Quantifying Lexical Semantic Shift via Unbalanced Optimal Transport

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Background

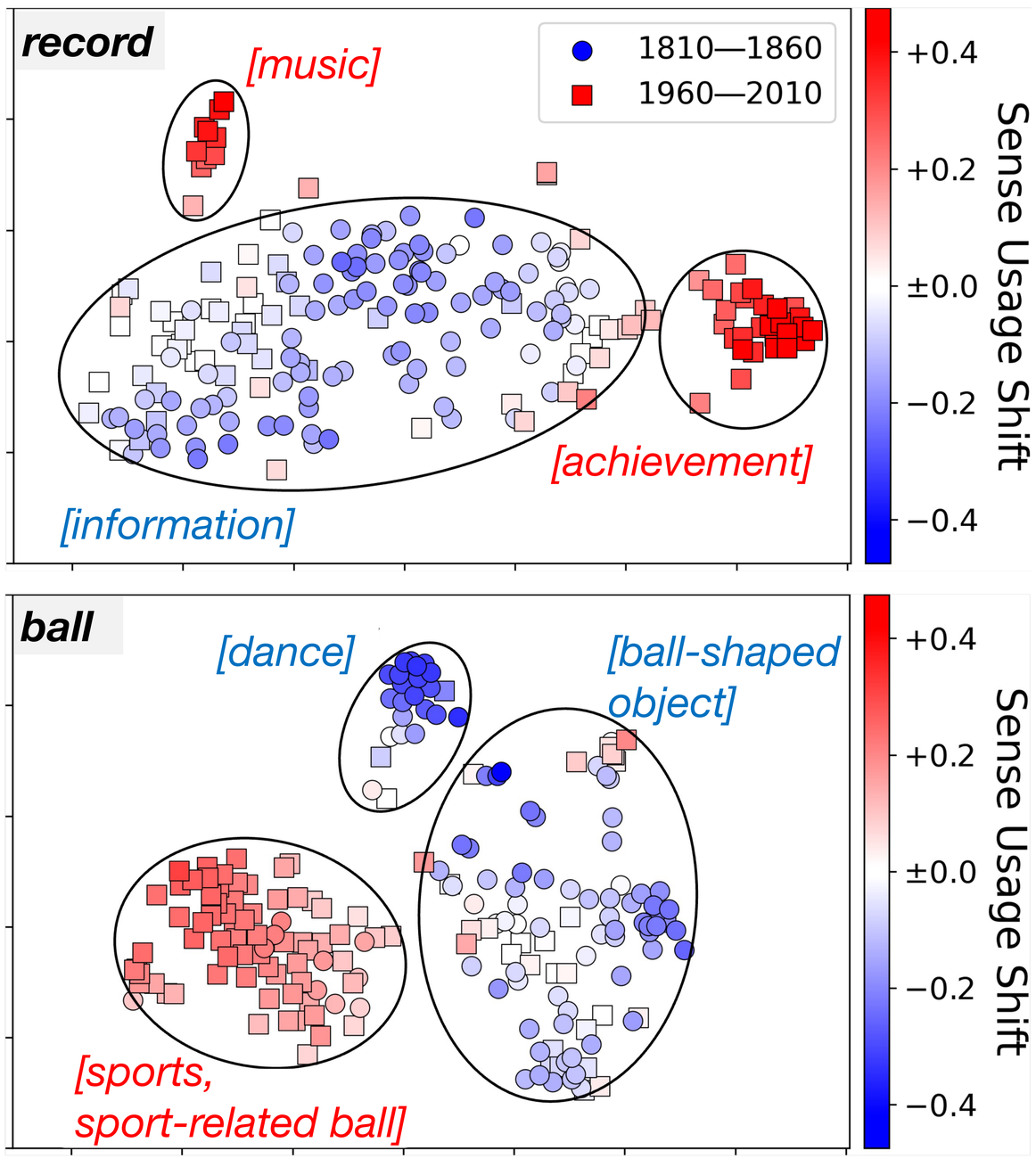
- Some word senses disappear/emerge over time.
- Existing methods mainly address detecting word-level semantic shift [1], offering limited insight into instance-level shift.
- Unbalanced optimal transport provides alignment with excess and deficit between old and modern instances.

