Semantics-Space-Time Cube: A Conceptual Framework for Systematic Analysis of Texts in Space and Time

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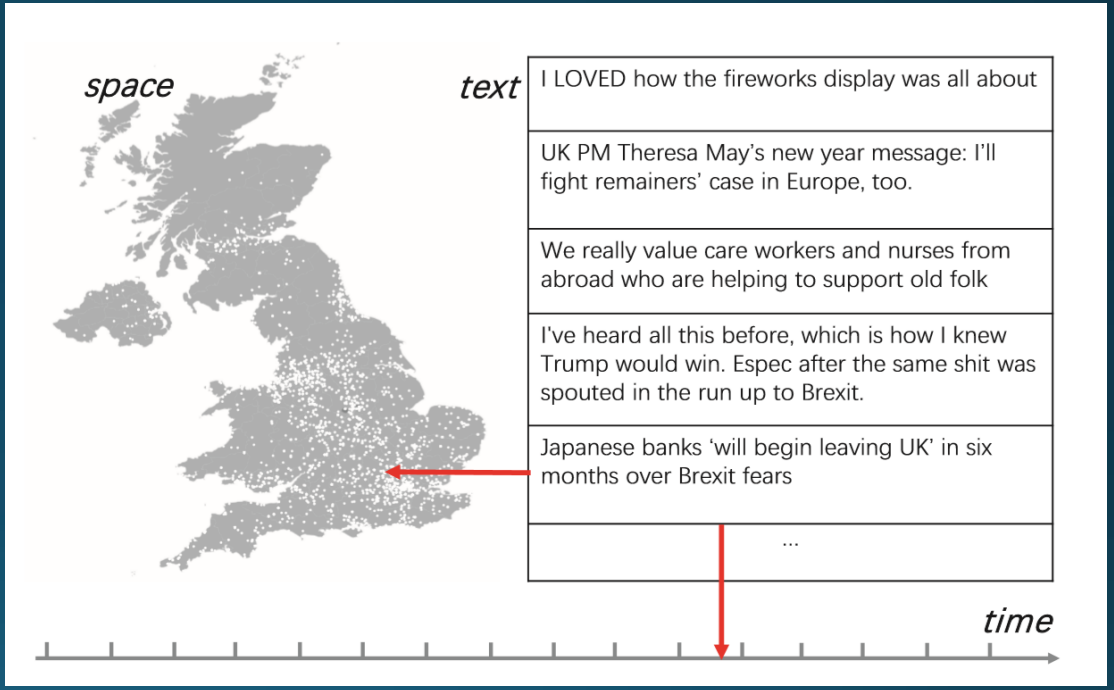
IEEE Transactions on Visualization and Computer Graphics.

Presented by Mint Tanprasert
CPSC 547, Winter 2019, UBC

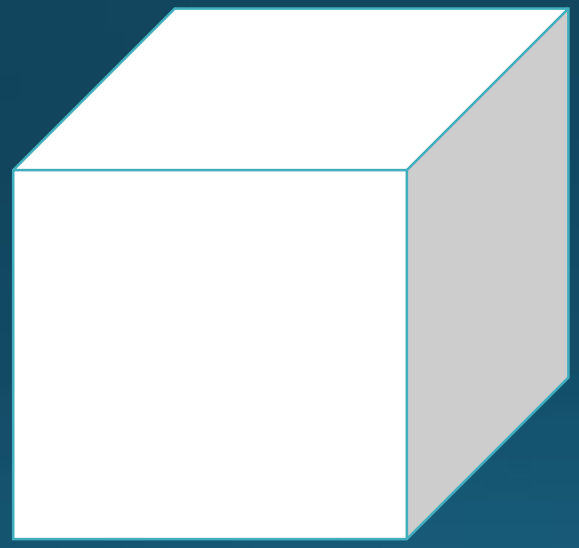
Text – Space – Time

- How does text semantics vary over space and time?
  - Explore complex relationship between the three facets
    - E.g. trend of topic popularity
  - Data example: geolocated social media posts



