

Evolving Social Structures

Networks with People as the Edges

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Evolving Graphs

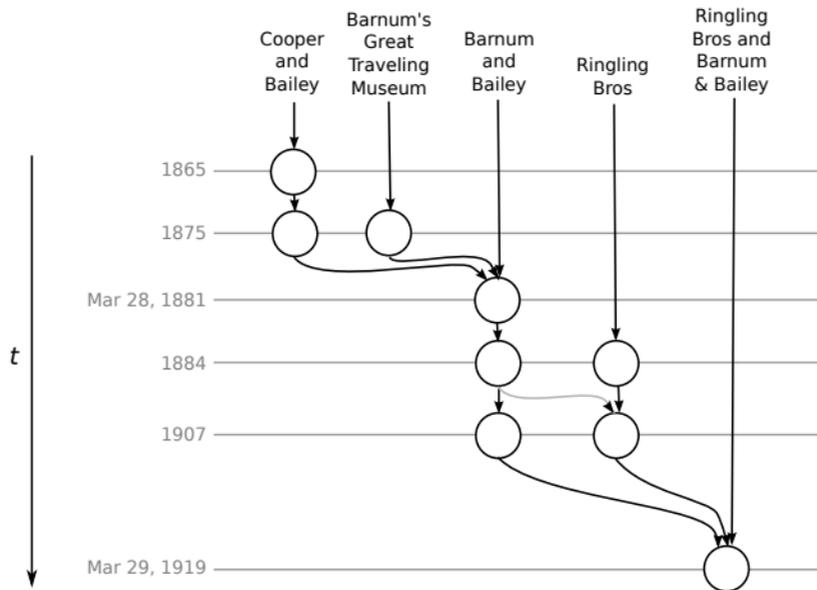
Evolve: form, dissolve, morph

- Form: elements are created over time
- Dissolve: elements disappear or die at a point in time
- Morph: elements change fundamental properties or major characteristics

Embodied in entities and relationships

Evolving Nodes

Example: How might nodes change?



Figure

Time

Different ways to measure time

- Wall-clock time
 - “Actual time” measured in temporal denomination: years, days, minutes, seconds, milliseconds
 - ISO Standard [Int04]: 2014-09-02T11:28:56+00:00
 - Provides a total ordering on events
 - Considerations
 - Must use smallest unit of time between events as clock, or
 - Multiple events in one time unit must be aggregated or missed

Time

Different ways to measure time

- Event-driven time
 - Time only changes at an event
 - Only store updates to network when events occur
 - No need for aggregation of multiple events
 - Event time may occur in different order from wall-clock time
 - Must reconstruct wall-clock time for conformable total ordering

Time

Algorithm tradeoff: Space vs Time Complexity

- Generically, we may choose to:
 - Save computation time at the expense of space by precomputation
 - Save space at the expense of computation time
- Event-driven time
 - Store only components that change at a time
 - Requires computation time to recreate
 - The wall-clock steps leading to any event
 - The entire state of the network at any time point

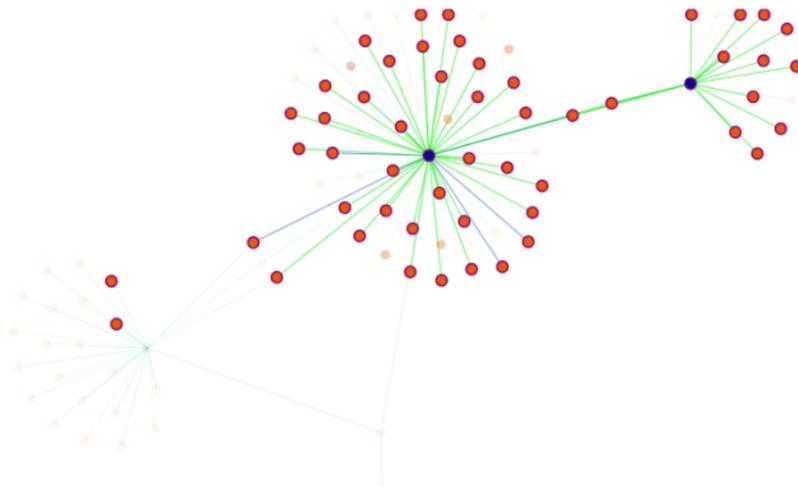
“Time-Dependent Graphs”

