



Variational Inference

Material adapted from David Blei
University of Maryland

EXERCISE

Feedback

- Disagreement from you: flipped classroom (but most like), theory
- I agree with you: one size fits all, inconsistent notation, reading inconsistent, questions in random order
- Sorry: Slides w/ video, hard to hear questions, too much NLP
- Huh?: Online judge, ask questions on same interface, A cutoff, video speed
- Thinking about: second midterm

Announcements

- Next class: unflipped VAE / GAN
- Reading: Goodfellow
- Next week: LSTM / RNN
- Rest of course remains unchanged
- Default project: more data, Kaggle site this week

Useful Reference: $\Psi(x)$

x	$\Psi(x)$
1	-0.577215664902
2	0.422784335098
3	0.922784335098
4	1.25611766843
5	1.50611766843
6	1.70611766843
7	1.8727843351
8	2.01564147796
9	2.14064147796

Also: from `scipy.special` import `digamma`

Example

- Three topics, same documents as last time

$$\beta = \begin{bmatrix} \text{cat} & \text{dog} & \text{hamburger} & \text{iron} & \text{pig} \\ .26 & .185 & .185 & .185 & .185 \\ .185 & .185 & .26 & .185 & .185 \\ .185 & .185 & .185 & .26 & .185 \end{bmatrix} \quad (1)$$

- Assume uniform γ : $(2.0, 2.0, 2.0)$
- Compute update for ϕ

$$\phi_{ni} \propto \beta_{iv} \exp \left(\Psi(\gamma_i) - \Psi \left(\sum_j \gamma_j \right) \right) \quad (2)$$

- For a the first word (dog) in the document: **dog cat cat pig**

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Update ϕ for dog

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$$\phi_{ni} \propto \beta_{iv} \exp \left(\Psi(\gamma_i) - \Psi \left(\sum_j \gamma_j \right) \right)$$

- $\gamma = (2.000, 2.000, 2.000)$

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- $\gamma = (2.000, 2.000, 2.000)$
- $\phi(0) \propto 0.185 \times \exp(\Psi(2.000) - \Psi(2.000 + 2.000 + 2.000)) = 0.051$

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- After normalization: $\{0.333, 0.333, 0.333\}$

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- $\gamma = (2.000, 2.000, 2.000)$
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- After normalization: $\{0.413, 0.294, 0.294\}$

Update γ

- Document: dog cat cat pig
- Update equation

$$\gamma_i = \alpha_i + \sum_n \phi_{ni} \quad (3)$$

- Assume $\alpha = (.1, .1, .1)$

Update γ

- Document: dog cat cat pig
- Update equation

$$\gamma_i = \alpha_i + \sum_n \phi_{ni} \quad (3)$$

- Assume $\alpha = (.1, .1, .1)$

	ϕ_0	ϕ_1	ϕ_2
dog	.333	.333	.333
cat	.413	.294	.294
pig	.333	.333	.333
α	0.1	0.1	0.1
sum	1.592	1.354	1.354

- Note: **do not normalize!**

Update γ

- Document: dog cat cat pig
- Update equation

$$\gamma_i = \alpha_i + \sum_n \phi_{ni} \quad (3)$$

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- Note: **do not normalize!**

Update β

- Count up all of the ϕ across all documents
- For each topic, divide by total
- Corresponds to maximum likelihood of expected counts

Update β

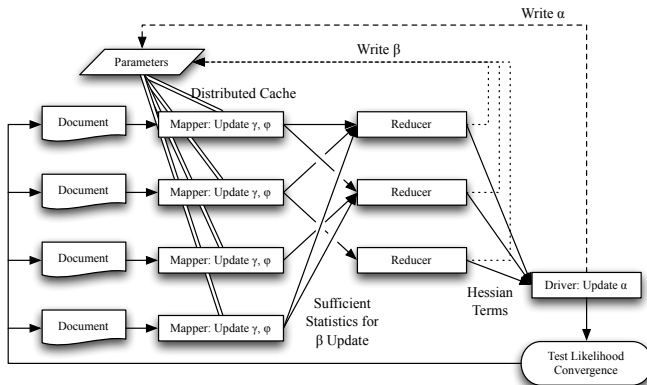
- Count up all of the ϕ across all documents
- For each topic, divide by total
- Corresponds to maximum likelihood of expected counts
- Unlike Gibbs sampling, no Dirichlet prior

Automatic Inference



Parallel LDA

Zhai et al, 2012



Online LDA

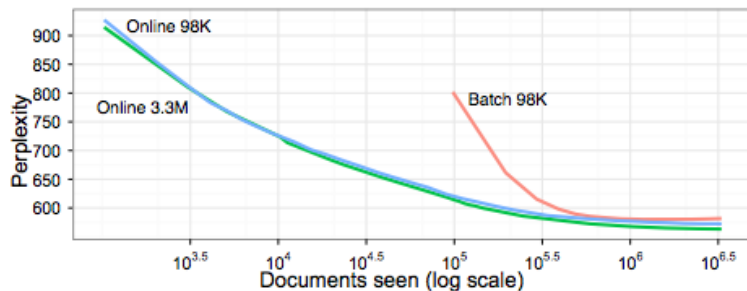
Hoffman and Blei, 2010

Algorithm 2 Online variational Bayes for LDA

Define $\rho_t \triangleq (\tau_0 + t)^{-\kappa}$
 Initialize λ randomly.
for $t = 0$ to ∞ **do**
 E step:
 Initialize $\gamma_{tk} = 1$. (The constant 1 is arbitrary.)
 repeat
 Set $\phi_{twk} \propto \exp\{\mathbb{E}_q[\log \theta_{tk}] + \mathbb{E}_q[\log \beta_{kw}]\}$
 Set $\gamma_{tk} = \alpha + \sum_w \phi_{twk} n_{tw}$
 until $\frac{1}{K} \sum_k |\text{change in } \gamma_{tk}| < 0.00001$
 M step:
 Compute $\tilde{\lambda}_{kw} = \eta + D n_{tw} \phi_{twk}$
 Set $\lambda = (1 - \rho_t) \lambda + \rho_t \tilde{\lambda}$.
end for

