Chain Rule

- P(A,B) =
- P(A,B,C) =
- P(A,B,C,D) =

Chain Rule

- $P(A,B) = P(A)P(B|A) = P(B)P(A|B)$
- $P(A,B,C) = P(A)P(B,C|A) = P(A)P(B|A)P(C|A,B)$
- $P(A,B,C,D) = P(A)P(B|A)P(C|A,B)P(D|A,B,C)$

(Conditional) Independence

- Knowing about A doesn't help you narrow down the likelihood of B taking on a certain value.
    - e.g. A = temperature in Claremont, B = value of the U.S. dollar
    - What does that mean for the chain rule?
- Conditional independence example: Word likelihood and topic

Joint Probabilities

- In the real world, we commonly observe the interaction of many related random variables.

- Language example: Word frequencies and text type; alignments and translation likelihoods

Marginal Probabilities

- For analysis, we commonly want to know about the behavior of a single variable

- “If I pick a random word from a random book at the library, what is the probability that my word is “sauté”?

Putting it Together…

- Is the chance of rain on a given day in Seattle (S) and Claremont (c) independently distributed?

- Hint: Calculate the marginal chance of rain in each city.

s	Rain	Rain	No Rain	No Rain
c	Rain	No Rain	Rain	No Rain
P(S=s,C=c)	0.043	0.387	0.057	0.513

Bayes Rule

- P(A|B) = (P(B|A)P(A))/P(B)

- Why might this be useful to us in MT?

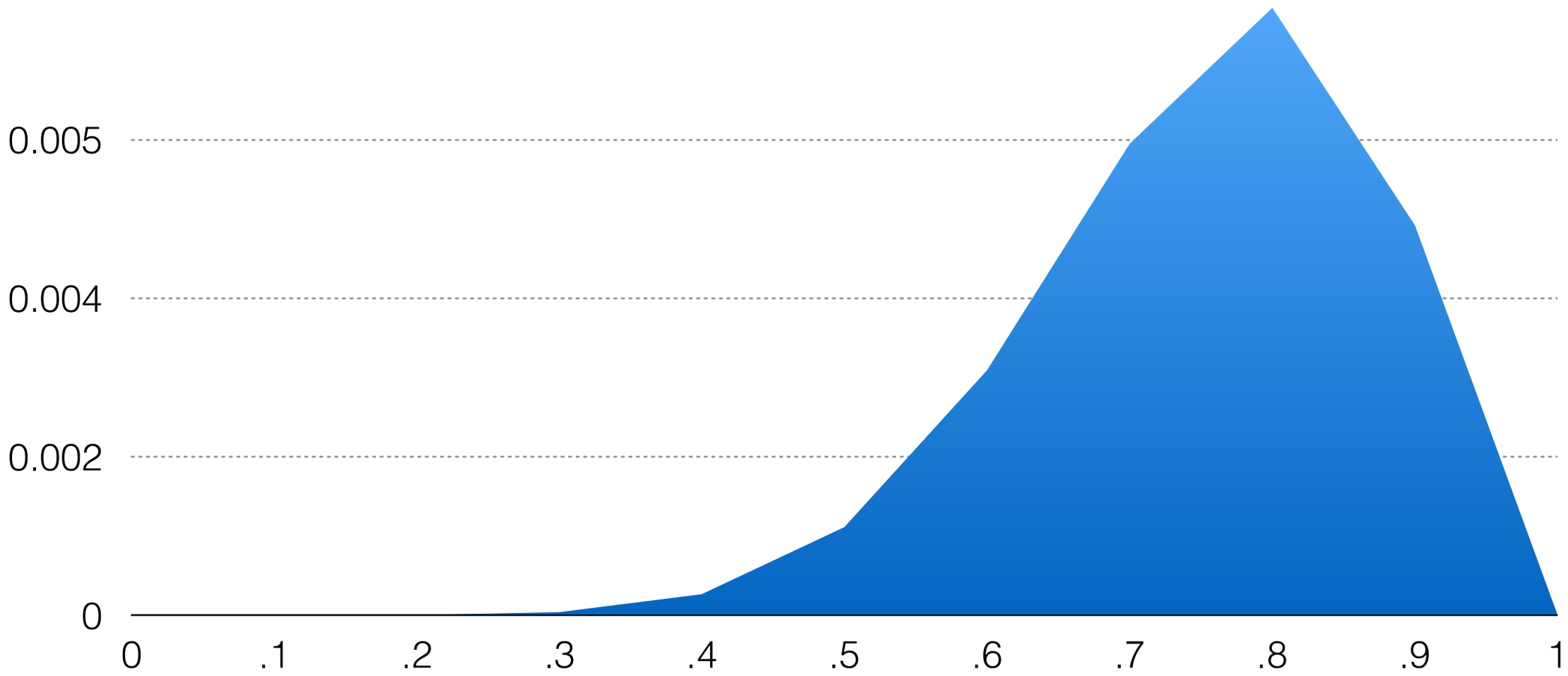
MLE

- Maximum Likelihood Estimate
  - Given observations, estimate parameters
    - Non-language example: Flipping a potentially unfair coin
    - Language example: Given alignments, estimate translation probabilities

MLE Example

- Suppose I toss a coin 10 times
- Result: 8 heads, then 2 tails
    - Sketch likelihood of this result as a function of p(heads)

P(8 heads, 2 tails)



Another MLE Example

- Unknown language alignment
  - Suppose we know the alignments between the words in two sets of words.
  - Then we can estimate the parameters of the model that make that alignment most likely.

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mb	12007	qptuf	20	pggjdf	39	ftu	5556	eênpdsbujf	144
mf	7812	qptubvy	3	cvsfbv	17	(	769	mb	99
mft	5867	qptuft	2	qptuf	9	t(	428	ef	10
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uif qptu pggjdf jt efnpdsbdz

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eênpdsbujf mb ftu d(qptuf mb

Project 1

- Implement word alignment: IBM Model 1 plus one extension
  - A model that prefers to align words close to the diagonal.
  - An HMM alignment model.
  - Combine French-English model and English-French model.
  - Supervised discriminative alignment model
  - Unsupervised discriminative alignment model.