Snapshots to address time

- Graph is a series of snapshots
- Entire graph is stored at each point in time
- Extra edges connect a node to itself in the next snapshot
- Graph measurements and analysis per snapshot

“Time-Dependent Graphs”

Example: SNAC Subgraph



Thomas Jefferson (1743-1826)
Elbridge Gerry (1744-1814)

Figure: Snapshot 1772

“Time-Dependent Graphs”

Example: SNAC Subgraph

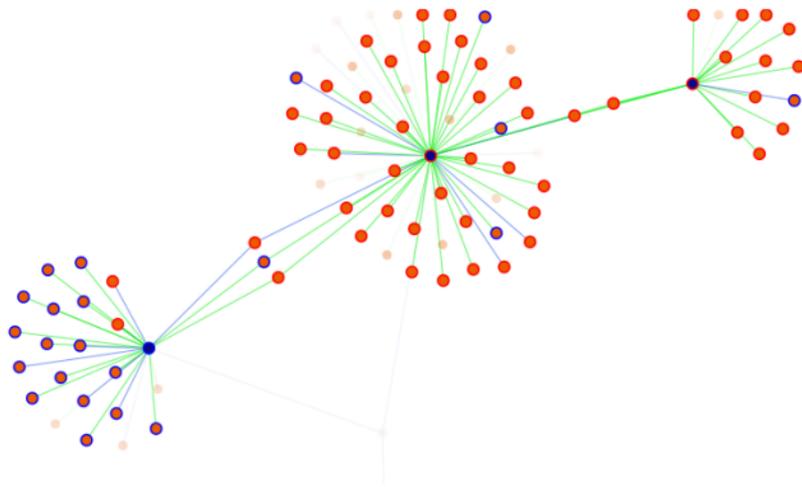


Martin Van Buren (1782-1862)

Figure: Snapshot 1850

“Time-Dependent Graphs”

Example: SNAC Subgraph



Thomas Jefferson (1743-1826)
Elbridge Gerry (1744-1814)
Martin Van Buren (1782-1862)

Nicholas Trist (1800-1874)
Samuel Smith (1752-1839)
Marie Lafayette (1757-1834)

Figure: Snapshots 1772 (r), 1850 (b)

“Time-Aggregate Graphs”

Motivating application: traffic along roadways

- Intersections as nodes
- Streets as edges (with travel cost)

Time-indexed series of edge values stored with edges [GK13]

- Saves storage space by reducing snapshot cost
- Does not address evolving nodes

Motivating Application

Evolving dynamics of early Mormonism in Nauvoo, Illinois (around 1845)

- Kathleen Flake, Richard Lyman Bushman Professor of Mormon Studies
- Institute for Advanced Technology in the Humanities

