THE OHIO STATE UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

SYLLABUS: STAT 8810
FUNCTIONAL AND SHAPE DATA ANALYSIS
AUTUMN 2021

Course overview

Instructor

Instructor: Dr. Sebastian Kurtek
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Office hours: Wednesdays 4PM-5PM
Office location: Cockins Hall 440B

Course description

Due to recent developments in science and technology, novel types of structured data under nonlinear constraints are now prevalent in various application domains. Such data naturally take values on nonlinear manifolds rather than Euclidean spaces, where the type of nonlinear constraint determines the manifold structure. Due to this nonlinearity of data representation spaces, standard statistical techniques cannot be applied directly, prompting developments of new theoretical and computational tools for statistical analyses. Prominent examples include functional data and shapes of two- and three-dimensional objects. Shape is an important physical property of objects that characterizes their appearance, and plays a key role in the detection, tracking and recognition of objects in images and videos. Statistical shape analysis represents shape as a random object and develops tools for shape registrations, comparisons, averages, probability models, hypothesis tests, Bayesian estimates, and other statistical procedures on shape spaces. One is usually concerned with analyzing object boundaries, which leads to shape analysis of parameterized curves and surfaces.

This course will introduce students to modern methods in functional and shape data analysis and will closely follow the book of Srivastava and Klassen (2016) titled *Functional and Shape Data Analysis*. A free online version of this book is available through The Ohio State University library. The course will contain a computational component where students will be asked to implement

the various mathematical and statistical tools covered in class, and apply them to real datasets in computer vision, biology, medical imaging and other disciplines. The main topics covered in this course will include:

(1) Introduction and previous techniques in shape analysis (Chapters 1-2),
(2) Background: relevant tools from geometry (Chapter 3 and Appendices),
(3) Functional data analysis and elastic registration (Chapter 4),
(4) Shapes of planar open curves (Chapter 5),
(5) Shapes of planar closed curves (Chapter 6),
(6) Statistical modeling on nonlinear manifolds (Chapter 7),
(7) Statistical modeling of planar shapes (Chapter 9)

Course learning outcomes

By the end of this course, students should:

- Have sufficient background in geometry to read and critique papers related to functional data analysis and statistical shape analysis;
- Be familiar with different representations and metrics used for statistical analysis of functional and shape data;
- Be able to implement functional and shape data analysis procedures;
- Understand how to summarize and model datasets taking values on nonlinear manifolds.

Prerequisites

Although this course does not have any formal pre-requisites, sufficient background equivalent to the first year Ph.D. in Statistics or Biostatistics courses is needed to complete the course.

Course materials

The primary resources will be notes (mostly written on the board during class) and additional references assigned for reading by the instructor. There is one required book for the course. The title of the book and link to access it are provided below.

Required

Srivastava and Klassen, *Functional and Shape Data Analysis*, Springer.
https://link.springer.com/book/10.1007/978-1-4939-4020-2

Course technology

For help with your password, university e-mail, Carmen, or any other technology issues, questions, or requests, contact the OSU IT Service Desk. Standard support hours are available at https://ocio.osu.edu/help/hours, and support for urgent issues is available 24x7.

- **Self-Service and Chat support:** http://ocio.osu.edu/selfservice
- **Phone:** 614-688-HELP (4357)
- **Email:** 8help@osu.edu
- **TDD:** 614-688-8743

Baseline technical skills necessary for this course

- Basic computer and web-browsing skills
- Navigating Carmen
- CarmenZoom

Necessary equipment

- Computer: current Mac (OS X) or PC (Windows 10+) with high-speed internet connection

Necessary software

- This class requires you to use the statistical software package called R (The R Project for Statistical Computing; http://www.r-project.org/). This software package is available as Free Software.
    - You can download R for Windows, Mac, and Linux, from the CRAN archive at https://cran.r-project.org.
    - An in-depth introduction to R is available at http://cran.r-project.org/doc/manuals/R-intro.pdf
    - Hands-on tutorials are available in the Swirl system, which you can learn about at http://swirlstats.com/. In particular, "R Programming: The basics of programming in R" is an appropriate first tutorial for students who have never used R.
- An easier to use interface to R is available in the software package RStudio. This package is available for Windows, Mac, and Linux and can be downloaded for free from http://rstudio.org. **Note that RStudio requires R to be installed.**

Course delivery

- This class will take place in-person twice per week on Tuesdays and Thursdays, 12:40PM-2:30PM in Jennings Hall 140. This is a half semester course with a starting date of 8/24 and ending date of 10/7.

- All assignments will be posted on the Carmen class website. You will be given ample time to complete the assignments. Assignment due dates will be announced in class and on the Carmen course webpage.

- I will hold weekly office hours in-person in my office, Cockins Hall 440B. The dates and times will be announced later.

Grading and faculty response

Grades

Assignment or category	Percentage
Homework	**40**
Participation	**30**
Final Project	**30**
Total	**100**

All course grades will be recorded on the class website (Carmen).

Assignment information

Homework

- Homeworks will generally be assigned on a biweekly basis.

Participation

- A major part of your grade is devoted to participation. You are required to attend the in-person lectures. I will also post weekly discussion topics on the Carmen course webpage that you will be asked to respond to regularly.

Final Project

- About midway through the course, I will assign a final group project that will involve an in-class presentation.

Late assignments

Generally, late assignments will not be accepted. However, if there are extenuating circumstances beyond your control, please contact the course instructor immediately.

Grading scale

93–100: A
90–92.9: A-
87–89.9: B+
83–86.9: B
80–82.9: B-
77–79.9: C+
73–76.9: C
70 –72.9: C-
67 –69.9: D+
60 –66.9: D
Below 60: E

Faculty feedback and response time

I am providing the following list to give you an idea of my intended availability throughout the course. (Remember that you can call **614-688-HELP** at any time if you have a technical problem.)