Proposed Visualization

"Cube"
metaphor

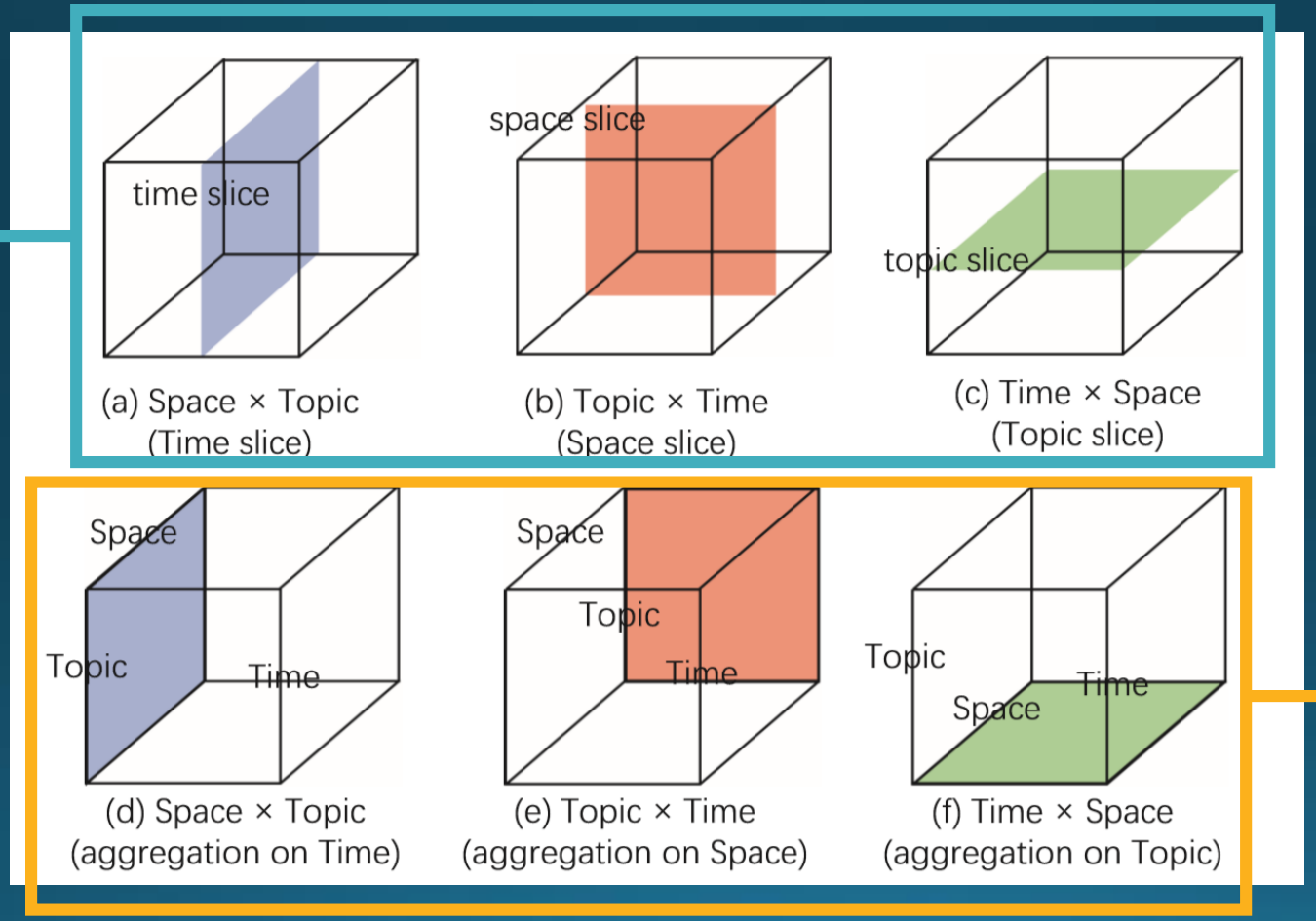


P x S x T

to**P**ics x **S**pace x **T**ime

