MATH 442: Mathematical Modeling

Fall 2015

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Lecture:	Tuesdays + Thursdays, 12:45–2:00pm Blocker Bldg., Room 122
Office hours:	Thursdays, 2:00–4:00pm or by appointment

Textbooks

There are many books about mathematical modeling that you may find helpful. That said, this course does not require you to have any of them, though you will frequently have to go to the internet to find information, data, or inspiration.
You will have to do a lot of writing this semester. I leave it up to you what program you want to do this in, but here are two considerations:

- Entering a lot of formulas is something that is at best awkward in Microsoft Word. Formulas also look terrible in Word.
- All math department computers, including the ones in the calclab room where we will meet only run Linux and, consequently, there is no Microsoft Word. (Though there will be OpenOffice/LibreOffice.)

Consequently, I will introduce you to http://www.overleaf.com, a service that provides a cloud-based graphical frontend to the LaTeX system used to typeset practically all mathematical literature. A good book on LaTeX is this one:

H. Kopka and P. W. Daly: *A Guide to LATEX*, 4th edition. Addison Wesley, 2003.

It is not mandatory that you have it: there are a lot of resources on LaTeX on the internet if you ever have a question. Overleaf.com is also a very useful tool for groups of people writing parts of the same text since multiple people can edit different parts of the same document at the same time.

Prerequisites

Prerequisites: MATH 304 (Linear Algebra) and MATH 308 (Differential Equations), or consent of instructor. We will be using Maple for many computations, but if you are more comfortable with other programs such as Mathematica or Matlab, you are free to use those as well. **One way or the other, you will be doing some programming in each of your assignments, and you need to be comfortable with programming small programs.**

Catalog description

The construction of mathematical models from areas such as economics, game theory, integer programming, mathematical biology and mathematical physics.

Webpage

Assignments and other course information will be posted at the course website:
http://www.math.tamu.edu/~bangerth/teaching.html

Course goals

Modeling is about describing the world around us in a mathematical way. For example, we might want to describe how the number of ants on an island is going to change, how clouds form, how traffic flows, how a bridge deforms when you drive over it, how the stock market works, etc.
Why would we want to do this? There are basically three reasons for this:

- Understand: Sometimes we see things we cannot intuitively understand, but we can try to describe them in mathematical models and using these models provides us with insight as to why things may be this way. For example, ever noticed that branches don't attach to the trunk of a tree at an angle (as one would get if you welded one pipe to another) but instead in a smooth curve? If we model this situation with the equations of elasticity, then they predict that we would get an infinite stress (force) if there was an angle, which wood cannot support, and consequently trees must accommodate for this by using smooth curves. Likewise, one can observe that populations of predators and prey often oscillate over time. Why? Well, models can explain this.

- Predict: If you're an engineer or a policy maker, you probably want to predict what will happen if you do X. How far will the bridge bend when you drive a truck with maximal load over it, and will the bending be small enough for it not to snap? Will Earth warm if the amount of carbon dioxide in the atmosphere doubles? To answer such questions, one needs *quantitative* ways of predicting what will happen, and this requires a mathematical formulation.

- Optimize: Of course, for the engineer, the ultimate question is not *Will the bridge snap or not?* but *How can I build a bridge in the cheapest/most efficient/fastest way so that it does not snap but stay within safety limits?* This is an *optimization problem* and, again, one needs quantitative models to solve it.

Mathematical models underlie all of these questions. They are often formulated as (partial) differential equations, but other methods are also often used.
My primary goal for this course is to teach you the way we come up with models, to extract information from them, and to write and communicate about them (this is a "C" course, after all). Developing a model for situation X often comes down to a process such as the following:

- State what we know about the system.
- Determine what factors may affect it.
- Determine which of these factors we think is important.
- Express in mathematical terms what each of these factors does.
- Bring these effects together into one consistent whole.

The point is that, unlike many of the other math classes you have taken so far, here our goal is not to derive a formula that is "correct". Rather, we will try to come up with one that in mathematical terms describes what we intuitively know but that is still, probably, only an approximation of reality. Estimating and evaluation how good an approximation it is to reality is an important second step, as is assessing which of multiple possible models matches real data best. It is this process that I want to teach you.
Additional objectives I have for this course are:

- To make you familiar with symbolic mathematical software such as Maple: Most models you will ever encounter in life are stated in terms of formulas that do not allow simple solutions with paper and pencil. Rather, they will require the use of computers, and knowing the right tools and how to operate them is an important skill.
- To be able to communicate results through presentations and comprehensive reports: We no longer live in a world of private scholars, but rather work in teams where exchanging information is a part of daily life. Doing so concisely and efficiently is something you can learn and practice, and we will do so in this class.

