Conditional Word Embedding and Hypothesis Testing via Bayes-by-Backprop

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A Bayes-by-Backprop

We describe the steps for computing the per-example cost function of the proposed approach below.

1. Sample noise $\epsilon \sim \mathcal{N}(0, I)$.

2. Compute standard deviations $\sigma = \log(1 + \exp(\rho_v))$ and $\sigma_c = \log(1 + \exp(\rho_{v_c}))$

3. Sample a target word vector $\tilde{\theta}_{v|x} = f(\mu_v^{(v)}, \mu_x^{(x)}) + \sigma \odot \epsilon$, where $\odot$ is an element-wise product.

4. Sample a context word vector $\tilde{\theta}_{v_c} = \mu_{v_c} + \sigma_c \odot \epsilon$.

5. Compute approximate log-posteriors

$$\log q(\tilde{\theta}_{v|x}|\phi) = \log \left(\frac{\exp(-\frac{1}{2}(\tilde{\theta}_{v|x} - f(\mu_v, \mu_x))^\top \Sigma^{-1}(\tilde{\theta}_{v|x} - f(\mu_v, \mu_x)))}{\sqrt{(2\pi)^d \mid \Sigma \mid}} \right)$$

$$= -\frac{1}{2}\sum_i^d \epsilon_i^2 - \sum_i^d \log \sigma_i + C$$

$$\log q(\tilde{\theta}_{v_c}^c) = \log \left(\frac{\exp(-\frac{1}{2}(\tilde{\theta}_{v_c}^c - \mu_{v_c})^\top \Sigma^{-1}(\tilde{\theta}_{v_c}^c - \mu_{v_c}))}{\sqrt{(2\pi)^d \mid \Sigma \mid}} \right)$$

$$= -\frac{1}{2}\sum_i^d \epsilon_i^2 - \sum_i^d \log \sigma_i + C$$

6. Compute a prior

$$\log p(\tilde{\theta}_i) = \log \left(u\mathcal{N}(\tilde{\theta}_i|0, \sigma_1^2) + (1 - u)\mathcal{N}(\tilde{\theta}_i|0, \sigma_2^2) \right)$$

$$= \sum_i \log[u\frac{\exp(-\frac{\tilde{\theta}_i^2}{2\sigma_1^2})}{\sigma_1} + (1 - u)\frac{\exp(-\frac{\tilde{\theta}_i^2}{2\sigma_2^2})}{\sigma_2}] + C$$

7. Compute the log-likelihood

$$\log p(v_c|v, x) \approx \log \sigma(\tilde{\theta}_{v|x}^{\top} \tilde{\theta}_{v_c}^{c}) + \frac{1}{M} \sum_{m=1}^{M} \log(1 - \sigma(\tilde{\theta}_{v|x}^{\top} \tilde{\theta}_{v_c^m}^{c})),$$

B Data Summary

The UK Parliament Speech Records includes 4,075,701 records, totaling approximately 10GB of data (when put in .json files.) It covers the records from 1935 to 2012.

C Hyperparameters

Hyper-parameters	Values
Window size	6
Embedding size	100
# of negative samples M	6
Initial learning rate	0.05
Prior mixture stdev (σ_1, σ_2)	(0.2, 1)
Prior weights u	0.5

Table 1: Hyperparameters used in the experiments.

In Table 1, we list the key hyperparameters used in the experiments.

D Case Study: "currency" vs. "sterling" and "pound"

As shown by Fig. 1 in the main text, we see that initially "currency" and "sterling" become more similar to one another, but then depart in meaning from the 1960s and 1970s onwards. This *change point* makes substantive sense, since this is the time in which the UK was essentially abandoning the "sterling area"—a set of countries using sterling (or pegging their currencies to it)—and ceasing to coordinate monetary policy across its members. Thus, sterling as a *currency* became a lower priority for parliamentary business as a whole. In the meantime, "pound" as a "competitive" currency of "sterling", is likely to gain power over the period due to the same policy change. In this way then, our model is able to capture opposing trends between these two pairs of words.

E Word Drifts

Below, we list top-100 words among the 2,000 most frequent words according to their drifts. Each word is shown together with the t^2 statistic and whether the drift is statistically significant (*, ** and *** for the thresholds 0.1, 0.05 and 0.01, respectively.)

- BBP: and (153.6***), through (150.3***), its (148.8***), on (148.8***), from (147.3***), new (146.7***), including (145.3***), against (143.6***), our (143.5***), by (143.4***), across (143.3***), upon (142.1***), council (142.0***), of (141.9***), major (139.4***), national (139.3***), business (138.6***), post (138.4***), in (137.7***), british (137.5***), under (136.9***), role (136.3***), the (136.0***), between (135.9***), central (135.6**), private (135.5**), which (135.5**), both (135.3**), programme (135.1**), international (134.9**), into (134.1**), with (133.8**), power (133.6**), also (133.1**), change (132.8**), trust (132.5**), future (132.3**), public (132.2**), defence (132.2**), up (132.0**), financial (131.9**), police (131.9**), community (131.8**), for (131.4**), towards (131.0**), free (130.5**), group (130.3**), particular

(130.3**), instead (130.3**), open (130.0**), development (130.0**), called (130.0**), about (129.8**), an (129.7**), indeed (129.6**), without (129.5**), policy (129.5**), such (129.4**), their (129.3**), support (129.2**), or (129.0**), rather (128.9**), a (128.9**), however (128.5**), whose (128.2**), trade (127.8**), while (127.7**), either (127.5**), particularly (127.4**), use (127.2**), as (127.2**), who (127.1**), european (127.1**), fund (127.1**), therefore (126.9**), system (126.6**), scheme (126.5**), respect (126.5**), now (126.5**), duty (126.4**), authority (126.3**), only (126.2**), councils (126.2**), form (126.2**), regional (126.2**), current (126.0**), act (125.9**), commission (125.9**), all (125.9**), economic (125.8**), down (125.5**), at (125.5**), importance (125.3**), but (125.0**), recent (124.9**), home (124.9**), labour (124.8**), having (124.7**), because (124.7**), part (124.6**)

- DBE: uk (99.7), eu (89.2), gallant (48.2), funding (116.4), nhs (48.6), war (96.8), billion (101.1), council (142.0***), currently (63.6), president (65.7), g (66.5), upon (142.1***), ministry (104.6), th (80.4), labour (124.8**), regulation (98.5), d (60.8), p (50.9), sir (89.4), community (131.8**), regime (73.0), colonial (59.2), tax (121.4*), st (103.6), b (89.3), men (82.2), e (80.0), commonwealth (104.6), t (92.8), nato (66.4), environment (106.2), africa (83.4), terrorism (55.9), agency (100.3), deliver (72.7), european (127.1**), assembly (86.1), skills (74.3), concerns (108.0), tons (65.5), special (122.6*), issue (118.8*), environmental (59.7), energy (107.0), corporation (109.0), issues (112.8), parliamentary (68.7), problem (109.6), damage (55.4), role (136.3***), current (126.0**), defence (132.2**), estimates (98.0), investment (109.0), credit (106.3), asked (72.5), opposite (55.2)