Slices and Projections

Fix one variable

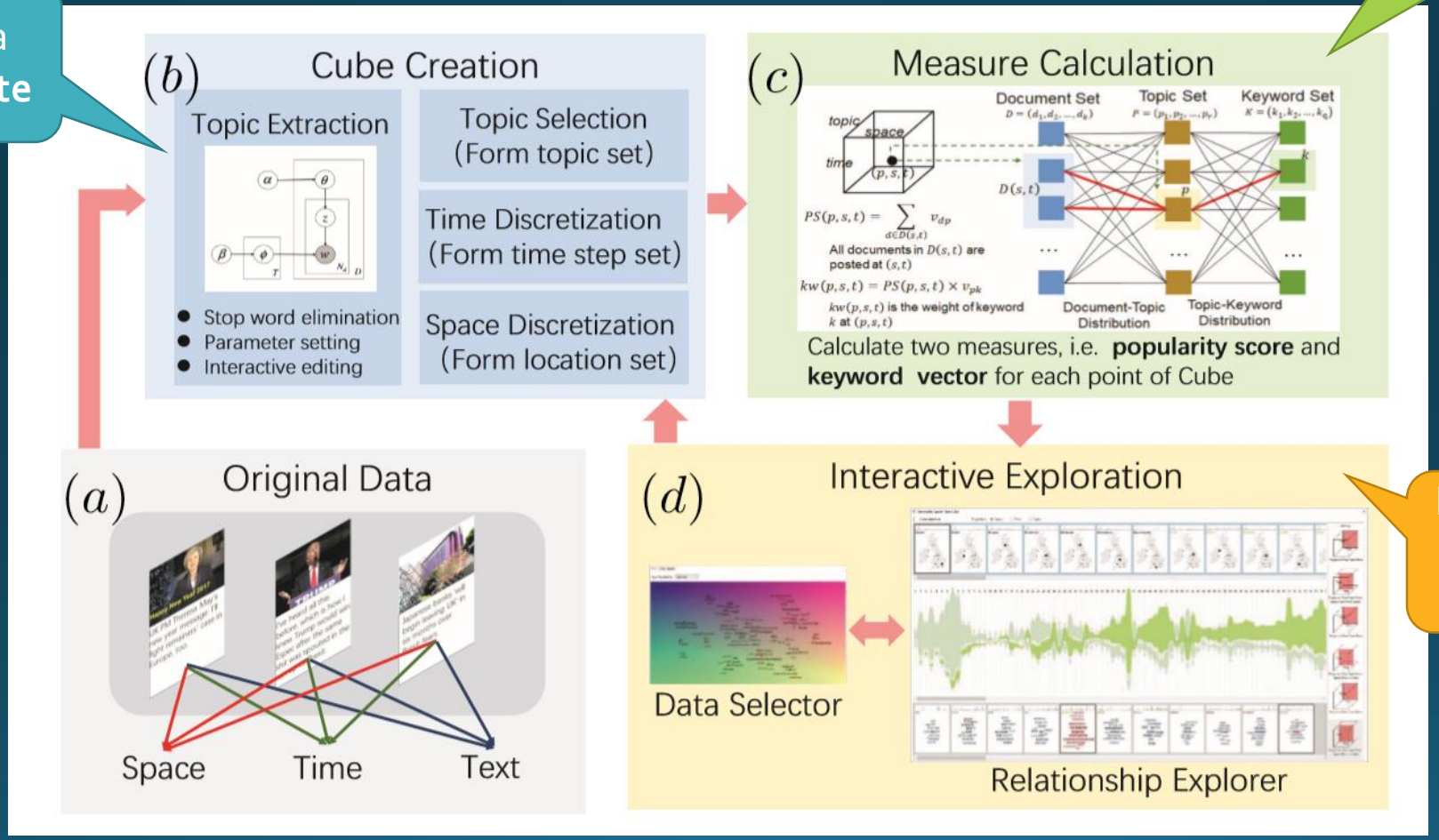


Aggregate over multiple slices (sum, mean, mode, quartiles, etc.)

