TIMME: Twitter Ideology-detection via Multi-task Multi-relational Embedding

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Outline

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Code & Data
Motivation

Problem: Ideology Classification on Twitter
Contribution

- TIMME: learning embeddings on sparsely-labeled heterogeneous graph
  - MTL: handles the sparsity of labels
    - *Optionally* handles incomplete input features
- Political-Centered Social Network Dataset
  - Described in Appendix, released with code
|                  | PureP | P50     | P20～50 | P+all |
|------------------|-------|---------|---------|-------|
| # User           | 583   | 5,435   | 12,103  | 20,811|
| # Link           | 122,347 | 1,593,721 | 1,976,985 | 6,496,107 |
| # Labeled User   | 581   | 759     | 961     | 1,206 |
| # Featured User  | 579   | 5,149   | 11,725  | 19,418 |
| # Follow-Link    | 59,073 | 529,448 | 158,746 | 915,438 |
| # Reply-Link     | 1,451 | 96,757  | 121,133 | 530,598 |
| # Retweet-Link   | 19,760 | 311,359 | 595,030 | 1,684,023 |
| # Like-Link      | 14,381 | 302,571 | 562,496 | 1,794,111 |
| # Mention-Link   | 27,682 | 353,586 | 539,580 | 1,571,937 |

Political-Centered Social Network Dataset
Model: Encoder

Encoder

|N| Features

Multi-relational GCN

2|R| Adjacency matrixes
   1 Identical matrix

Decoder

2|N| Embeddings

Tasks

Relation #1
Relation #2

Relation #|\mathcal{R}|

Entity Classification

Link Prediction

Layer 1

\begin{align*}
W_1 & \rightarrow \alpha_1 \\
W_2 & \rightarrow \alpha_2 \\
\vdots & \rightarrow \alpha_{|\mathcal{R}|} \\
W_{|\mathcal{R}|+1} & \rightarrow \alpha_{|\mathcal{R}|+1}
\end{align*}

Layer 2

\begin{align*}
W_1 & \rightarrow \alpha_1 \\
W_2 & \rightarrow \alpha_2 \\
\vdots & \rightarrow \alpha_{|\mathcal{R}|} \\
W_{|\mathcal{R}|+1} & \rightarrow \alpha_{|\mathcal{R}|+1}
\end{align*}

σ

Layer 1 Layer 2

loss \mathcal{L}
Model: TIMME-hierarchical Decoder

Link 1 Prediction

| Embeddings
| Neural Tensor Networks (NTN)
| Scores
| Loss $L_1$

Link 2 Prediction

| Embeddings
| Neural Tensor Networks (NTN)
| Scores
| Loss $L_2$

Link $|\mathcal{R}|$ Prediction

| Embeddings
| Neural Tensor Networks (NTN)
| Scores
| Loss $L_{|\mathcal{R}|}$

Link Prediction Tasks

| Embeddings
| Neural Tensor Networks (NTN)
| Scores

Entity Classification Task

| Embeddings
| Fully-Connected Layer
| Softmax
| Predictions

$\lambda_1$

$\lambda_2$

$\lambda_{|\mathcal{R}|}$
TIMME and TIMME-hierarchical:

\[
\mathcal{L} = \sum_{i=0}^{\lvert \mathcal{R} \rvert} \mathcal{L}_i
\]

loss is the sum of losses from all \(\lvert \mathcal{R} \rvert + 1\) tasks.

- TIMME-hierarchical gives us clues on each relation’s importance to ideology classification via \(\lambda\).

TIMME-single:

\[
\mathcal{L} = \mathcal{L}_i
\]

for a single task \(i, i \in \{0, 1, 2, \ldots \lvert \mathcal{R} \rvert\}\).

- TIMME-single proves that multi-task version is better.
### Results Compared with Baselines

| Model              | PureP   | P50     | P20–50  | P=all  |
|--------------------|---------|---------|---------|--------|
| GCN                | 1.0000/1.0000 | 0.9600/0.9600 | 0.9895/0.9895 | 0.9076/0.9083 |
| r-GCN              | 1.0000/1.0000 | 0.9733/0.9733 | 0.9895/0.9895 | 0.9327/0.9333 |
| HAN                | 0.9825/0.9824 | 0.9466/0.9467 | 0.9789/0.9789 | 0.9238/0.9250 |
| TIMME-single       | 1.0000/1.0000 | 0.9733/0.9733 | 0.9895/0.9895 | 0.9333/0.9324 |
| TIMME              | 0.9825/0.9824 | 0.9867/0.9867 | 1.0000/1.0000 | 0.9495/0.9500 |
| TIMME-hierarchical | 1.0000/1.0000 | 0.9733/0.9733 | 0.9895/0.9895 | 0.9580/0.9583 |

