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Report Title

A Graphical Exploration of the IkeNet E-mail Dataset

ABSTRACT

This is a set of powerpoint slides regarding the IKENET database and a preliminary analysis.

A Graphical Exploration of the IkeNet E-mail Dataset

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UCLA Applied Math

March 15, 2012

What is the IkeNet e-mail dataset?

- ▶ Certain cadets at West Point are given Blackberries in exchange for their willingness to have data about their communication activity logged and studied.
- ▶ We have a database on the e-mail communications within a network of 22 such students over ≈ 1 year, from May 2010 to May 2011.
- ▶ Note that only the e-mails sent *within* the network are included, not all e-mails sent by each subject.
- ▶ There are ≈ 8500 such emails, and each includes three pieces of information: sender, receiver, and timestamp.
- ▶ Today I will show you several plots made from this data, to hopefully elicit ideas about further avenues of exploration.

First, the network of e-mail traffic.

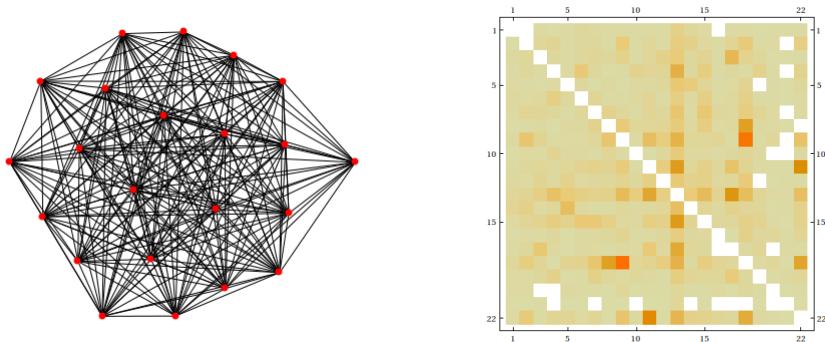


Figure 1: (Left) Dots represent the 22 subjects, and a line connects two dots if there is at least 1 correspondence between the two in our dataset. There is only 1 component, but it is not fully connected. (Right) A plot showing the number of e-mails sent from subject i (row) to subject j (column). Note this is a directed graph, and the matrix is not symmetric.

A histogram of e-mails per pair.

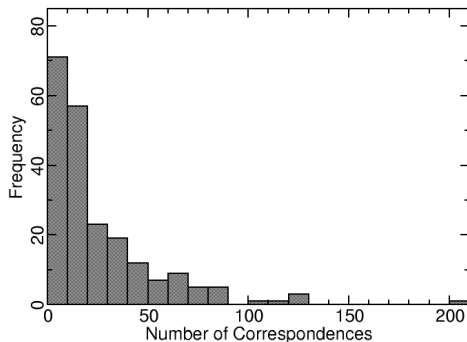


Figure 2: This is data from a symmetric version of the graph, and shows frequency of correspondences per pair. There are 5 pairs not shown here, each with many more correspondences. For example, pair (9, 18) has 1032 messages!

Now, if we threshold the graph at 20 e-mails, we see some more detail.

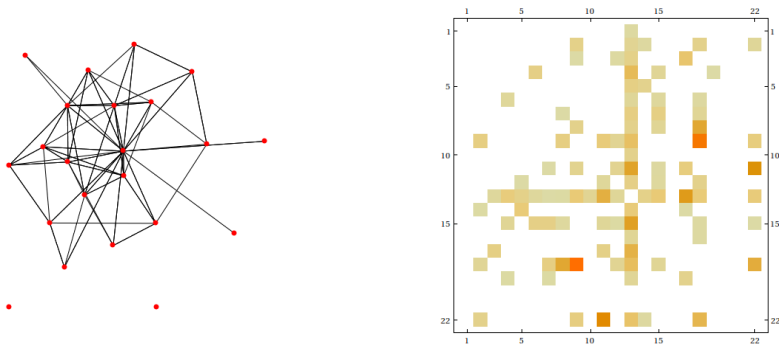


Figure 3: (Left) Here, we see that subject 13 begins to stand out as a central figure with by far the most “significant” connections. Subjects 20 and 21 are no longer a part of the network at all.

Now some temporal properties.

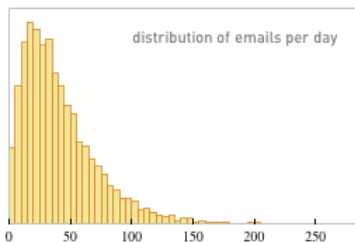
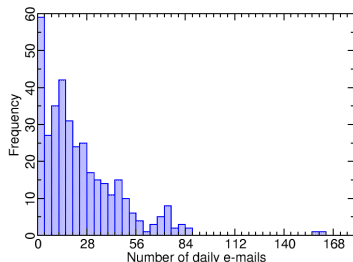


Figure 4: (Left) Histogram of e-mails sent per day in the IKeNet dataset. Note the large bar at < 4 e-mails – weekends? (Right) For fun, a similar plot from Stephen Wolfram, using his sent e-mails since 1989 (!). He is clearly more e-mail happy than the West Points cadets, but the general shape (omitting the origin) is similar. . .

