

Filtered Latent Dirichlet Allocation: Variational Bayes Algorithm

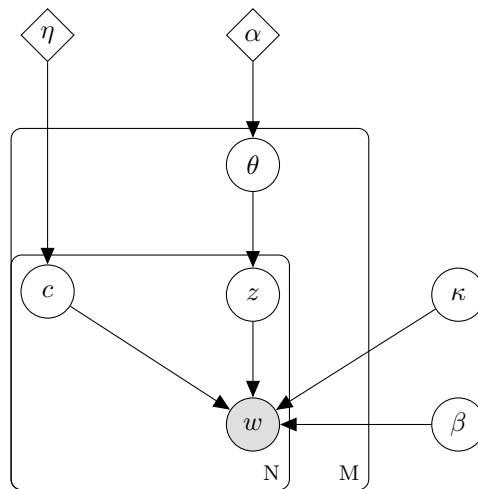
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Filtered latent Dirichlet allocation is a natural extension of latent Dirichlet allocation that organically captures and filters out corpus-specific stop-words which are not otherwise caught by generic stop-word lists.

Probabilistic Graphical Model:

θ_d	$\sim \text{Dirichlet}(\alpha)$
c_{d_n}	$\sim \text{Binomial}(\eta)$
z_{d_n}	$\sim \text{Categorical}(\theta_d)$
w_{d_n}	$\sim \text{Categorical}(\kappa) \quad \text{if } c_{d_n} = 0$
w_{d_n}	$\sim \text{Categorical}(\beta_{z_{d_n}}) \quad \text{if } c_{d_n} = 1$



The marginal log-likelihood for this PGM, in expected value form, is:

$$\begin{aligned}
\log p(w|\alpha, \beta, \kappa, \eta) &\geq \sum_{d=1}^M \left[\mathbb{E}_q[\log p(w_d, z_d, \theta_d|\alpha, \beta, \kappa, \eta)] - \mathbb{E}_q[\log q(z_d, c_d, \theta_d|\phi_d, \tau_d, \gamma_d)] \right] \\
&= \sum_{d=1}^M \left[\mathbb{E}_q[\log p(w_d|z_d, c_d, \beta, \kappa)] + \mathbb{E}_q[\log p(z_d|\theta_d)] + \mathbb{E}_q[\log p(c_d|\eta)] + \mathbb{E}_q[\log p(\theta_d|\alpha)] \right. \\
&\quad \left. - \mathbb{E}_q[\log q(z_d|\phi_d)] - \mathbb{E}_q[\log q(c_d|\tau_d)] - \mathbb{E}_q[\log q(\theta_d|\gamma_d)] \right]
\end{aligned}$$

In particular:

$$\begin{aligned}
\bullet \sum_{d=1}^M \mathbb{E}_q[\log p(w_d|z_d, c_d, \beta, \kappa)] &= \sum_{d=1}^M \sum_{n=1}^{N_d} \mathbb{E}_q[\log p(w_{d_n}|z_{d_n}, c_{d_n}, \beta, \kappa)] \\
&= \sum_{d=1}^M \sum_{n=1}^{N_d} \mathbb{E}_q[\log(\beta_{z_{d_n}, w_{d_n}}^{c_{d_n}} \cdot \kappa_{w_{d_n}}^{1-c_{d_n}})] \\
&= \sum_{d=1}^M \sum_{n=1}^{N_d} [\mathbb{E}_q[c_{d_n}] \cdot \mathbb{E}_q[\log \beta_{z_{d_n}, w_{d_n}}] + \mathbb{E}_q[1 - c_{d_n}] \log \kappa_{w_{d_n}}] \\
&= \sum_{d=1}^M \sum_{n=1}^{N_d} [\tau_{d_n} (-\log \kappa_{w_{d_n}} + \sum_{i=1}^K \phi_{d_{in}} \log \beta_{i w_{d_n}}) + \log \kappa_{w_{d_n}}] \\
\bullet \sum_{d=1}^M \mathbb{E}_q[\log p(c_d|\eta)] &= \sum_{d=1}^M [N_d \log(1 - \eta) + \log(\frac{\eta}{1 - \eta}) \sum_{n=1}^{N_d} \tau_n] \\
\bullet \sum_{d=1}^M \mathbb{E}_q[\log q(c_d|\tau_d)] &= \sum_{d=1}^M \sum_{n=1}^{N_d} [\tau_{d_n} \log \tau_{d_n} + (1 - \tau_{d_n}) \log(1 - \tau_{d_n})]
\end{aligned}$$

The remaining expected values are identical to those found in Blei's paper, *Latent Dirichlet Allocation* (2003).

The relevant update equations are as follows:

- $\eta = \frac{\sum_{d=1}^M \sum_{n=1}^{N_d}}{\sum_{d=1}^M N_d}$
- $\kappa_j \propto \sum_{d=1}^M \sum_{n=1}^{N_d} (1 - \tau_{d_n}) w_{d_n}^j$
- $\tau_{d_n} = \frac{\eta}{\eta + (1 - \eta) \kappa_{w_{d_n}} \prod_{i=1}^K \beta_{i w_{d_n}}^{-\phi_{d_{in}}}}$
- $\phi_{d_{in}} \propto \beta_{i w_{d_n}}^{\tau_{d_n}} \exp\left(\psi(\gamma_i) - \psi\left(\sum_{l=1}^K \gamma_l\right)\right)$
- $\beta_{ij} \propto \sum_{d=1}^M \sum_{n=1}^{N_d} \tau_{d_n} \phi_{d_{in}} w_{d_n}^j$