CSE 545, Error Correcting Codes: Combinatorics, Algorithms and Applications
SPRING 2013

Mon Wed Fri 2:00-2:50pm, Norton 218

- Please complete the (anonymous) feedback form on the blog.

Instructor information

Atri Rudra (Webpage)

- *Email:* atri "at" buffalo "dot" edu

- *Office:* Davis 319

- *Phone:* 645-2464

- *Office Hours: By Appointment.*

It is preferable to set up an appointment if you want to talk to me. However, you can drop by if my office door is open.

Course Description

Error correcting codes are systematic ways of introducing redundancy into data so that the original information can be recovered even when the data is corrupted. Error correcting codes (or just codes) are used ubiquitously in communication systems and data storage. The study of error correcting codes (or coding theory) started with the seminal works of Shannon and Hamming in the late 1940s.

This course will discuss the theoretical aspects of codes and will focus mostly on the worst case noise model pioneered by Hamming. However, we will discuss quite a few results on the stochastic noise model pioneered by Shannon. We will use techniques from combinatorics, probability theory and algebra among other areas.

The course will be roughly divided into three parts. The first part will look at the combinatorial issues in the design of codes. This part will mostly be classical results that talk about limits to what can and cannot be done using codes. The second part of the course will deal with the algorithmic aspects of codes. In particular, we will focus on efficient algorithms that recover the original information from corrupted data (called decoding). In this part we will discuss some exciting recent developments that bridge the "divergent" schools of thoughts of Shannon and Hamming. Finally, we will study some application of codes outside of the "traditional" error correcting applications. In particular, we will see how codes can be used to obtain results in theoretical computer science in general. If there is interest, we might also look at more practically motivated applications e.g. secure biometrics.

Pre-requisites

There is no specific course pre-requisite for this course. However, some "mathematical maturity" will be essential. In particular, comfort with basics of linear algebra (vector spaces, basis, dual spaces); finite fields, field extensions and polynomials over finite fields; elementary probability; analysis of algorithms; and (some exposure to) computational complexity will be useful. Some of these topics (for example finite fields) can be learned on a need to know basis as the course progresses. Email the instructor if you have any questions on the pre-requisites.

References

We will follow draft of a book that I am writing with Venkat Guruswami and Madhu Sudan. Some chapters might get uploaded as we go along. The current version of the draft can be found at

> http://www.cse.buffalo.edu/~atri/courses/coding-theory/book/

The basic material on codes that we will discuss in initial lectures can be found in many textbooks (some of the standard ones are listed below), but the recent algorithmic developments and applications in computer science are not covered in any of these:

- *Introduction to Coding Theory*, by J. H. van Lint, GTM 86.

- *The Theory of Error Correcting Codes*, by F. J. MacWilliams and N. J. A. Sloane, North-Holland, Amsterdam.

- *Algebraic codes for data transmission*, by Richard E. Blahut.

Class Blog

> http://codingtheory.wordpress.com

We will be using a blog for the course in lieu of a course webpage and newsgroup. It will be the one-stop-shop for the course. All announcements will be made on the blog. If you are registered for the course, you **must** check the blog regularly (and consider subscribing to the RSS feed or subscribing to receive notifications by email via links on the blog). These announcements would include the ones that inform if and when classes/office hours are re-scheduled as well as reminders for deadlines etc.

Usually, I will be the only one who will write the blog entries. There will be an entry for each lecture and homework. You are encouraged to use piazza to post questions and/or comments. (More on this in a bit.) Sometimes, the blog may include side comments or stories that I feel are relevant to the course (but are not directly related to the lectures).

Discussion Forum

This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates and myself. Rather than emailing questions to me, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com. To familiarize yourself with the system, look at their help page.

You will need to sign up for Piazza. To do so, go to https://piazza.com/buffalo/spring2013/cse545.

Grading Policy

Here is a rough split of grades:

- Proof-reading (20%)

- Homeworks (45-35%)

- Updating Wikipedia (35-45%)

See the next few sections for more details on each of the above components.

Proof-reading

For each lecture, one student will volunteer to proof-read the corresponding part of the book and email me a list of corrections, passages that are not clear, some suggestions for improvement etc. Below are some things that you can look for:

- Typos (there will invariably be some!)

- Formatting: If you do not like the "look" of the book (or parts of it).

- If you think an example would help in some place, let me know. (Just don't say that an example will be useful– send me the example too.)

- If you think a figure would help in some place, please let me know. (Again, if you think a figure would be useful, at least send me a rough figure.)

- If you think the explanation is terse/unclear, let me know. (Again, please be specific and let me know what exactly needs to be explained better and your suggestions for improvement.)

I will typically ask for a volunteer at the beginning of the class. Please don't try to flatter me by saying that the writeup is perfect :-) It certainly is not and you will be graded on the depth of your comments. Depending on the number of students in the class, each student might have to do 3-4 proof-readings. Take this as an opportunity to understand the lecture material even better!

The email is due by noon of the day of the next lecture. For example, the notes for Monday, January 14 are due Wednesday January 16 by noon.

Updating Wikipedia

Depending on the class strength, students will form groups of up to 2-3 and each group will pick a coding theory topic that is either absent or not well documented on Wikipedia and write/edit the corresponding entry. You will have the opportunity to work on initial versions of the entry on an in-house wiki page before the entries are posted on Wikipedia (you'll need to get my OK before you post your entry on Wikipedia).

To ensure a timely completion of this part of the course, you will have to follow the following deadlines:

- *March 20, 2012.* You should inform me about the entry in Wikipedia that your group will work on by this date. (Note that this right after the spring break.)

- *March 27, 2012.* You should submit a one page "report" outlining what will appear in your entry. Further, it should be clearly indicated what each group group member will be working on. (*Note:* You are allowed to deviate a bit from what you say in this document in your final entry. This document is supposed to me more of a guideline so that I can make sure your entry has the right feel to it.)

- *April 17, 2012.* The deadline to submit your entry on the in-house Wiki.

- *April 24, 2012.* I will hand back my comments to you for the final version to be uploaded to Wikipedia.

- *May 1, 2012.* The date by which your entry should be uploaded to Wikipedia. You should also update your entry in the in-house wiki by this date.

- *May 8, 2012.* The date by which you should take care of any (reasonable) comments that other readers might put on your Wikipedia entry.

Your group will be graded on the quality and depth of your entry. Below is how the grade for this part of the course will be distributed:

1. 60% for the version that you turn in by April 17.

2. 30% for the final version in the in-house wiki.

3. 10% for the final version uploaded to Wikipedia.

Note that I expect one person from your group to *take ownership* of your Wikipedia entry (if your group created a new Wikipedia page).

Homeworks

There will about three short ones due in a week. Collaboration in groups of size at most three is allowed (and encouraged). However, every student is expected to do their own writeup and clearly state the names of their collaborators.

My homework philosophy for this course is that they are meant for you to work on stuff that I did not have time to cover in the lectures. (Don't worry: you will be provided with hints for the tougher problems!) Note that this is **not** the same philosophy for a usual course, where homeworks are used to re-enforce material covered in the lectures.

More details will be available when the homeworks are handed out.

Academic Honesty

I will follow the CSE department academic integrity policy. Details can be found at

http://www.cse.buffalo.edu/shared/policies/academic.php

Suggestions or Comments?

I would be happy to get feedback from you. You can either

- Talk/send email to me, or

- Use piazza, or

- Fill in the feedback forms that will be handed periodically in class.