How I teach this course

From the description above, you probably already guess that this is not a math course like any other. It requires using common sense and good judgment. It will integrate many of the things you have learned throughout the previous semesters, such as calculus, differential equations, and some linear algebra. It is also a communication intensive (C) course.

In other words, the course is more like an engineering "capstone" course in which you get to apply a lot of the things you've learned so far, and to use it in a realistic context. Like many other capstone courses, such a class works best through project work. I will therefore spend relatively little time standing at the whiteboard lecturing. Rather, the emphasis will be on project work – in class, outside class, in small groups or individually, and with my feedback. You will have to read up on material, read and correct what others read, and write your own documents. If you want see a few of the ideas that inspire the way I want to teach this course, take a look at a paper a former colleague of mine (Dr Jean Marie Linhart) wrote and that is available at http://www.jeanmarielinhart.info/wp-content/uploads/2014/04/linhart_primus_2014.pdf.

It will probably be more work than any "normal" class. I hope you will also find it more fun.

Projects and grading

Assignments and projects: Your grade in this class will be determined by how you do in the project and writing assignments, and in your final presentation. There will be 4 assignments over the course of the semester:

- Assignment 1 (worth 20%)
- Assignment 2 (worth 20%)
- Assignment 3 (worth 20%)
- Assignment 4 (final project, worth 30%)

What each of these assignments involves and when it is due will be discussed for each assignment individually. The assignments will all involve thinking and writing, not just doing – you will find that you will be better off if you start work on them early.

In addition to the assignments above, you will need to present your work to the class at the end of the semester. This will be worth 10%. There will be no midterm or final exams.

By university policy, since this is a C course, you must pass the writing and presentation components in order to pass the course. To aid you with the writing portion of the course, we will run peer review sessions before reports are due (see below), and I will leave detailed comments during grading of earlier reports that will help you in writing the later ones.

Make-up work: You must make arrangements in advance if you will not be handing in homework on time or will miss an exam. Absences due to recognized University-related activities, religious holidays, verifiable illness, and family/medical emergencies will be dealt with on an individual basis, but require a written excuse. Please let me know about this as soon as possible, and preferably in advance.

Research, citations, plagiarism, peer review: Your writing assignments will require you to find data and resources in the library, on the internet, or elsewhere. Using what others have done before is part of research, but you must clearly label what is your work and what you got from elsewhere. In other words, you must make it obvious to the reader if you are directly quoting what others have written and you must provide references to original sources of both quotes and ideas you are using. If you don't, this is called plagiarism, and it is not acceptable – neither in this class, nor anywhere else in life. People lose their jobs by plagiarizing others, and you will get zero points on your assignments if you do. In other words: don't. If you use what others have said or written, give credit where credit is due.
Since writing is such an important part of this class, we will also peer review each other's work. This implies that others will get to see what you are writing for your assignments. This may seem intimidating at first, but it is really the best way to write a project to let others around you give feedback, tell you what worked and what didn't, which parts were unclear, etc., before you give your report to me. Reading what others write also gives you an idea of the level at which this class operates, and whether you need to step up or can relax a bit.
If you would like to use an idea of one of your classmates in your report, discuss this with the person who had it and if you do incorporate it provide adequate credit in the form of a reference. You can never copy or use a classmate's work without their consent and without proper attribution.

Policies

Academic integrity: The usual rules of academic intregrity apply. In particular, the Aggie Honor Code "An Aggie does not lie, cheat or steal, or tolerate those who do" should be selfevident, see

http://www.tamu.edu/aggiehonor.html

You may, and are encouraged to, work together and discuss homework problems with each other. However, copying work done by others is an act of scholastic dishonesty and will be persecuted to the full extent allowed by University policy.

Absences: Let me know if you have to miss a class in the future. If you missed a class without telling, let me know as soon as possible afterwards. In general, Rule 7 of the Texas A&M University Student Rules applies, as do the other rules.

Americans with Disabilities Act (ADA) Policy Statement: The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact the Department of Student Life, Services for Students with Disabilities, in Cain Hall or call 845-1637. See also http://disability.tamu.edu.

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