psychology and neuroscience (Reading: Chapter 6, TBN)</p>
Week 7	<p>Attractors, fractals and generalized dimensions (Chapter 6, MFC)</p> <p><i>Companion Topic:</i> Beauty and complexity (Reading: Chapter 4, TBN)</p>
Week 8	<p>Cellular automata and Random Boolean networks (Chapter 9, MFC)</p> <p><i>Companion Topic:</i> Beauty, religion and theology (Reading: Chapter 8, TBN; Chapters 3 and 5, TDA)</p>

Week 9 Cellular automata and Random Boolean networks (ctd.)

Companion Topic: Art, literature and information
(Reading: Chapter 5, TBN; Chapter 4, TDA)

Week 10 Self-organized criticality
(Chapter 10, MFC)

Companion topic: Beauty as a cross-cultural and
interdisciplinary bridge
(Reading: Chapter 9, TBN; Chapter 8, TDA)

GENERAL INFORMATION

OFFICE: SCDI 4025 – O
OFFICE HOURS: Tuesdays and Thursdays, 4:00-5:00, and by appointment.
PHONE: (408) 554-2394
E-MAIL: azecevic@scu.edu
WEBSITE: <http://www.engr.scu.edu/~azecevic/>

Academic Integrity

The Academic Integrity pledge is an expression of the University's commitment to fostering an understanding of—and commitment to—a culture of integrity at Santa Clara University. The Academic Integrity pledge, which applies to all students, states:

I am committed to being a person of integrity. I pledge, as a member of the Santa Clara University community, to abide by and uphold the standards of academic integrity contained in the Student Conduct Code.

Academic integrity is part of your intellectual, ethical, and professional development. I expect you to uphold the principles of this pledge for all work in this class. I will clarify expectations on academic integrity -- including the use of AI tools such as ChatGPT and course sharing sites for all assignments and exams in this course. If you have questions about what is appropriate on any assignment, please let me know before you hand in work. For more resources about ensuring academic integrity in your work, see:

<https://libguides.scu.edu/academic-integrity>

Discrimination, Harassment and Sexual Misconduct (Title IX)

Santa Clara University is committed to providing all students with a safe learning environment free of all forms of discrimination, sexual harassment, and sexual violence. Please know that as a faculty member, California law SB 493 requires me to report any information brought to my attention about incidents of sexual harassment or misconduct to the SCU Equal Opportunity and Title IX Office ((408) 551-3043). This includes, but is not limited to, disclosures in writing assignments, class discussions, and one-on-one conversations.

Should you need support, SCU has dedicated staff trained to assist you in navigating campus resources, accessing health and counseling services, providing academic and housing accommodations, helping with legal protective orders, and filing a formal complaint with the University or with law enforcement. Please see the Student Resources page for more information about reporting options and resources.

If you or someone you know has experienced sexual harassment or sexual violence and wishes to speak to a confidential resource who is not required to report, please contact one of the following SCU resources for support:

- SCU Wellness Center
- CAPS
- Any individual (clergy, counselors) acting in a professional capacity for which confidentiality is mandated by law

I am happy to help connect you with any of these resources.

Accommodations for Pregnant and Parenting Students

Santa Clara University does not discriminate against any student on the basis of pregnancy or related medical conditions. Absences due to medical conditions relating to pregnancy and childbirth will be excused for as long as deemed medically necessary by a student's doctor, and students will be given the opportunity to make up missed work. Students needing accommodations can often arrange accommodations by working directly with their instructors, supervisors, or departments. Students needing accommodations can also seek assistance with accommodations from the Office of Accessible Education (OAE) or from the Office of Equal Opportunity and Title IX Office. This resource page from Title IX provides information for students and faculty regarding pregnancy rights.

Office of Accessible Education

If you have a documented disability for which accommodations may be required in this class, please contact the Office of Accessible Education (oea@scu.edu),

<http://www.scu.edu/oae>) as soon as possible to discuss your needs and register for accommodations with the University. If you have already arranged accommodations through OAE, please be sure to request your accommodations through your myOAE portal and discuss them with me during my office hours within the first two weeks of class.

To ensure fairness and consistency, individual faculty members are required to receive verification from the Office of Accessible Education before providing accommodations. OAE will work with students and faculty to arrange proctored exams for students whose accommodations include double time for exams and/or assistive technology. Students with approved accommodations of time-and-a-half should talk with me as soon as possible. The Office of Accessible Education must be contacted in advance (at least two weeks notice recommended) to schedule proctored examinations or to arrange other accommodations.