Approach Overview

Make each data **discrete** and **finite**

Calculate **measures** for each point of the cube



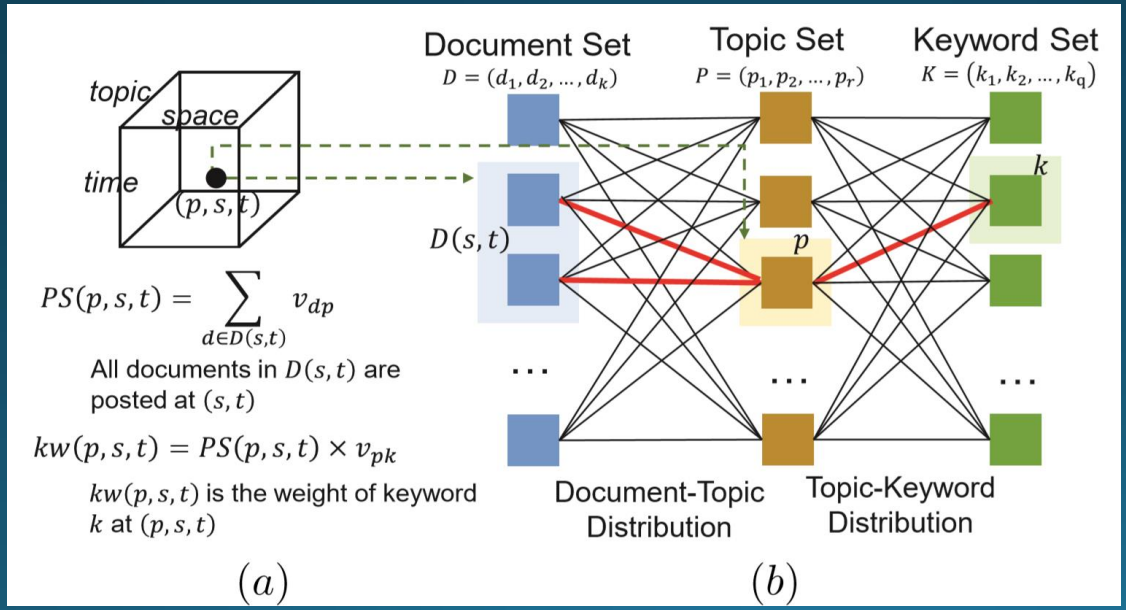
Design **interactive interface** for exploring data