Typical family tree

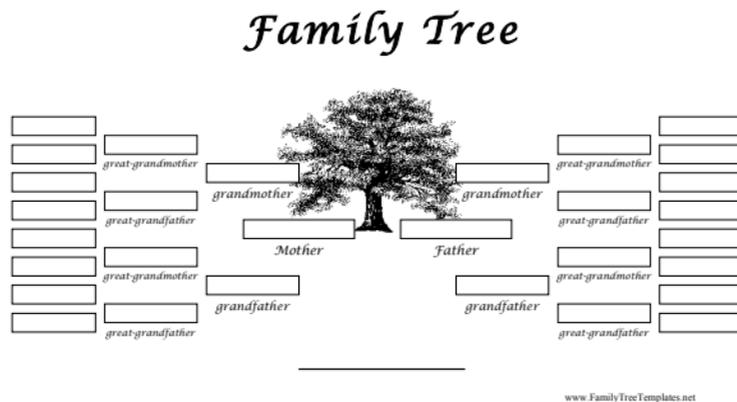


Figure: From <http://www.familytreetemplates.net>

Motivating Application

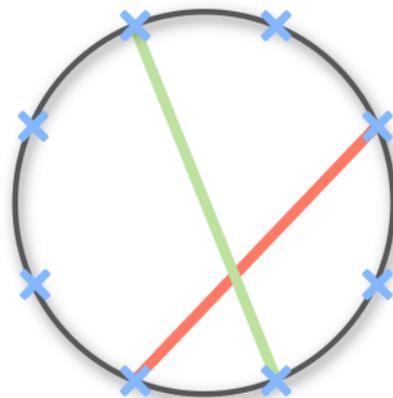
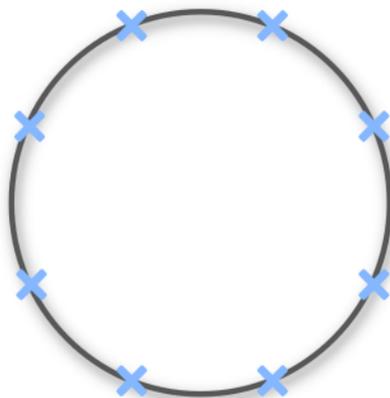
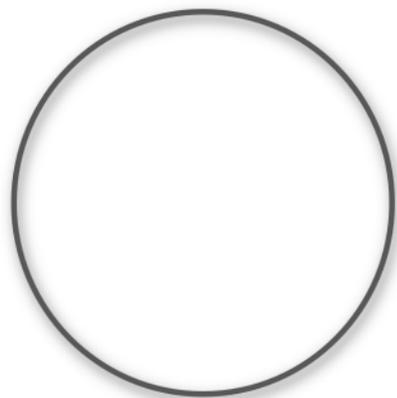
Intricate marriages

- Polygamous marriages: polygyny and polyandry
- Three definitions of marriage: civil, time, eternal
- Divorces and cancellations
- Biological and adopted children
 - Brother may be adopted to sister's marriage

Levels of ecclesiastical organization

- Anointed Quorum
- Relief Society
- First Presidency
- Quorum of the Seventy

Chord Diagrams



Chord Diagrams

Depict one marriage unit

- Organize parents and children
- Display relationships between participants in the marriage

Chord Diagrams

William Marks, all time

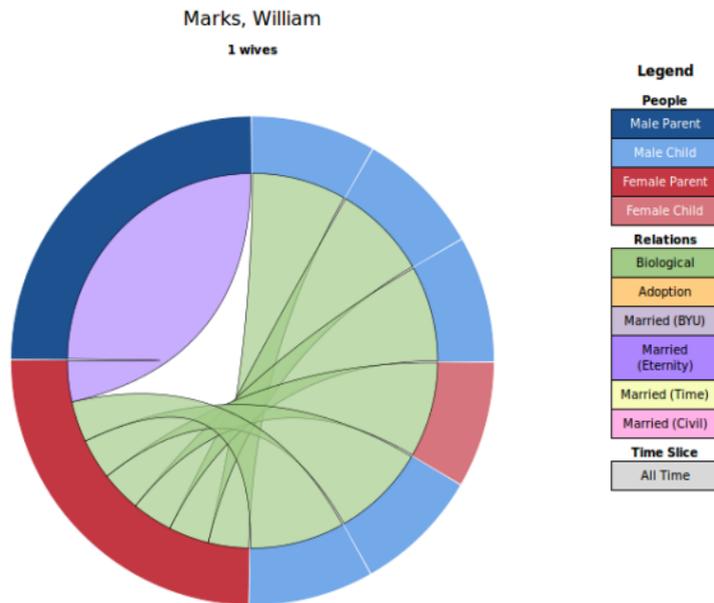
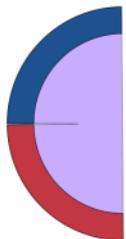


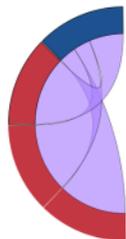
Figure: <http://ford.cs.virginia.edu/nauvoo> [Live demo](#)

