Discussion of the 2014 Markov Lecture

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What’s in a Traffic Model?
My First Traffic Model…

- AR(1) one of most widely used stochastic models

\[ X_t = c + aX_{t-1} + Z_t \]

- If \(|a| < 1\) is process always stable?
Modeling Traffic

![Graph showing the number of arrivals over time for different days of the week. The graph has a y-axis labeled 'Number of Arrivals' ranging from 0 to 400 and an x-axis labeled 'Time' ranging from 7 to 24. Different colors represent each day: Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday. The graph shows the variation in arrival rates throughout the day for each day.](image-url)
A Closer Look

Arrival rate calls/hr

95% Confidence bands

Forecast

Time (8am-8pm)
## Poisson?

<table>
<thead>
<tr>
<th>Day</th>
<th>Mean no. of arriving calls</th>
<th>C.V. <a href="%25">empirical</a></th>
<th>CV [Poisson] (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon</td>
<td>943</td>
<td>26.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Tue</td>
<td>824</td>
<td>22.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Wed</td>
<td>807</td>
<td>26.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Thu</td>
<td>778</td>
<td>28.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Fri</td>
<td>767</td>
<td>33.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Sat</td>
<td>293</td>
<td>61.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Sun</td>
<td>139</td>
<td>148.1</td>
<td>8.5</td>
</tr>
</tbody>
</table>
Variability versus Uncertainty

- Uncertainty dominates variability => coarse analysis ignoring CLT-type effects
- Variability dominates uncertainty => fine grain analysis w/ CLT-type corrections
- Relationship between coefficient of variation and function of offered load…
Atomistic User Behavior

- Many instances of traffic involve atomistic users that seek to maximize their own utility...and make choices accordingly
- Gives rise to more complicated models that need to incorporate this behavior
- Original (and still classic) instances drawn from transportation networks
Important modeling primitives

- User choice (utility function)
- Feedback from system (congestion announcements, mobile GPS, feedback from other users etc)
- Pricing congestion externalities
- Traffic shaping
“Price of Anarchy”
Queueing Questions

• Does ample capacity always lead to short delays?
• Delays can help force user “self selection”…
• What happens when users act strategically?
• Observational learning phenomena…
Queueing Questions (cont’d)

- What/how should congestion information be shared with users?
- Does truthful information sharing improve system-wide performance?
- Is a precise delay estimate announcement better (or worse) relative to “vaguer” information?
- How do the above affect resulting traffic patterns?
Content on the Internet

- Close to million new content pages a day
- How does this content behave in terms of user interest?
Aggregate Traffic Patterns

Single-Day Traffic
Temporal Interest Patterns

- Football article
- Crime article
- Celebrities article
- Politics article
Aging Patterns

Remaining traffic (%) = 56 \exp\{-t/30\}
High Frequency Trading
HFT (cont’d)

- How do capacity constraints affect trade dynamics?
- How does user strategic behavior impact traffic “peak” formations?
- Recent queueing theoretic models of limit order book dynamics and strategic execution patterns…
Modeling Patient Sensor Data

![Graph showing shock index and HRsmoothed signal over time in minutes.](image)
THANK YOU!
Boston Area Traffic Density