18.440: Lecture 37

Review: practice problems

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Expectation and variance

- Eight athletic teams are ranked 1 through 8 after season one, and ranked 1 through 8 again after season two. Assume that each set of rankings is chosen uniformly from the set of 8! possible rankings and that the two rankings are independent. Let N be the number of teams whose rank does not change from season one to season two. Let N_+ the number of teams whose rank improves by exactly two spots. Let N_- be the number whose rank declines by exactly two spots. Compute the following:
  - $E[N]$, $E[N_+]$, and $E[N_-]$
  - $\mathrm{Var}[N]$
  - $\mathrm{Var}[N_+]$

Expectation and variance — answers

- Let N_i be 1 if team ranked ith first season remains ith second seasons. Then $E[N] = E[\sum_{i=1}^{8} N_i] = 8 \cdot \frac{1}{8} = 1$. Similarly, $E[N_+] = E[N_-] = 6 \cdot \frac{1}{8} = 3/4$
- $\mathrm{Var}[N] = E[N^2] - E[N]^2$ and $E[N^2] = E[\sum_{i=1}^{8} \sum_{j=1}^{8} N_i N_j] = 8 \cdot \frac{1}{8} + 56 \cdot \frac{1}{56} = 2$.
- N_+^i be 1 if team ranked ith has rank improve to $(i-2)$th for second seasons. Then $E[(N_+)^2] = E[\sum_{3=1}^{8} \sum_{3=1}^{8} N_+^i N_+^j] = 6 \cdot \frac{1}{8} + 30 \cdot \frac{1}{56} = 9/7$, so $\mathrm{Var}[N_+] = 9/7 - (3/4)^2$.

Conditional distributions

- Roll ten dice. Find the conditional probability that there are exactly 4 ones, given that there are exactly 4 sixes.

Conditional distributions — answers

- Straightforward approach: $P(A|B) = P(AB)/P(B)$.
- Numerator: is $\frac{\binom{10}{4}\binom{6}{4}4^2}{6^{10}}$. Denominator is $\frac{\binom{10}{4}5^6}{6^10}$.
- Ratio is $\binom{6}{4}4^2/5^6 = \binom{6}{4}(\frac{1}{5})^4(\frac{4}{5})^2$.
- Alternate solution: first condition on location of the 6's and then use binomial theorem.

Poisson point processes

- Suppose that in a certain town earthquakes are a Poisson point process, with an average of one per decade, and volcano eruptions are an independent Poisson point process, with an average of two per decade. The V be length of time (in decades) until the first volcano eruption and E the length of time (in decades) until the first earthquake. Compute the following:
  - $\mathbb{E}[E^2]$ and $\mathrm{Cov}[E, V]$.
  - The expected number of calendar years, in the next decade (ten calendar years), that have no earthquakes and no volcano eruptions.
  - The probability density function of $\min\{E, V\}$.

Poisson point processes — answers

- $E[E^2] = 2$ and $\mathrm{Cov}[E, V] = 0$.
- Probability of no earthquake or eruption in first year is $e^{-(2+1)\frac{1}{10}} = e^{-.3}$ (see next part). Same for any year by memoryless property. Expected number of quake/eruption-free years is $10e^{-.3} \approx 7.4$.
- Probability density function of $\min\{E, V\}$ is $3e^{-(2+1)x}$ for $x \geq 0$, and 0 for $x < 0$.

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