Chord Diagrams

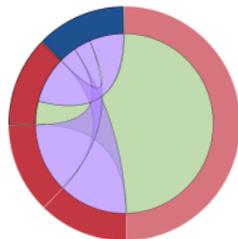
Willard Richards



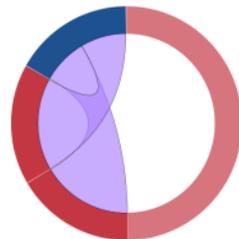
(a) 1838



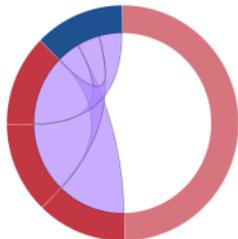
(b) 1843



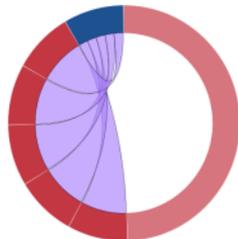
(c) 1843



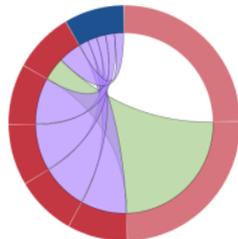
(d) 1845



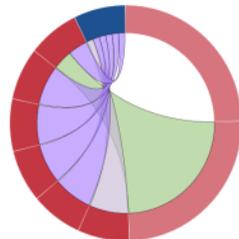
(e) 1845



(f) 1846



(g) 1850



(h) 1850

Chord Diagrams

Cornelius Lott, all time

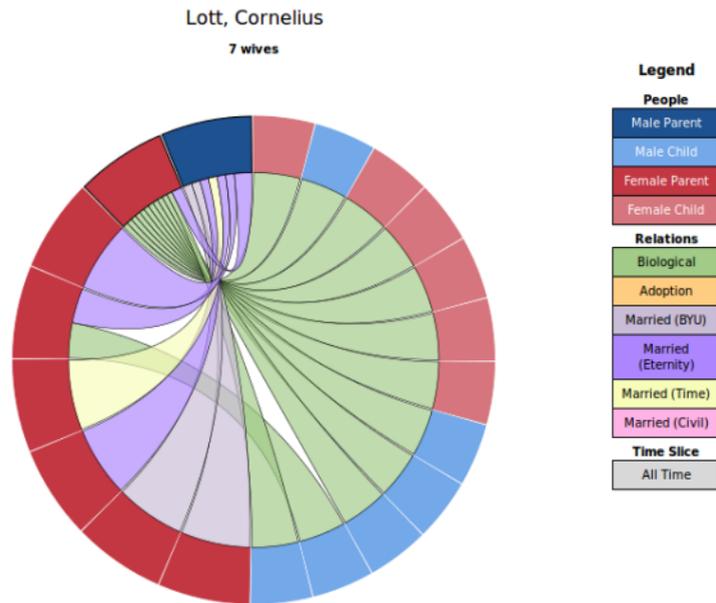


Figure: <http://ford.cs.virginia.edu/nauvoo> [Live demo](#)

