NYC Restaurant Inspections

Analysis and k-Means Clustering

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Sources

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Sources: Data

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Restaurant Inspections

- Began July 2010
- Itemized violations contribute to a score based on severity
  - 2B: Hot food not held at or above 140°F, 7 to 28 points
  - 10J: "Wash Hands" sign not posted at hand-wash facility, 2 points
  - etc.
- A: 0–13, B: 14–27, C: 28 and higher
- Not all inspections are graded, low grades lead to re-inspection

Getting and Cleaning the Data

- Data set available through NYC Open Data
- Data needs to be cleaned
  - e.g. `Fontana"s` $\rightarrow$ `Fontana's`
- Data needs to be parsed
- Code performance concerns
  - $\approx 24,500$ rows of data
  - R quirks

Preliminary Analysis

Time between inspections

- Mean time between inspections around 130 days
- Inspections that end in an A grade have a shorter time since last inspection (about 120 days)

Number of inspections

- Mean of about 7 inspections per restaurant

Score

- Mean score of 16 (a B, but this includes ungraded inspections)
- Mean score of Starbucks is 9

Clustering

Why do we cluster things?

- Exploratory analysis
- Classification

k-Means clustering

- Clusters defined by their means
- Originated as an information theory problem (S. P. Lloyd, 1957)
- Analogy to the case of estimating a single mean

k-Means Clustering

Notation

Event space E

Probability mass function p

$\{z_i\}_{i=1}^{\infty}$ random points in E

$x = \{x_i\}_{i=1}^{k}$, $x_i \in E$

Partition $S = \{S_i\}_{i=1}^{k}$

$$\mu_i = \frac{\int_{S_i} z \, dp(z)}{p(S_i)}$$

Given x, define $S(x) = \{S_i(x)\}_{i=1}^{k}$ the minimum distance partition of E

Algorithm (MacQueen)

At each step n we have the k-means $x^n = \{x_i^n\}_{i=1}^k$, (integer) weights $w^n = \{w_i^n\}_{i=1}^k$, and partition $S^n = S(x^n)$

At the start

$$x_i^1 = z_i \qquad\qquad w_i^1 = 1$$

For each subsequent step, we incorporate a new point z_{k+n} and update

$$\text{if } z_{k+n} \in S_i^n \text{ then } x_i^{n+1} = \frac{x_i^n w_i^n + z_{k+n}}{w_i^n + 1}$$

$$w_i^{n+1} = w_i^n + 1$$

$$x_j^{n+1} = x_j^n \text{ and } w_j^{n+1} = w_j^n \text{ for } j \neq i$$

Convergence of k-Means

We define

$$W(x) = \sum_{i=1}^{k} \int_{S_i} |z - x_i| dp(z)$$

$$V(x) = \sum_{i=1}^{k} \int_{S_i} |z - \mu_i(x)| dp(z)$$

Theorem

The sequence $\{W(x^1), W(x^2), \ldots\}$ *of random variables converges and* $\lim_{n\to\infty} W(x^n) = V(x)$ *for some* x *where* $x_i = \mu_i$ *and* $x_i \neq x_j$ *for* $i \neq j$.

A sketch of the proof

Pathological Distributions

- Circle
- Square
- Rectangle

What do we want to cluster?

Frequency of violations

- Tally occurrences of each violation
- Scale by number of inspections

Transitions between grades

- Treat the grades as a Markov chain
- Build a matrix of transition probabilities
- How to treat transitions we don't have data for?

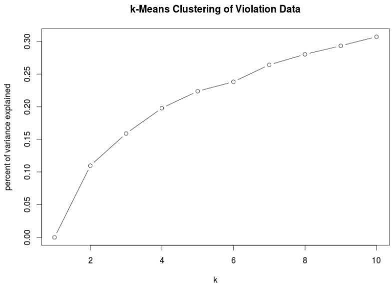
Finding *k*

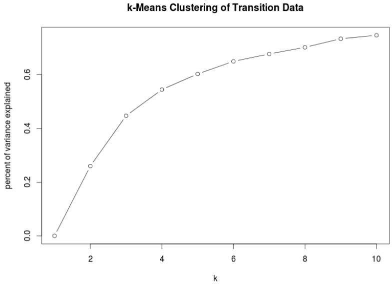
How do we find *k*?

- Increasing *k* will always reduce sum-of-squares

The elbow method

- Find where increasing *k* has less of an impact (the "elbow")





Clustering Results

Violation frequencies

- Very sparse data
- Clusters don't account for much of the variance (about 25%)
- Hard to interpret

Transition matrices

- Good accounting of the variance (about 60%)
- Can interpret cluster centers
- Problems of scaling from missing data

Transition Clusters

$k = 5$

- $A \to A$, $B \to B$, and $C \to C$ dominated restaurants all end up clustered together
- Two clusters with dominant $B \to A$ transitions
  - one has notable $A \to A$ and $A \to B$ transitions, with barely any transitions to C
  - other splits evenly from A, when at C, the $C \to A$ transition is dominant

Transition Clusters

$k = 9$

- $A \to A$ dominated cluster is identifiable
- "re-scaling" of matrices helps make sense of centers
- Clusters with dominant $B \to A$ transitions still identifiable
  - Third one appears that drifts down, with relatively small $A \to A$ transition
- Sizeable cluster with a strong $C \to A$ transition that then goes between A and B with slight chances of dropping to C
  - Looking at unscaled version, see most of the data comes from transitions out of C

Conclusion

Conclusions!

Questions?