Approach

- Using the alignment excess and deficit via UOT, define **Sense Usage Shift (SUS)**, which captures instance-level semantic shift.

Results

- SUS can quantify shifts in the relative frequency of word sense over time at the instance level.
- Aggregating SUS across instances enables to quantify word-level semantic shift.

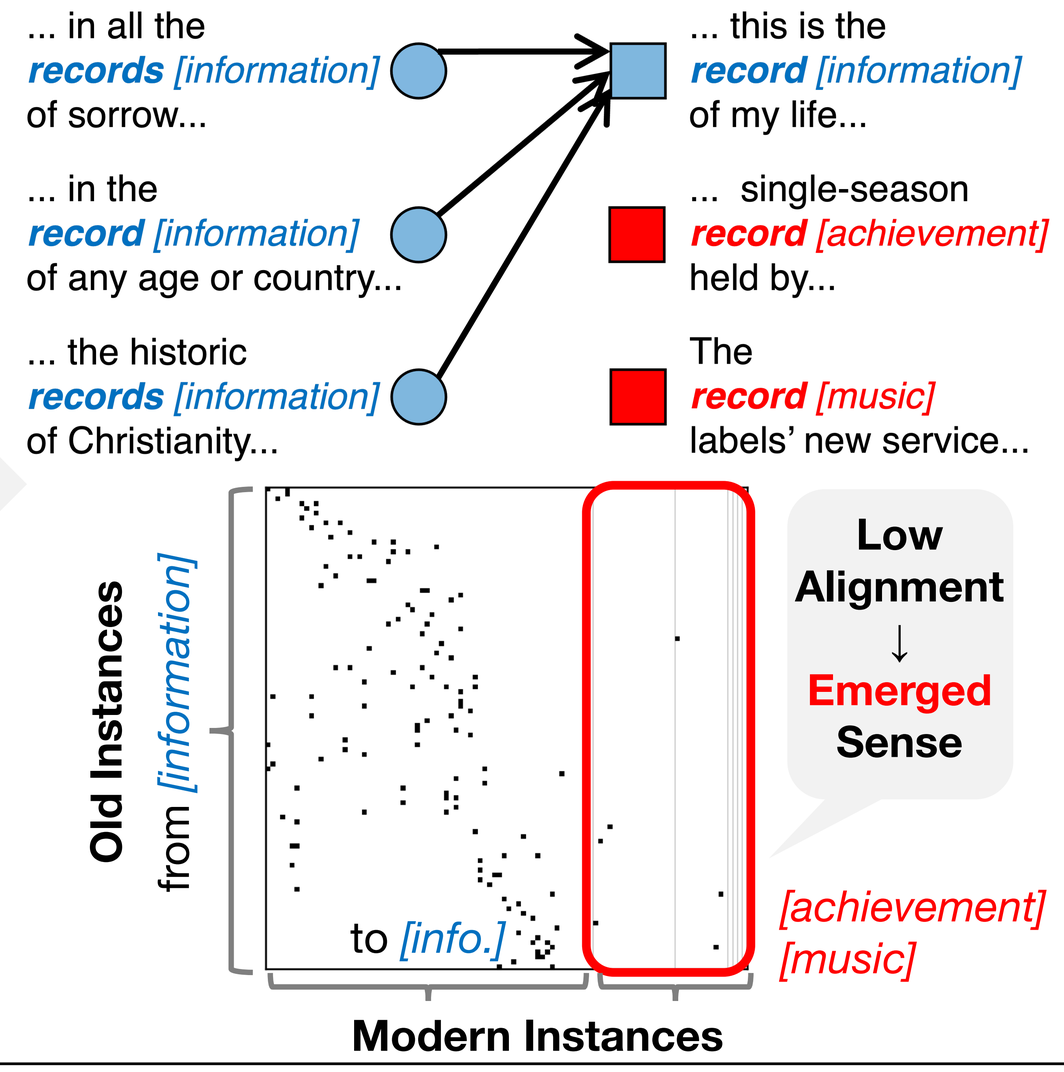


Quantifying Instance-Level Semantic Shift via UOT

- Use old/modern contexts containing the target word (e.g., *record*) from the DWUG dataset [2].
- $\{\boldsymbol{u}_i\}_{i=1}^{100}, \{\boldsymbol{v}_j\}_{j=1}^{100} \subset \mathbb{R}^{1024}$: old/modern embeddings
- $\boldsymbol{a}, \boldsymbol{b}$: uniform weights
- $\boldsymbol{C}$: cost matrix, $C_{ij} = 1 - \cos(\boldsymbol{u}_i, \boldsymbol{v}_j)$
- Find best unbalanced alignment $\boldsymbol{T}$ solving