Chord Diagrams

Parley Pratt, all time

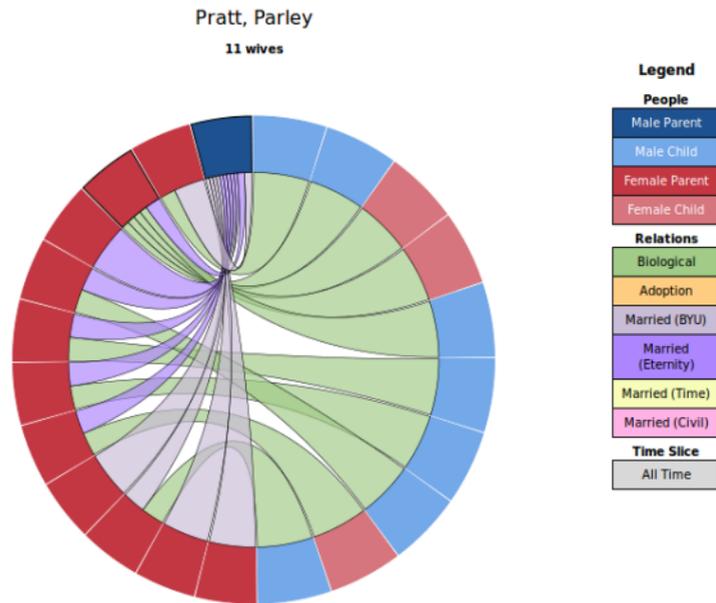


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Chord Diagrams

Brigham Young, all time

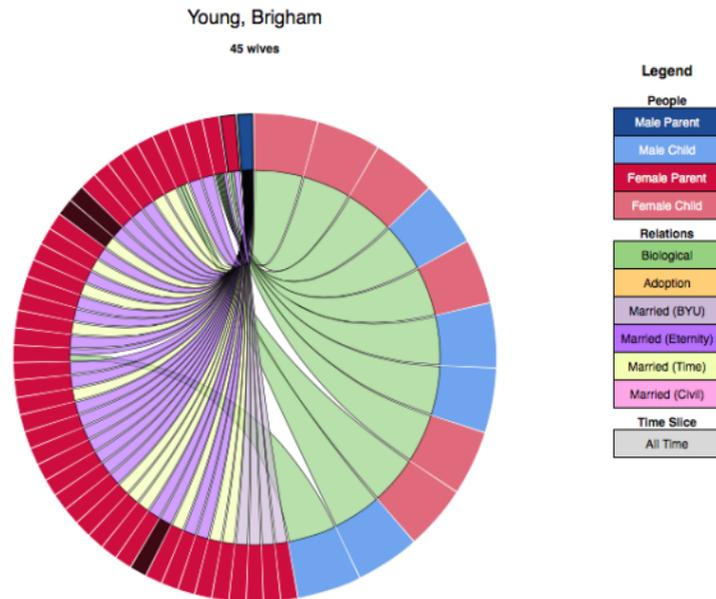


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Sankey Diagrams: Introduction

Sankey flow

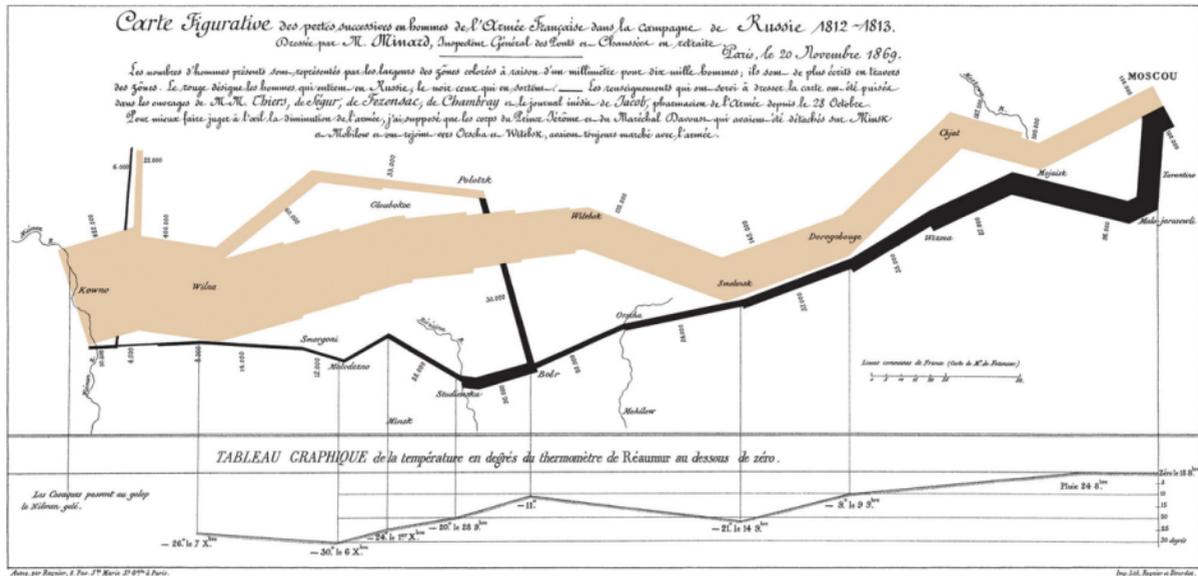


Figure: Minard's Diagram: Napoleon's invasion of Russia. From [Wik14]