Online LDA

Hoffman and Blei, 2010



Online LDA

Hoffman and Blei, 2010

- 1: Initialize $\lambda^{(0)}$ randomly.
- 2: Set the step-size schedule ρ_t appropriately.
- 3: **repeat**
- 4: Sample a data point x_i uniformly from the data set.
- 5: Compute its local variational parameter,

$$\phi = \mathbb{E}_{\lambda^{(t-1)}}[\eta_g(x_i^{(N)}, z_i^{(N)})].$$

- 6: Compute intermediate global parameters as though x_i is replicated N times,

$$\hat{\lambda} = \mathbb{E}_{\phi}[\eta_g(x_i^{(N)}, z_i^{(N)})].$$

- 7: Update the current estimate of the global variational parameters,

$$\lambda^{(t)} = (1 - \rho_t)\lambda^{(t-1)} + \rho_t \hat{\lambda}.$$

- 8: **until** forever

Best of Both Worlds

Algorithm 1 Algorithm for hybrid stochastic variational-Gibbs inference.

```

for  $t \in 1, \dots, \infty$  do
   $\rho_t \leftarrow \left( \frac{1}{t_0 + t} \right)^\kappa$ 
  sample minibatch  $\mathcal{B}$ 
  for  $d \in \mathcal{B}$  do
    initialize  $\mathbf{z}_d^0$ 
    discard  $B$  burn-in sweeps
    for sample  $s \in 1, \dots, S$  do
      for token  $i \in 1, \dots, N_d$  do
        sample  $z_{di}^s \propto (\alpha + N_{dk}) e^{\mathbb{E}_q[\log \beta_{kw}]}$ 
      end for
    end for
  end for
   $\lambda_{kw}^t \leftarrow (1 - \rho_t) \lambda_{kw}^{t-1} + \rho_t \left( \eta + \frac{D}{|\mathcal{B}|} \hat{N}_{kw} \right)$ 
end for

```

Matching Models and Inference

Zhai and Boyd-Graber, 2013

minibatch-5	minibatch-8	minibatch-10	minibatch-16	minibatch-17	minibatch-39	minibatch-83	minibatch-120
102-club	118-club	132-rock	87-series	82-series	1-annual	0-captain	0-appear
115-issue	128-copy	194-issue	161-issue	162-issue	2-rock	1-appear	1-hulk
127-cover	137-cover	215-series	283-copy	288-copy	3-wolverin	3-hulk	2-wolverin
130-copy	138-issue	217-copy	306-appear	294-appear	4-appear	5-rock	3-annual
197-appear	180-appear	226-cover	307-cover	311-cover	5-comicstrip	6-wolverin	4-copy
289-rock	319-rock	261-appear	502-annual	512-annual	6-series	9-comicstrip	5-rider
450-annual	493-annual	588-annual	814-force	830-force	7-mutant	12-annal	6-comicstrip
584-series	639-series	949-force	1194-rider	4782-wolverin	8-cover	13-mutant	7-cover
811-force	877-force	1074-rider	8944-hulk	9659-hulk	12-issue	15-series	8-force
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	7075-captain	6520-mutant	11301-mutant	12009-mutant	16-copy	19-copy	11-issue
		9569-captain	14335-captain	15040-captain	53-force	23-issue	12-series
					57-rider	280-rider	16-mutant
					86-captain		41-rock
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197-appear	180-appear	226-cover	307-cover	311-cover	5-comicstrip	6-wolverin	4-copy
289-rock	319-rock	261-appear	502-annual	512-annual	6-series	9-comicstrip	5-rider
450-annual	493-annual	588-annual	814-force	830-force	7-mutant	12-annal	6-comicstrip
584-series	639-series	949-force	1194-rider	4782-wolverin	8-cover	13-mutant	7-cover
811-forcee	877-force	1074-rider	8944-hulk	9659-hulk	12-issue	15-series	8-force
1090-rider	1003-rider	6038-comicstrip	10819-comicstrip	11527-comicstrip	14-hulk	16-cover	9-captain
	7075-captain	6520-mutant	11301-mutant	12009-mutant	16-copy	19-copy	11-issue
		9569-captain	14335-captain	15040-captain	53-force	23-issue	12-series
					57-rider	280-rider	16-mutant
					86-captain		41-rock
5	8	10	16	17	39	83	
captain	comicstrip	hulk	wolverin	lacy	izzo	gown	
sequitur	mutant	mazelyah	albion				
	patlafountain						

Matching Models and Inference

Zhai and Boyd-Graber, 2013

minibatch-5	minibatch-8	minibatch-10	minibatch-16	minibatch-17	minibatch-39	minibatch-83	minibatch-120
102-club	118-club	132-rock	87-series	82-series	1-annual	0-captain	0-appear
115-issuee	128-copy	194-issue	161-issue	162-issue	2-rock	1-appear	1-hulk
127-cover	137-cover	215-series	283-copy	288-copy	3-wolverin	3-hulk	2-wolverin
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