Latent Space Models for Temporal Networks

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Latent Space Models for Temporal Networks

Jasper Alt

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References

- This talk based on work (with Rajesh Venkatachalapathy) submitted to NetSci 2019.
- A fuller manuscript (with Rajesh) is in progress.
- Peres et. al. “Mobile Geometric Graphs” (2010)
- Holme, P. “Modern Temporal Network Theory: A Colloquium”
Outline

- Homophily and latent space
- Random geometric graphs and Brownian motion
- Mobile geometric graphs
- Implementation
- Observations
- Current and future work
0. Social Networks

- Maps of relationships between actors

- What do the actors tell us about the networks?

- What do the networks tell us about the actors?
1. Homophily
“Birds of a feather flock together”

- Actors with common attributes are more likely to form ties
- Ties between actors may indicate common attributes
- Typically expressed in an informal way

- Latin prefix, Greek Suffix
- Idiophily?

2. Latent Space
Can we state something more formal?

Combinations & intensities of attributes assign the actors to coordinates in a latent space.

More attributes in common, or attributes with similar intensities, mean the actors are closer together in this space.

Tobler's Law: Everything is related to everything else, but near things are more related than distant things.

(Q. Are there any networks that do not correspond to a latent space?)
Wikipedia: The political compass
3. Homophily in Latent Space

The graph at right is described by an $n \times n$ adjacency matrix $A$, where $n = 10$. The entries of $A$ are defined as:

$$A_{ij} = \begin{cases} f(d_{ij}) & \text{if } f(d_{ij}) > m \\ 0 & \text{otherwise} \end{cases}$$

where $f(d_{ij}) = \frac{1}{1 + e^{0.5(5 - d_{ij})}}$. The matrix is:

$$A = \begin{pmatrix} f(d_{11}) & \cdots & f(d_{1n}) \\ \vdots & \ddots & \vdots \\ f(d_{n1}) & \cdots & f(d_{nn}) \end{pmatrix}$$

These entries represent the homophily in the latent space. The graph shows the relationship between different attitudes and behaviors, with the adjacency matrix capturing the connections between these attributes.
4. Latent Space Dynamics

- We know attributes can change.

- This means the actors' positions in latent space change.

- There are many possible ways this could happen.

- In social contexts, we expect nontrivial dynamics.
• People influence each other and are influenced by social forces.

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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Ancient, advanced civilizations, such as Atlantis, once existed</td>
<td>39.6</td>
<td>55.0</td>
<td>56.9%</td>
<td>17.3%</td>
</tr>
<tr>
<td>Aliens have visited Earth in our ancient past</td>
<td>27.0</td>
<td>35.0</td>
<td>41.4%</td>
<td>14.4%</td>
</tr>
<tr>
<td>Places can be haunted by spirits</td>
<td>46.6</td>
<td>52.3</td>
<td>57.7%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Aliens have come to Earth in modern times</td>
<td>24.7</td>
<td>26.2</td>
<td>35.1%</td>
<td>10.4%</td>
</tr>
<tr>
<td>Bigfoot is a real creature</td>
<td>13.5</td>
<td>16.2</td>
<td>20.7%</td>
<td>7.2%</td>
</tr>
<tr>
<td>Some people can move objects with their minds</td>
<td>19.1</td>
<td>25.0</td>
<td>26.2%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Fortune tellers and psychics can foresee the future</td>
<td>14.1</td>
<td>19.4</td>
<td>17.2%</td>
<td>3.1%</td>
</tr>
</tbody>
</table>

*Chapman University Survey of American Fears*
5. Null Models

- Network science has some big null models.
- Erdos-Renyi — random graphs
- Configuration models — random with fixed degree sequence
- Stochastic block models — random with some community structure
Wikipedia: Erdos-Renyi model
Wikipedia: Configuration model
• Good null models show what can be explained by chance.

• Random dynamics are useful for testing non-random alternatives.

• A good null model for latent space network dynamics will have random dynamics.
6. Temporal Networks

- We typically understand static networks to be ‘snapshots’ of dynamic networks.

- Real networks are temporal.

- Static networks can be instantaneous snapshots or aggregate over a window of time.

- What is a null model for temporal networks?

- Random, but time dependent
Building Blocks

6. Random Geometric Graphs

- Graphs

- Geometric

- Random
Wikipedia: Random geometric graph
- Nodes are placed using some point process

- (say, uniformly at random)

- Nodes within some radius of one another are connected.

- Studied in the context of wireless networks.

7. Brownian Motion

- Move a normally distributed distance in either direction.

- Like a particle in a fluid.

- Shows up in physics, statistics, quantitative finance, etc.

- Preserves the intensity of point processes.
8. Mobile Geometric Graphs

- Random geometric graphs with Brownian motion

- Brownian motion adds time dependence while preserving randomness

- Very little studied

- Existing work focuses on the mathematical statistics of their communication properties.

Contd