Sankey Diagrams: Introduction

Sankey flow

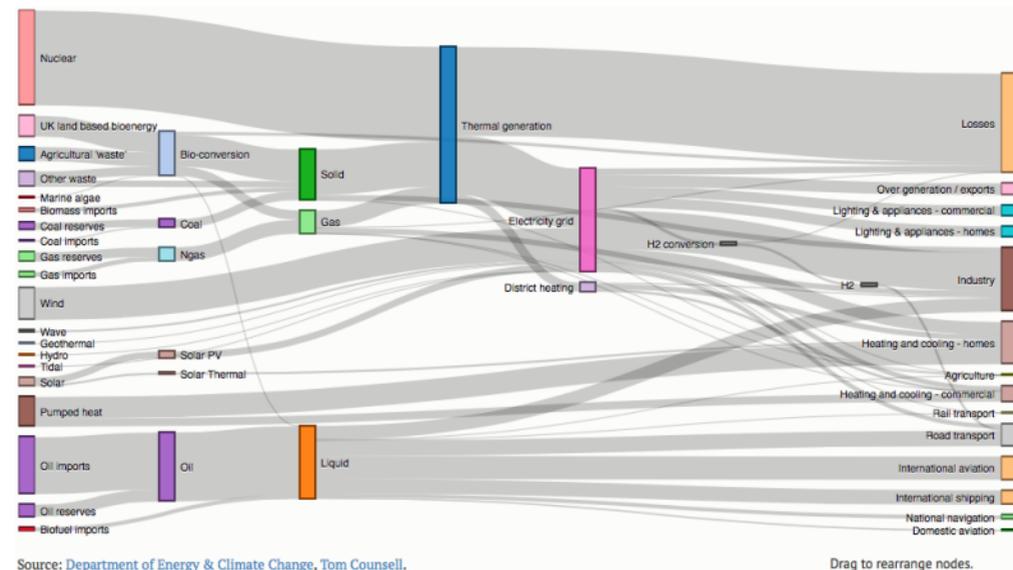


Figure: Possible UK energy production and consumption 2050. From [Bos12]

Sankey Diagrams: Connecting Marriages

Show the flow of lineage across marital units

- Marriages as nodes
- Connect birth-marriage to adult-marriage

Sankey Diagrams

William Marks' Ancestry

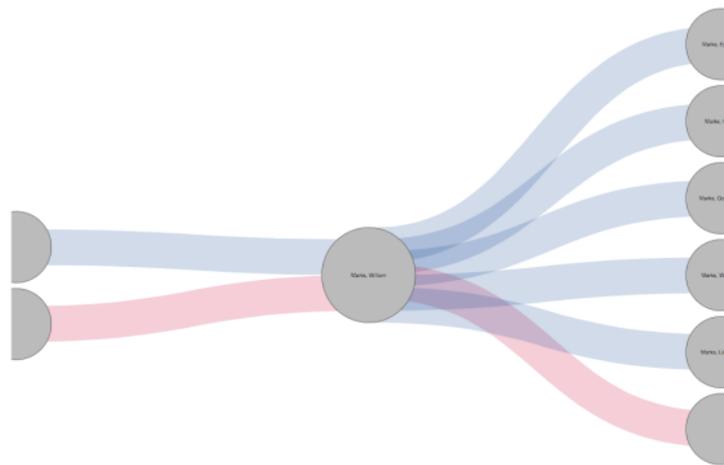


Figure: <http://ford.cs.virginia.edu/nauvoo> [Live demo](#)