Grading and feedback

For homeworks, you can generally expect feedback within **7 days**.

E-mail

I will reply to e-mails within **24 hours on school days**.

Attendance and participation

Student participation requirements

Your participation is based on your in-person attendance and online discussion activity. The following is a summary of everyone's expected participation:

- **Logging in**: **AT LEAST ONCE PER WEEK**
  Be sure you are logging in to the course in Carmen each week, including weeks with holidays. (During most weeks you will probably log in many times.) If you have a situation that might cause you to miss an entire week of class, discuss it with me *as soon as possible.*
- **In-person class meetings**: **REQUIRED**
  You are required to attend all in-person lectures and you are responsible for all material presented during these lectures. However, formal attendance will not be taken during the class.

- **Discussion**: **REQUIRED**

  You are required to participate in the weekly course discussions posted on the Carmen course webpage.
- **Office hours**: **OPTIONAL**
  My office hours will be held in-persion in my office in Cockins Hall 440B. If you are required to discuss an assignment with me, please contact me at the beginning of the week if you need a time outside of my scheduled office hours.

Communication guidelines

The following are my expectations for how we should communicate as a class. Above all, please remember to be respectful and thoughtful.

- **Tone and civility**: Let's maintain a supportive learning community where everyone feels safe and where people can disagree amicably. Remember that sarcasm doesn't always come across online.
- **Citing your sources**: When we have academic discussions, please cite your sources to back up what you say. (For the textbook or other course materials, list at least the title and page numbers. For online sources, include a link.)

Other course policies

Health and safety

The Ohio State University Wexner Medical Center's Cornavirus Outbreak site (https://wexnermedical.osu.edu/features/coronavirus) includes the latest information about COVID-19 as well as guidance for students, faculty and staff. Guidelines and requirements for campus safety from the University's COVID-19 Transition Task Force were published on July 1 on the Safe and Healthy website (https://safeandhealthy.osu.edu).

Potential disruptions to instruction

- As much as is possible, students will have access to material online if they are unable to attend class because of positive diagnosis, symptoms, or quarantine required following contact tracing.
- If the instructor is unable to be present in person because of positive diagnosis, symptoms, or quarantine following contact tracing, the course will temporarily shift to online instruction. Details will be given on the course website if this arises.

Student academic services

Student academic services offered on the OSU main campus
http://advising.osu.edu/welcome.shtml.

Student support services

Student support services offered on the OSU main campus http://ssc.osu.edu.

Academic integrity policy

Policies for this hybrid course

- **Homework and project assignments**: You are expected to produce original and independent work for homework and project assignments. Although students are often encouraged to work together on homework assignments, all students must submit their own written work **in their own words**. Note that allowing others to copy your work is considered academic misconduct. Academic misconduct will not be tolerated and will be dealt with procedurally in accordance with University Rule 3335-31-02. (This policy can be found at http://oaa.osu.edu/coam.html.)
- **Reusing past work**: In general, you are prohibited in university courses from turning in work from a past class to your current class, even if you modify it. If you want to build on past research or revisit a topic you've explored in previous courses, please discuss the situation with me.
- **Falsifying research or results**: All research you will conduct in this course is intended to be a learning experience; you should never feel tempted to make your results or your library research look more successful than it was.
- **Collaboration and informal peer-review**: The course includes many opportunities for formal collaboration with your classmates. While study groups and peer-review of major written projects is encouraged, remember that comparing answers on an assignment is not permitted. If you're unsure about a particular situation, please feel free just to ask ahead of time.

Ohio State's academic integrity policy

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentlife.osu.edu/csc/.

Copyright disclaimer

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

Statement on title IX (Recommended)

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator, Kellie Brennan, at titleix@osu.edu

Accessibility accommodations for students with disabilities

The university strives to make all learning experiences as accessible as possible. In light of the current pandemic, students seeking to request COVID-related accommodations may do so through the university's request process, managed by Student Life Disability Services. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely

fashion. SLDS contact information: slds@osu.edu; 614-292-3307; http://slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

Accessibility of course technology

This course requires use of Carmen (Ohio State's learning management system). If you need additional services to use these technologies, please request accommodations with your instructor.

Your mental health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614- 292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available through the 24/7 National Suicide Prevention Hotline at 1-800-273- TALK or at suicidepreventionlifeline.org

Disclaimer

This syllabus should be taken as a fairly reliable guide for the course content. However, you cannot claim any rights from it and in particular we reserve the right to change due dates or the methods of grading and/or assessment if necessary. Any changes will be communicated to you through official course announcements.

Course schedule (tentative)

This schedule is subject to revision. Students are expected to attend class meetings and to regularly check for updates.

Week	Dates	Topics
1	Tu 8/24	Course overview, Previous techniques in shape analysis
1	Th 8/26	Background: relevant tools from geometry
2	Tu 8/31	Background: relevant tools from geometry
2	Th 9/2	Background: relevant tools from geometry
3	Tu 9/7	Functional data analysis and elastic registration
3	Th 9/9	Functional data analysis and elastic registration
4	Tu 9/14	Functional data analysis and elastic registration
4	Th 9/16	Shapes of planar open curves
5	Tu 9/21	Shapes of planar open curves
5	Th 9/23	Shapes of planar closed curves
6	Tu 9/28	Statistical modeling on nonlinear manifolds
6	Th 9/30	Statistical modeling on nonlinear manifolds/Statistical modeling of planar shapes
7	Tu 10/5	Project presentations
7	Th 10/7	Project presentations