Cube Creation

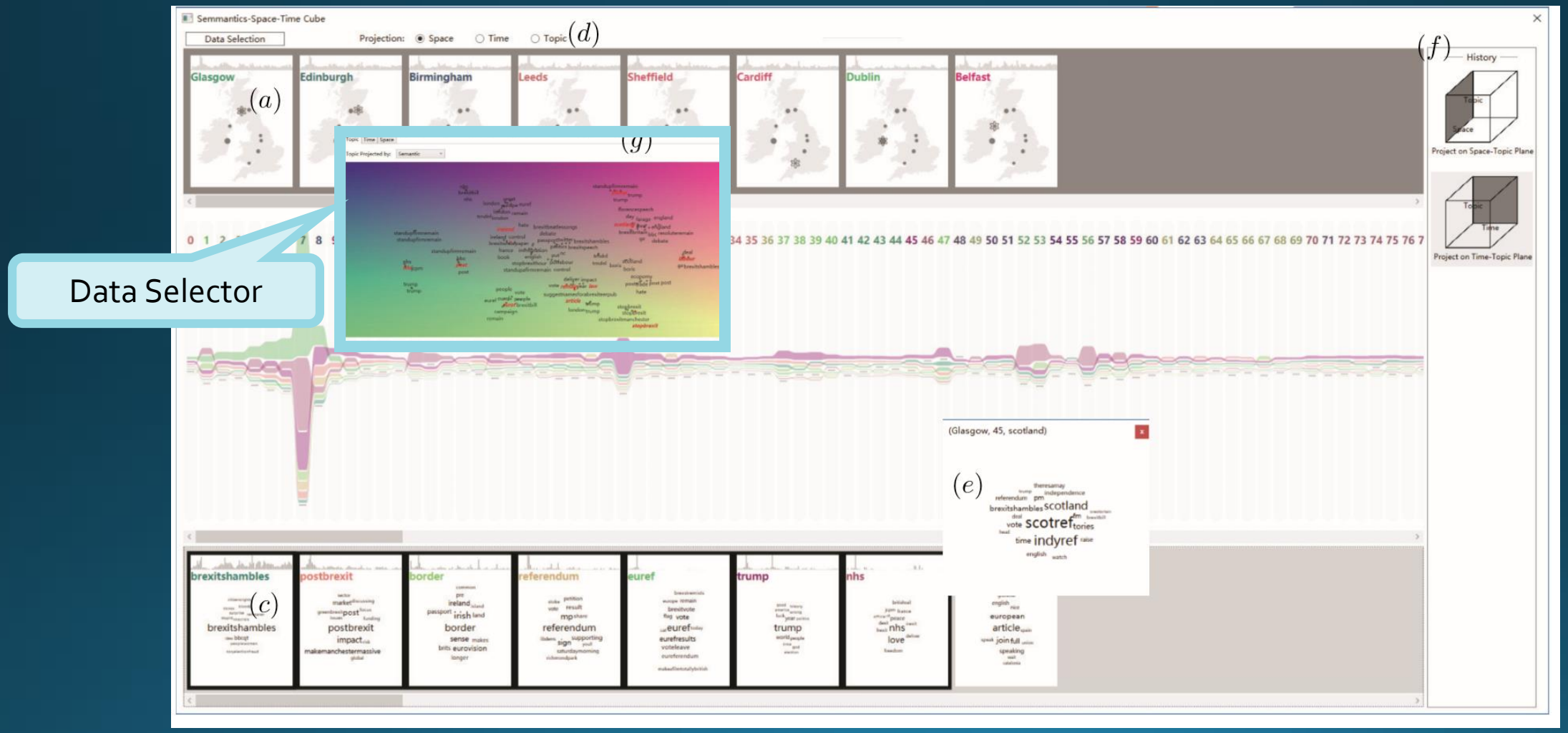
- **TEXT**: is represented by a vector of topic weights
  - *Topic* is defined as a probability distribution over a given set of *keywords*
  - Latent Dirichlet Allocation (LDA) – a probabilistic topic modeling method
  - Show all topics and let users select the ones they want to explore
- **TIME**: divide into intervals that are meaningful to humans e.g. weeks.
- **SPACE**: use individual and public activity locations, e.g. cities.