Sankey Diagrams

Joseph Richards' Ancestry

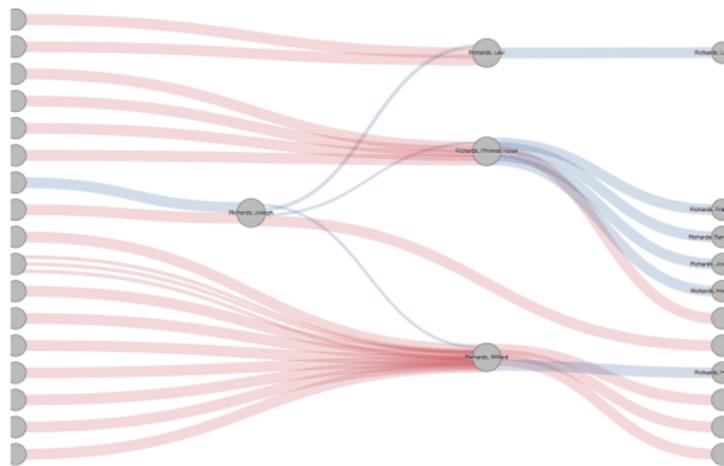


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Sankey Diagrams

Brigham Young's Ancestry

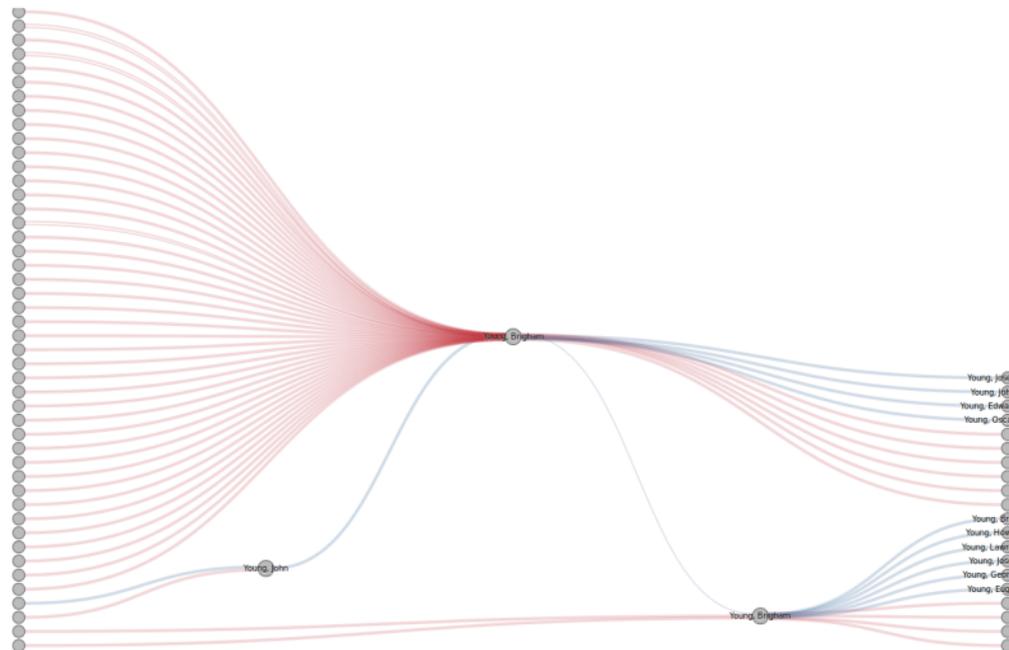


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Sankey Diagrams

Joseph Richards' Ancestry

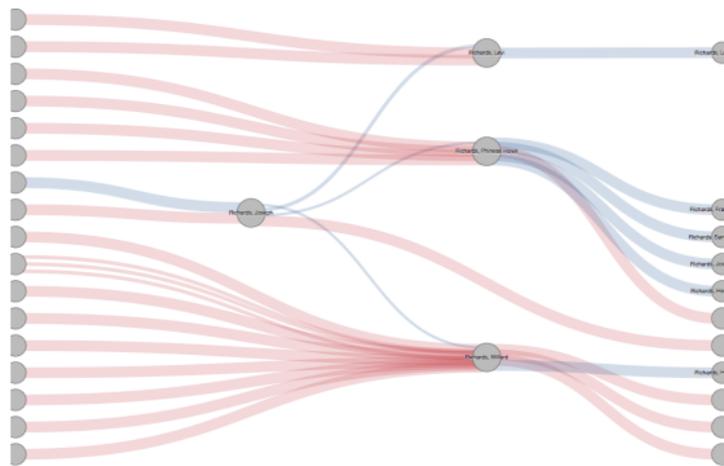


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Future Work

Measurements over Sankey evolving network

- Dynamic measurements across time
- Interesting, relevant measures for the motivating application

Comparing evolving networks

- Interaction between two or more evolving graphs
- Appropriate comparison of time measurements
- Applicable measures for comparison

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Questions?

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- Samples: <http://ford.cs.virginia.edu/nauvoo>

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