This document contains a synthesis of the presentation by Professor Stark on earthquake modeling and prediction on 10/3 as well as Professor Stark's presentation on earthquake modeling and prediction on 10/18.

Stark Notes 10/3

You can read Prof. Stark's and Freedman's 2001 paper on Earthquake Prediction, which motivated much of the presentation, here:

http://www.stat.berkeley.edu/~stark/Preprints/611.pdf

Synthesis

0 Main Takeaways (TL;DR)

- Statistical modeling of poorly understood natural disasters is unreliable. Misapplication of statistical theory to phenomenal can get one arrested for 'failing to predict'!
- Instead of predictions, we should be focusing on protection and sensibly informing the public.

1 Attempts at Modeling Earthquakes

Statistical Models Used

- Poisson Distribution
- Casinos or Terrorism?
  - Some statisticians try to compute P(earthquake) using models similar to those modeling toy games. Prof Stark pointed out that this doesn't have strong reasonable assumptions. Why should earthquakes be modeled like casino games? Why not think of them instead like terrorist attacks?
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2 Why Current Earthquake Modeling Fails

What is probability, anyways?

- Rabbit-Hat Theorem
  - testing whether something is random using the assumption that it's random doesn't prove that it's random (that's recursive)

    - just assuming that something has average time between failures does not imply that this is true
- Kolmogorov's Axioms
    - Making Sense of Nonsense
    - Kolmogorov axiomatized probability, which you can read more about here.
- The Frequentist Approach
    - Long Run Frequency -- can earthquakes be thought of in terms of long-run frequency? That doesn't seem to make sense.
    - Replication is a problem, the article uses the example of repeating years (2000-2030) over and over again, which can only be done via imagination.
- The Bayesian Conspiracy
    - Subjective Belief -- can we talk about earthquakes as properties of our own beliefs about the world? Yes, but then what does it mean for P(Earthquake) = 1? Should national policies be dictated on subjective beliefs of individuals? What if they come into conflict.
    - Opinionated and people have different interpretations / insights.

The Physics Behind Earthquakes

- How much do 'experts' really know?
    - Not Very Much -- Italian scientists failed to predict the quakes that shook a major city. Most experts in seismology, statistics and geography are still unable to come to a tenable conclusion as to how in the world we can grapple with the seemingly intractable problem of earthquake predictions.
- some predictions hold "by chance"
    - can't conclude a method has merit just because some predictions come true

Stark Notes 10/18

This document contains a synthesis of the presentation by Professor Stark on earthquake modeling and prediction on 10/18

You can read Prof. Stark's Magnitude-dependent automatic Alarms presentation slide deck here:

Prof. Stark's Magnitude-dependent automatic Alarms presentation slide

Synthesis

In summary, Professor Stark addressed the faults of the ETAS system of predicting earthquakes. The system is quite complex and makes faulty assumptions about earthquakes following probability distributions. Not only is ETAS built upon faulty assumptions, it only performs marginally better than magnitude-dependent automatic alarms. Magnitude-dependent automatic alarms trigger an alarm system that indicates the probability and size of future earthquakes after a trigger. Our project this semester will be to improve upon this system. It is much simpler than ETAS but is not built upon a faulty application of statistics. Specifically, we want to improve Tau*mu^Magnitude so as to make the model a better predictor than the ETAS model. We will build upon other people's code and use the data we gather online to find a better estimate for Tau*mu^Magnitude.

2. Magnitude-dependent Automatic Alarms

a. Gave a speech at Samsi

b. The ETAS model assumes earthquakes are a stochastic model, which may be a faulty assumption

c. New project is designed to give an alternative to ETAS

3. Rabbit-Hat Theorem

a. We assume too much about earthquakes following a probability distribution.

b. Probability does not apply if assumptions are wrong: Just because something has a rate does not mean it is random.

4. What would make casino metaphor apt?

a. The physics of earthquakes may be stochastic

b. Stochastic models may provide compact, accurate, description of earthquake phenomenology

c. May be useful to predict the future

5. Applicability of Poisson Process

a. Doesn’t fit: too little clustering

b. Gamma renewal doesn’t fit either because gamma is memoryless and we know earthquakes are more likely to come after other earthquakes.

c. ETAS doesn’t fit

d. Test for Poisson behavior: highly iterative.

  i. Testing ECDFs and CDFs using a non-parametric test.

  ii. Physics, data do not justify using a Poisson

6. Strong statistical evidence that Data renewal and ETAS are not adequate to describe data

7. Automatic Alarms:

a. Automatic alarms are triggered after every event with a particular magnitude. Alarm of a duration tau.

  i. No free parameters

b. Magnitude-dependent automatic alarms: triggered after many events with the duration being proportional to the size of the earthquake.

c. Project is about lowering error for every given duration.

  i. ETAS doesn’t help much even if the assumptions were true

8. How to tweak magnitude dependent automatic alarms to make it more accurate. Using different parameters to minimize error in the first half of the chart (the part where alarms are on only a percentage of the time. All models do about the same when alarms are always on, and this isn’t practical anyway)

9. ETAS model:

a. Heuristic: some events are unpredictable background main shocks

b. Empirical relationships:

i. Gutenberg Richter law (Not a probability model, but people use it as such)

1. ETAS uses a particular value of b for everything. Turns the rate into a probability density.

ii. Omori-Utsu law:

1. The bigger the earthquake the more aftershocks you should expect

10. Fitting the ETAS model:

a. Using Maximum Likelihood

11. Using ETAS is predict

a. Optimal predictor of stochastic processes

Next steps:

- Reach out to grad. student for his code.
- Install etas.f; port etas.f to Python if we can't find an implementation in Python Download data from SCEC
- Replicate grad student's dissertation results and try to replicate the plots....