Measure Calculation

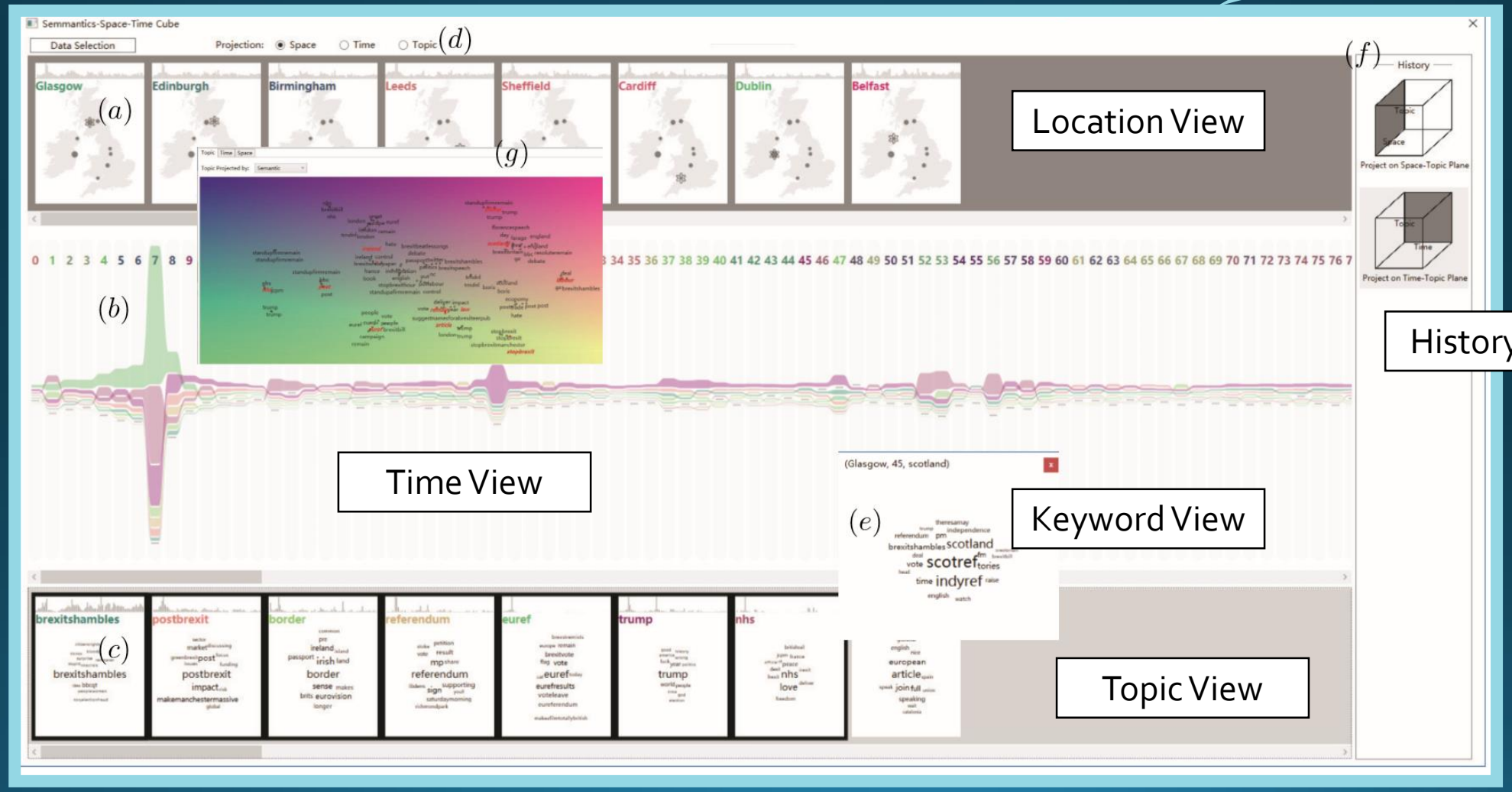
- At each *point (p, s, t)*, we can **derive** meaningful information
  - Popularity score
  - Keyword vector (list of <keyword, weight> pairs)