$$\min_{\boldsymbol{T}\geq 0} \sum_{i,j} T_{ij}C_{ij} + \lambda\|\boldsymbol{T}\mathbf{1}_n - \boldsymbol{a}\|^2 + \lambda\|\boldsymbol{T}^\top\mathbf{1}_m - \boldsymbol{b}\|^2$$

Visualize



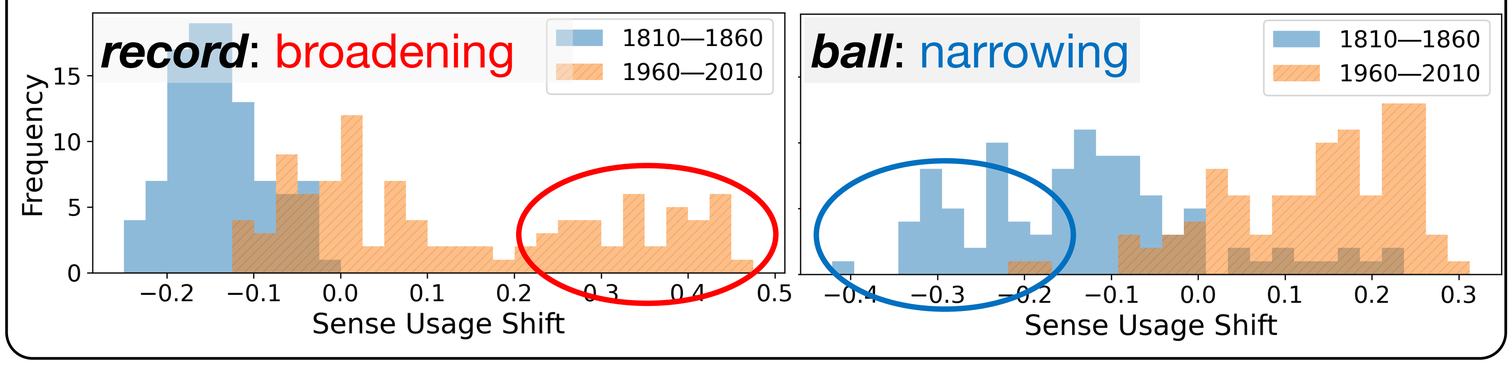
- We propose SUS, which quantifies shifts in the frequency of word usage at each instance:

$$\mathrm{SUS}(\boldsymbol{u}_i) = -\left(a_i - \sum_j T_{ij}\right)/a_i\,,$$

$$\mathrm{SUS}(\boldsymbol{v}_j) = \left(b_j - \sum_i T_{ij}\right)/b_j\,.$$

Quantifying Word-Level Semantic Shift

- Aggregating SUS across instances within each time period enables to quantify how much a word meaning has changed.



Paper

- More visualizations
- Quantitative evaluation comparing with other methods

References

[1] Periti&Montanelli. Lexical Semantic Change through Large Language Models: a Survey. ACM Comput. Surv. 2024.
[2] Schlechtweg, et al. DWUG: A large Resource of Diachronic Word Usage Graphs in Four Languages. EMNLP 2021.