

User Dynamics from Sentence Embeddings

Project Midterm Report

Steven Morse

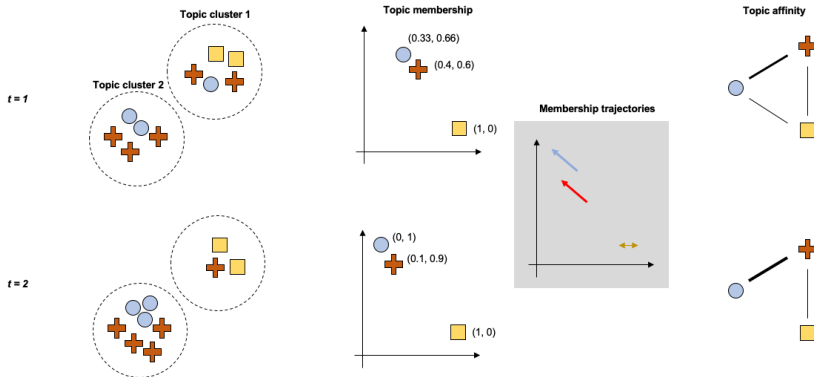
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Overview

Question

- Can we learn the **relational structure** of users in a social forum from their **posts**?
- Is the structure predictive of behavior over **time**?



Related work

1. User embedding via behavior
[Han et al., 2020]
2. Word + user embeddings
[Liang et al., 2018]
3. Link prediction with obs network
[Hasan and Zaki, 2011]
4. Link prediction with structured text
[Dileo et al., 2024]

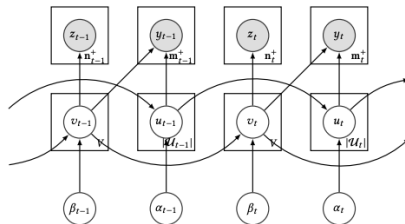
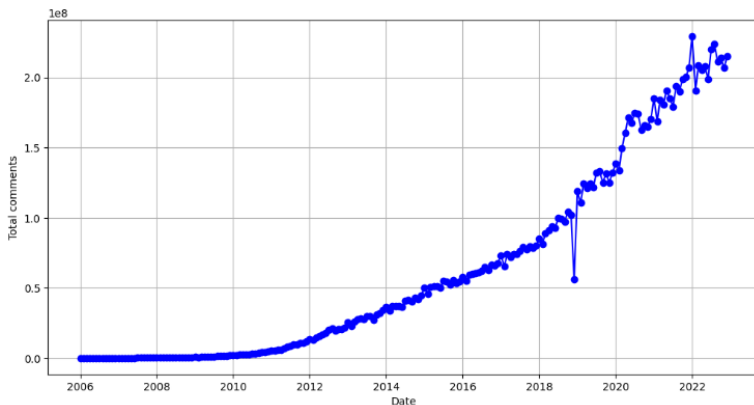


Figure: [Liang et al., 2018]

Reddit: data overview

- > 12.7 billion comments over 17 years (2007-2022)
- Source: pushshift.io [[Baumgartner et al., 2020](#)]
- Relevant metadata: author, timestamp, subreddit, comment text

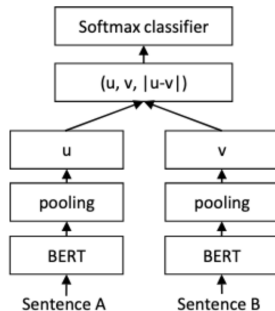


Sentence embedding

Idea

Just like word2vec, node2vec, we can “sentence2vec” by using embeddings of LLMs.

- Sentence-BERT trains a BERT model and softmax classifier on pairs of similar sentences.
- Can take any off-the-shelf model and fine-tune it to produce more accurate input for the prediction head:
 - Semantic
 - Sentiment
 - Personality
 - Whatever you want!