Interactive Exploration

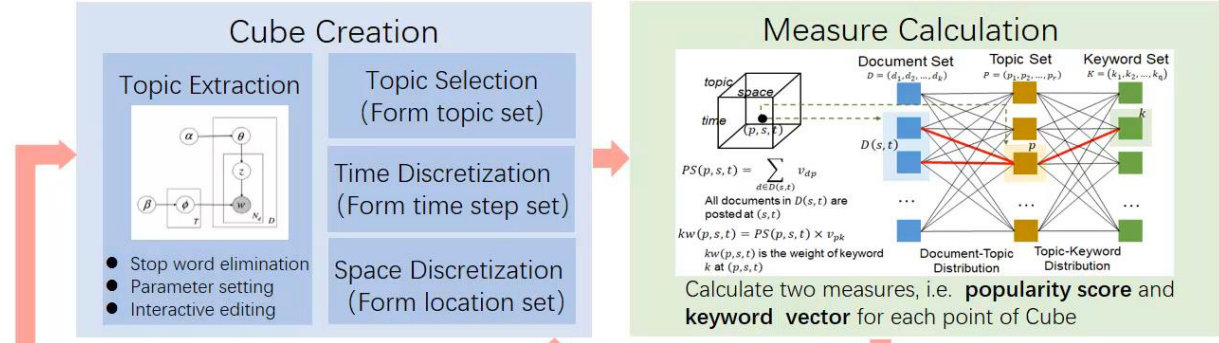


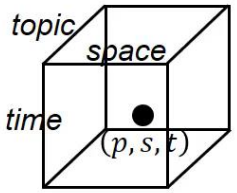
Interactive Exploration



Demo

Basic Idea





Goal: Exploration of various relationships among the space, time and topics.

T1: $t \rightarrow (S \rightarrow P \rightarrow M)$ or $\sum t \rightarrow (S \rightarrow P \rightarrow M)$

T2: $t \rightarrow (P \rightarrow S \rightarrow M)$ or $\sum t \rightarrow (P \rightarrow S \rightarrow M)$

T3: $s \rightarrow (T \rightarrow P \rightarrow M)$ or $\sum s \rightarrow (T \rightarrow P \rightarrow M)$

T4: $s \rightarrow (P \rightarrow T \rightarrow M)$ or $\sum s \rightarrow (P \rightarrow T \rightarrow M)$

T5: $p \rightarrow (S \rightarrow T \rightarrow M)$ or $\sum p \rightarrow (S \rightarrow T \rightarrow M)$

T6: $p \rightarrow (T \rightarrow S \rightarrow M)$ or $\sum p \rightarrow (T \rightarrow S \rightarrow M)$

https://ieeexplore.ieee.org/abstract/document/8540796/media#media

Analysis Summary: **WHAT**

- Data
  - A table where each item has 3 attributes
    - Text (arbitrary and unstructured)
    - Location (spatial)
    - Time (sequential)
- Derived
  - Discretized and finite representation of each attribute
  - Popularity score and keyword vector

Analysis Summary: **HOW**

- Encode
  - Color-code objects based on position in a projection
  - Use geographic map with glyphs
  - Size-code keyword based on importance
  - Indicate popularity score by linear ordering
- Manipulate
  - Pop-up window
  - 2D navigation
- Facet
  - Superimpose streams in time view (extended mode)
  - Linked navigation
- Reduce
  - Filter with “slices”
  - Aggregate with “projection”

Critiques – Strengths

- Good use of the metaphor
  - A good conceptual model for developing database operations (from paper)
- Filtering and aggregation allow for exploring large amount of data
- Responsive and well-organized view coordination
- Uniformity in visual design
- Flexible navigation that supports various topics and tasks
- Follow “Overview First, Zoom and Filter, Details on Demand”

Critiques – Weaknesses

- Cannot observe the variation for all 3 dimensions, simultaneously (must slice or project first)
- The "cube" dimensions can't be too big (from paper)
- Information loss in discretization (from paper)
- Limited number of "cards" can be shown at a time
- Automated item sorting could create change blindness
- Spatial positions of keywords in keyword view is meaningless
- "Number of specific mentioned keywords may not really reflect the public opinions." (Expert feedback from paper)

Thank you for your attention

Any questions?