**Table 2: Node classification measured by F1-score/accuracy.**

| Model              | PureP   | P50     | P20–50  | P=all  |
|--------------------|---------|---------|---------|--------|
| Follow Relation    |         |         |         |        |
| GCN+               | 0.8696/0.8167 | 0.9593/0.8308 | 0.9870/0.9576 | 0.9855/0.9329 |
| r-GCN              | 0.8596/0.6091 | 0.9488/0.8023 | 0.9872/0.9537 | 0.9685/0.9201 |
| HAN+               | 0.8891/0.7267 | 0.9598/0.8642 | 0.9620/0.8850 | 0.9723/0.9256 |
| TIMME-single       | 0.8809/0.6325 | 0.9717/0.8792 | 0.9920/0.9709 | 0.9936/0.9696 |
| TIMME              | 0.8763/0.6324 | 0.9811/0.9154 | 0.9945/0.9799 | 0.9943/0.9736 |
| TIMME-hierarchical | 0.8812/0.6409 | 0.9899/0.9185 | 0.9984/0.9813 | 0.9944/0.9739 |
| Reply Relation     |         |         |         |        |
| GCN+               | 0.8602/0.7386 | 0.9625/0.9022 | 0.9381/0.8665 | 0.9705/0.9154 |
| r-GCN              | 0.7962/0.6279 | 0.9421/0.8714 | 0.8668/0.7815 | 0.9640/0.9085 |
| HAN+               | 0.8445/0.6359 | 0.9598/0.8616 | 0.9495/0.8664 | 0.9757/0.9210 |
| TIMME-single       | 0.8685/0.7018 | 0.9695/0.9307 | 0.9593/0.9070 | 0.9775/0.9508 |
| TIMME              | 0.9077/0.8004 | 0.9781/0.9417 | 0.9747/0.9347 | 0.9849/0.9612 |
| TIMME-hierarchical | 0.9224/0.8152 | 0.9766/0.9409 | 0.9737/0.9341 | 0.9854/0.9629 |
| Retweet Relation   |         |         |         |        |
| GCN+               | 0.8955/0.7145 | 0.9574/0.8493 | 0.9351/0.8408 | 0.9724/0.9303 |
| r-GCN              | 0.8865/0.6895 | 0.9411/0.8084 | 0.9603/0.7728 | 0.9735/0.9326 |
| HAN+               | 0.7646/0.6139 | 0.9638/0.9213 | 0.9478/0.8962 | 0.9750/0.9424 |
| TIMME-single       | 0.9015/0.7202 | 0.9754/0.9127 | 0.9673/0.9073 | 0.9824/0.9424 |
| TIMME              | 0.9094/0.7285 | 0.9779/0.9181 | 0.9772/0.9291 | 0.9858/0.9511 |
| TIMME-hierarchical | 0.9105/0.7344 | 0.9780/0.9190 | 0.9766/0.9275 | 0.9869/0.9543 |
| Like Relation      |         |         |         |        |
| GCN+               | 0.9007/0.7259 | 0.9527/0.8499 | 0.9349/0.8400 | 0.9690/0.9032 |
| r-GCN              | 0.8924/0.7161 | 0.9433/0.7966 | 0.9038/0.7681 | 0.9510/0.8945 |
| HAN+               | 0.8606/0.6176 | 0.9733/0.8851 | 0.9611/0.9062 | 0.9894/0.9481 |
| TIMME-single       | 0.9113/0.7654 | 0.9725/0.9119 | 0.9655/0.9069 | 0.9796/0.9374 |
| TIMME              | 0.9249/0.7926 | 0.9753/0.9171 | 0.9759/0.9292 | 0.9846/0.9504 |
| TIMME-hierarchical | 0.9278/0.7945 | 0.9752/0.9175 | 0.9752/0.9271 | 0.9851/0.9518 |
| Mention Relation   |         |         |         |        |
| GCN+               | 0.8580/0.6333 | 0.9602/0.8617 | 0.9261/0.8170 | 0.9665/0.8910 |
| r-GCN              | 0.8312/0.6023 | 0.9382/0.7963 | 0.8938/0.7563 | 0.9640/0.8902 |
| HAN+               | 0.9000/0.7206 | 0.9573/0.8616 | 0.9574/0.8891 | 0.9724/0.9119 |
| TIMME-single       | 0.8587/0.6502 | 0.9713/0.8981 | 0.9614/0.8923 | 0.9725/0.9066 |
| TIMME              | 0.8684/0.6689 | 0.9730/0.9035 | 0.9730/0.9185 | 0.9839/0.9446 |
| TIMME-hierarchical | 0.8643/0.6597 | 0.9732/0.9046 | 0.9723/0.9166 | 0.9846/0.9463 |

**Table 3: Link-prediction measured by ROC-AUC/PR-AUC.**
Code & Data
Code with data available on Github:

▶ [https://github.com/PatriciaXiao/TIMME](https://github.com/PatriciaXiao/TIMME)
All information included in readme.

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