In light of shifting health advisories related to COVID-19, exams may be administered online. Students with approved testing accommodations should contact me (at least two weeks notice recommended) prior to an exam date to notify me of their intent to use their testing accommodations on the upcoming exam to ensure their accommodations are effectively implemented.

Safety Measures

In order to meet our learning objectives, we will adhere to the highest standards for safety and mutual respect. I expect everyone to adhere to current university mask mandates at all times; to make their best attempt to make themselves heard when asking questions or contributing to discussions; and refrain from eating or drinking in class. It is expected that everyone will follow university guidelines about health and public safety measures outlined on the Prepared SCU website.

Use of Classroom Recordings

All online class meetings will be recorded and made available on Camino. As is stated in the Student Conduct Code: "...Dissemination or sharing of any classroom recording without the permission of the instructor would be considered "misuse" and, therefore, prohibited. Violations of these policies may result in disciplinary action by the University. At the instructor's discretion, violations may also have an adverse effect on the student's grade."

Copyright Statement

Materials in this course are protected by United States copyright laws. I am the copyright holder of the materials I create, including notes, handouts, slides, and videos. You may

make copies of course materials for your own use and you may share the materials with other students enrolled in this course. You may not publicly distribute the course materials without my written permission.

Technology Support

SCU can provide you with technology assistance, and you can also reach out to our providers directly for questions. For Camino (SCU's branded instance of Canvas) support, contact caminosupport@scu.edu or call 408-551-3572. You can also use the help button within the Camino platform (on the left hand navigation) for 24/7 support via chat or phone with our vendor.

For Zoom assistance, contact Media Services at mediaservices@scu.edu or 408-554-4520. You can also get support from the Zoom Help Center website.

For SCU network and computing support, contact the SCU Technology Help Desk at techdesk@scu.edu or 408-554-5700. They can provide support for MySCU Portal, Duo, eCampus, hardware and software issues, and more.

Syllabus Statements on Diversity, Inclusion, and Wellness

Santa Clara University syllabi are encouraged to include information for students to promote a more inclusive classroom. Below are recommended examples of syllabi statements that faculty may use. For more on developing an inclusive syllabus and course design see a campus resource on Inclusive Teaching and a toolkit from the Association of College and University Educators (ACUE).

Land Acknowledgment

Santa Clara University occupies the unceded ancestral homeland of the Ohlone and Muwekma Ohlone people.

Respect for Diversity

It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diverse identities (e.g., those based on gender, sexuality, disability, age, socioeconomic status, ethnicity, race, religion, and culture). Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or

for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you.

Gender Inclusive Language

This course affirms people of all gender expressions and gender identities. If you go by a name different from what is on the class roster, please let me know. Using correct gender pronouns is important to me, so I encourage you to share your pronouns with me and correct me if I make a mistake. If you have any questions or concerns, please do not hesitate to contact me. For more on personal pronouns see www.mypronouns.org.

Wellness Statement and Mental Health Resources

I know you will do the best you can in this class (and all of your classes); however, it should never be at the expense of your own mental health, physical health, and/or well-being. Jesuit education is grounded in cura personalis, concern for the whole person—mind, body, and spirit. What does this mean for you? Be kind to others, and more importantly, be kind to yourself. Attend to your sleep (quantity and quality); drink lots of water; move; get outside; and pay attention to beauty that isn't coming to you on a screen. Eat good food; laugh; enjoy friends and family; look for opportunities to connect with others in new ways; pray, meditate, or otherwise attend to your spirit. And ask for help, even if you don't think you need it. Lots of folks, including me, are here to support you. It's never too late to reach out, and I am committed to helping you.

SCU has many resources and programs to support you. These resources may be especially helpful:

Wellness Center: <https://www.scu.edu/wellness/>

The Wellness center provides resources to aid and promote student well-being across the eight dimensions of wellness, including student peer groups for healthful living, violence prevention, and recovery.

CAPS: <https://www.scu.edu/cowell/counseling-and-psychological-services-caps/>

Santa Clara students are provided confidential counseling sessions at no cost through Counseling and Psychological Services (CAPS). Students have access to clinically appropriate, short-term therapy; group therapy; and other resources for care. A new 24/7 support line is also available: 408-554-5220.

SCU Culture of Care: <https://www.scu.edu/osl/culture-of-care/>

If you are concerned for the mental or physical welfare of one of your peers, the Office of Student Life Culture of Care website provides resources for recognizing and helping someone in distress.

Academic Concerns

If you are concerned with your progress in this class, please contact me so that we can find solutions together. Drahmman Center can also offer support with issues regarding your academic progress more broadly.