Statistics 597A.1: Functional Data Analysis
Fall 2014

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Class Schedule: MWF 10:10-11:00, 105 Wartick Lab

Office Hours: By appointment.

Textbook: Functional Data Analysis with R and Matlab, Ramsay, Hooker, and Graves. Inference for Functional Data with Applications, Horvath and Kokoszka. Both are available online. Additional notes will also be provided in class.

Webpage: Available through ANGEL, check regularly for updates.

Course Topics:
1. Examples and motivations
2. Basis expansions and nonparametric smoothing
3. Hilbert space framework for functional data
4. Estimating mean functions and covariance operators
5. Functional principal components
6. Functional linear models
7. Dependent functional data
8. Sparse functional data (time permitting)

Learning Objectives:
This course aims to provide an introduction to functional data analysis, FDA. The fundamental statistical tools for modeling and analyzing such data will be explored. There will also be heavy emphasis on statistical computing (using R) and applications. Specific objectives broken down by topic are included below. Each of the methodological objectives below will be complimented with corresponding computational methods and data examples.

1. The primary objective for the first course topic is to provide students with an understanding of how functional data arises and the areas where it is commonly encountered. We will go through many motivating examples as well as provide a basic probabilistic structure for how these data are generated.
2. Our next objective is to demonstrate how one moves from observed vectors to functional objects. We will discuss the basics of nonparametric smoothing, and in particular, demonstrate how basis expansions can be used to create and store (computationally) functional objects.
3. We will then discuss the Hilbert space based modeling framework for functional observations. A basic introduction to function space and operator theory will be provided. We will then discuss how functional objects can be modeled using this framework, and in particular, explore the basics of probability theory for function space valued objects (including distributions and expected values).

4. Once a basic framework for functional data is established, we will present the idea of mean functions and covariance operators. Once these objects are defined, we will discuss estimation procedures and their various properties.

5. One of the fundamental tools of FDA is the functional principal component analysis, FPCA. We will discuss the connections between FPCA, the spectral theorem for covariance operators, and the Karhunen-Loève expansion. Estimation methods and their properties will also be discussed.

6. Next we will discuss the various forms of the functional linear model. This will include function on function regression or function/scalar regression. Estimation methods and properties will be discussed.

7. While previous objectives are carried out with iid functional objects, we will discuss generalizations to dependent sequences, including functional time series and space-time functional data.

8. FDA methods are commonly carried out using high frequency or densely observed trajectories. The setting when this is not the case is referred to as sparse functional data analysis, and commonly comes up in longitudinal studies. We will explore how our methods change for such data.

**Grading:**

Homework: 50%
Midterm Report: 20%
Final Report + Presentation: 30%

**Homework:**

Homework will be assigned every other Wednesday and will be due two weeks later. All homework must be turned in by **Wednesday** to me. **No late homework will be accepted.** You are encouraged to work together on homework, but each student must turn in his/her own write up and answers.

**Exams:** There will be no exams for this course.

**Projects/Presentation:** Each student will work on a project throughout the semester. A midterm report will be submitted which outlines the primary goals and details of the project. A final report will be submitted at the end of the semester and students will give a 15-20 minute presentation based on that report. This project can fall under either one of two categories:

1. Students may investigate an FDA research paper/methodology not described in the class. Students will need to present a short simulation study, of their own design, which explores the procedure.
2. Students may present a novel data application where they apply FDA methods. The advantages/disadvantages of the FDA perspective, in the context of the application, should be discussed.

**Academic Integrity:**
Academic integrity is the pursuit of scholarly activity free from fraud and deception and is an educational objective of this institution. All University policies regarding academic integrity apply to this course. Academic dishonesty includes, but is not limited to, cheating, plagiarizing, fabricating of information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the instructor, or tampering with the academic work of other students. All exam answers must be your own, and you must not provide any assistance to other students during exams.

**Disability Services:**
Penn State welcomes students with disabilities into the University's educational programs. If you have a disability-related need for reasonable academic adjustments in this course, contact the Office for Disability Services (ODS) at 814-863-1807 (V/TTY). For further information regarding ODS, please visit the Office for Disability Services Web site at http://equity.psu.edu/ods/. In order to receive consideration for course accommodations, you must contact ODS and provide documentation. If the documentation supports the need for academic adjustments, ODS will provide a letter identifying appropriate academic adjustments. Please share this letter and discuss the adjustments with your instructor as early in the course as possible.