Topic clusters

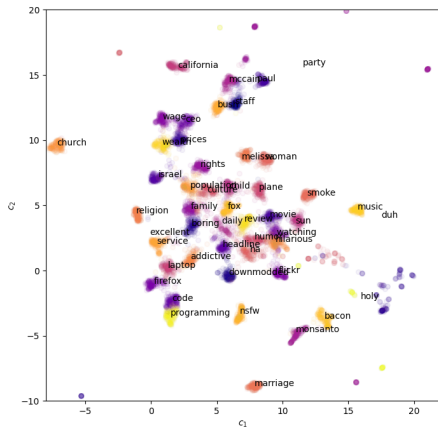


Figure: November 2008 — Topic clusters

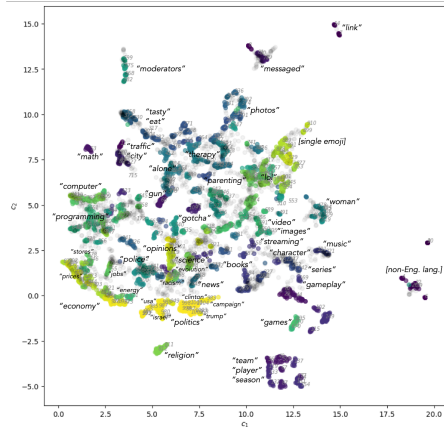
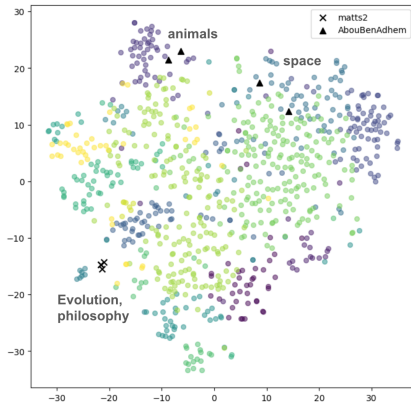


Figure: 2006-2022 (17 years) — Topic groups

User trajectories

- For user u , record participation in k topics at time t as $\tilde{\mathbf{m}}_t^{(u)}$ (normalize to $\mathbf{m}_t^{(u)} \in \mathbb{R}^k$)
- This membership vector indicates topic participation — similar vectors indicate similar preferences.
- Some users change patterns over time.
(Note: grouping here is tricky. A potential similarity metric:
 $d(u, v) = \sum_t \|\mathbf{m}_t^{(u)} - \mathbf{m}_t^{(v)}\|.$)



Next steps

- Re-implement the NRI model using PyG [Kipf et al., 2018]
- **Question 1:** (temporal) do individuals exhibit predictable dynamics similar to a physical system? (Q1a: do groups of similar individuals?)
- **Question 2:** (non-temporal) can we infer meaningful edges using the GAE approach?
- Other follow-ups:
 - Is there a more principled way to create the membership vectors? (yes)
 - Could we also capture agreement? (via sentiment embedding)
 - How does any inferred \mathbf{z}_{ij} compare with a simpler approach?

References I



Baumgartner, J., Zannettou, S., Keegan, B., Squire, M., and Blackburn, J. (2020).

The pushshift reddit dataset.

In Proceedings of the international AAAI conference on web and social media, volume 14, pages 830–839.



Dileo, M., Zignani, M., and Gaito, S. (2024).

Temporal graph learning for dynamic link prediction with text in online social networks.

Machine Learning, 113(4):2207–2226.



Han, L., Checco, A., Difallah, D., Demartini, G., and Sadiq, S. (2020).

Modelling user behavior dynamics with embeddings.

In Proceedings of the 29th ACM International Conference on Information & Knowledge Management, pages 445–454.



Hasan, M. A. and Zaki, M. J. (2011).

A survey of link prediction in social networks.

Social network data analytics, pages 243–275.

References II



Kipf, T., Fetaya, E., Wang, K.-C., Welling, M., and Zemel, R. (2018).

Neural relational inference for interacting systems.

In *International conference on machine learning*, pages 2688–2697. Pmlr.



Liang, S., Zhang, X., Ren, Z., and Kanoulas, E. (2018).

Dynamic embeddings for user profiling in twitter.

In *Proceedings of the 24th ACM SIGKDD international conference on knowledge discovery & data mining*, pages 1764–1773.

Questions?