But when are the e-mails sent?

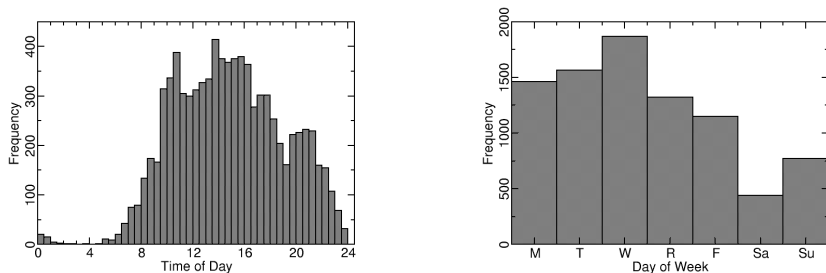


Figure 5: (Left) A histogram of when IkeNet e-mails were sent during the day. We clearly see a diurnal rhythm, modulated by lunch and dinner effects. (Right) Histogram of e-mails per weekday, clearly dropping off on the weekends.

We can see these cycles clearly in an auto-correlation analysis of the time series.

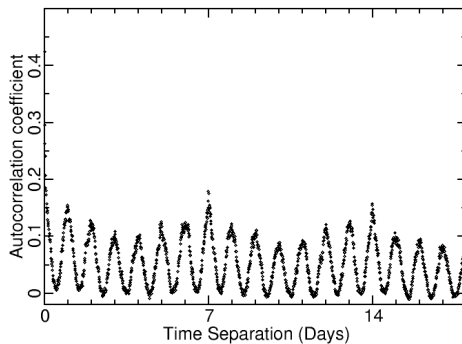


Figure 6: But, also note the large spike near the origin, indicating large correlation at very short timescales – self-excitation?

We can check for self-excitation using a “fixed-window” count.

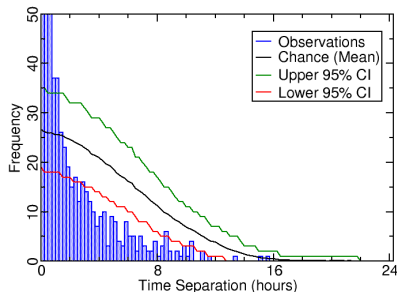


Figure 7: Here, we find all occurrences of subject pairs that exchanged exactly two e-mails on a calendar day (802 of these), then plot the frequency of time intervals between the two e-mails. The observations are vastly larger than chance at times less than around 1 hour. 311 are separated by less than 15 minutes.

We might try fitting a time series to a Hawkes process.

- ▶ Let's use the time series from pair (9, 18), which is most prolific at 1032 messages.
- ▶ Fit the data to a process of the form

$$\lambda(t) = \mu + k \sum_{t_i < t} \omega e^{-\omega(t-t_i)}$$

using Maximum Likelihood Estimation.

- ▶ The best fit parameters are: $\mu = 0.054$ per hour, $k = 0.585$, and $\omega^{-1} = 0.099$ hours, with a log-likelihood of -1303.6 .
- ▶ These parameters tell us that there were around 428 background events for this pair, and 604 excited events. That's a lot of excitation...

We can also fit non-parametrically using EM (as in Mohler *et al.*, 2011 *JASA*)

$$\text{Here } \lambda(t) = \mu(t) + \sum_{t_i < t} g(t - t_i) .$$

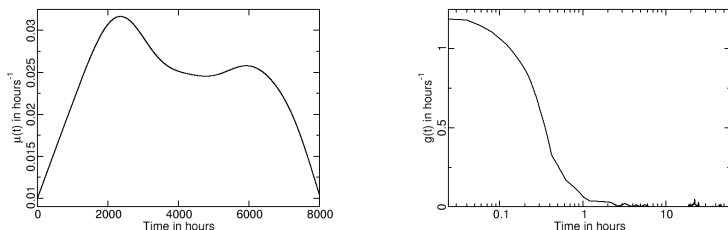


Figure 8: Here we show KDEs of the background $\mu(t)$ and excited kernel $g(t)$ for pair (9, 18). These kernels give roughly 202 background events, and 1,100 excited events. Log-likelihood is -1379.4 , though, which is worse than Hawkes.

What might we explore next?

- ▶ Do a more careful EM analysis (MPLE?).
- ▶ Build daily and weekly rhythms directly into the EM or Hawkes process, since a lot of information is there.
- ▶ Explore data from other pairs (i, j) , and perhaps include multi-party interactions.
- ▶ Look (much) more deeply into the graph structure. Perhaps using some of Uminsky's coalition finding techniques?
- ▶ Try to obtain more data from different sources (GMail?) on frequency of emails sent per day, to explore perhaps a simple model that explains similarities (and differences) between IkeNet and Wolfram.
- ▶ All this, and much, much more. . .