ISE 453: Design of PLS Systems

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Geometric Mean

- How many people can be crammed into a car?
 - Certainly more than one and less than 100: the average (50) seems to be too high, but the geometric mean (10) is reasonable

Geometric Mean: $X = \sqrt{LB \times UB} = \sqrt{1 \times 100} = 10$

- Often it is difficult to directly estimate input parameter X, but is easy to estimate reasonable lower and upper bounds (LB and UB) for the parameter
 - Since the guessed LB and UB are usually orders of magnitude apart, use of the arithmetic mean would give too much weight to UB
 - Geometric mean gives a more reasonable estimate because it is a logarithmic average of LB and UB

Fermi Problems

- Involves "reasonable" (i.e., +/- 10%) guesstimation of input parameters needed and back-of-the-envelope type approximations
 - Goal is to have an answer that is within an order of magnitude of the correct answer (or what is termed a *zeroth-order approximation*)
 - Works because over- and under-estimations of each parameter tend to cancel each other out as long as there is no consistent bias
- How many McDonald's restaurants in U.S.? (actual 2013: 14,267)

Parameter	LB		UB	Estimate	
Annual per capita demand	1	1 order/person-day x 350 day/yr =	350	18.71	(order/person-yr)
U.S. population				300,000,000	(person)
Operating hours per day				16	(hr/day)
Orders per store per minute (in-store + drive-thru)				1	(order/store-min)
Analysis					
Annual U.S. demand		(person) x (order/person-yr) =		5,612,486,080	(order/yr)
Daily U.S. demand		(order/yr)/365 day/yr =		15,376,674	(order/day)
Daily demand per store		(hrs/day) x 60 min/hr x (order/store-min) =		960	(order/store-day)
Est. number of U.S. stores		(order/day) / (order/store-day) =		16,017	(store)

System Performance Estimation

- Often easy to estimate performance of a new system if can assume either perfect (LB) or no (UB) control
- Example: estimate waiting time for a bus
 - 8 min. avg. time (aka "headway") between buses
 - Customers arrive at random
 - assuming no web-based bus tracking
 - Perfect control (LB): wait time = half of headway
 - No control (*practical* UB): wait time = headway
 - assuming buses arrive at random (Poisson process)

Estimated wait time =
$$\sqrt{LB \times UB} = \sqrt{\frac{8}{2} \times 8} = 5.67$$
 min

Bad control can result in higher values than no control

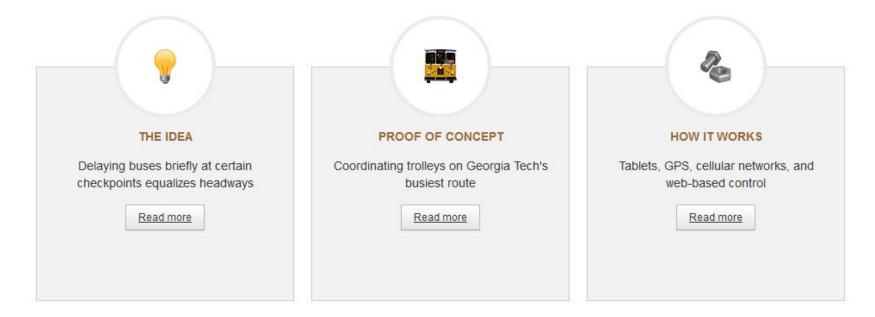
http://www.nextbuzz.gatech.edu/



HOME THE IDEA PROOF OF CONCEPT HOW IT WORKS CONTRIBUTORS

A BUS-HEADWAY CONTROLLER

A software system to coördinate buses on a route, based on an idea by John J. Bartholdi III and Donald D. Eisenstein. The current version of the software was designed and largely written by Loren K. Platzman. Implementation has been led by Russ Clark, Jin Lee, and David Williamson.



Ex 1: Geometric Mean

 If, during the morning rush, there are three buses operating on Wolfline Route 13 and it takes them 45 minutes, on average, to complete one circuit of the route, what is the estimated waiting time for a student who does not use TransLoc for real-time bus tracking?

Answer :

Frequency (TH)
$$= \frac{WIP}{CT} = \frac{3 \text{ bus/circuit}}{45 \text{ min/circuit}} = \frac{1}{15} \text{ bus/min}, \text{ Headway} = \frac{1}{\text{Freq.}} = 15 \text{ min/bus}$$

Estimated wait time $= \sqrt{LB \times UB} = \sqrt{\frac{15}{2} \times 15} = 10.61 \text{ min}$

Ex 2: Fermi Problem

 Estimate the average amount spent per trip to a grocery store. Total U.S. supermarket sales were recently determined to be \$649,087,000,000, but it is not clear whether this number refers to annual sales, or monthly, or weekly sales.

 $\frac{\$6.5e11}{3e8} \approx \$2,000 / \text{ person-yr}, \quad LB = 1 \text{ trips/wk}, UB = 7 \text{ trips/wk}$ **Answer**: $\Rightarrow \sqrt{1(7)} \times 52 \approx 2 \times 52 \approx 100 \text{ trips/yr} \Rightarrow \frac{\$2,000}{100} = \$20 \text{ / person-trip}$ Supermarket / Grocery Store Statistics Data Total number of grocery store employees 3,400,000 Total supermarket sales in 2015 \$649,087,000,000 Total supermarket sales in 2012 \$602.609.000.000 Total number of grocery stores / supermarkets 37,053 Median weekly sales per supermarket store \$384.911 Average grocery store transaction amount \$27.30 Average number of grocery store trips per week a consumers 2.2 makes Average number of items carried in a supermarket 38.718

Levels of Modeling

- 0. Guesstimation (order of magnitude)
- 1. Mean value analysis (linear, ±20%)
- 2. Nonlinear models (incl. variance, ±5%)
- 3. Simulation models (complex interactions)
- 4. Prototypes/pilot studies
- 5. Build/do and then tweak it