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Path statistics for letter correspondence networks of the European Reformation

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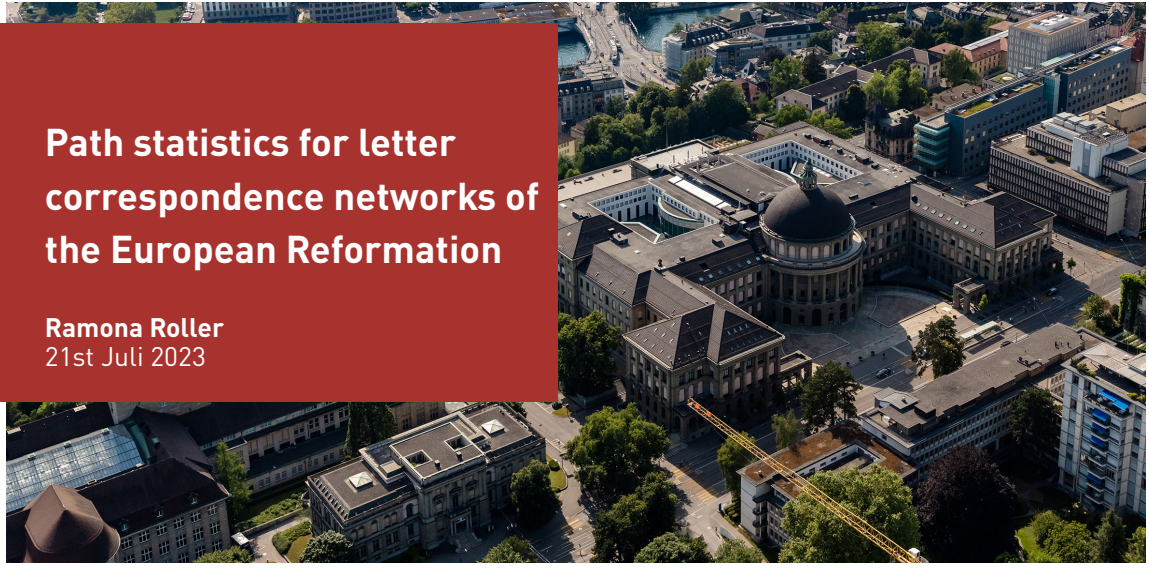
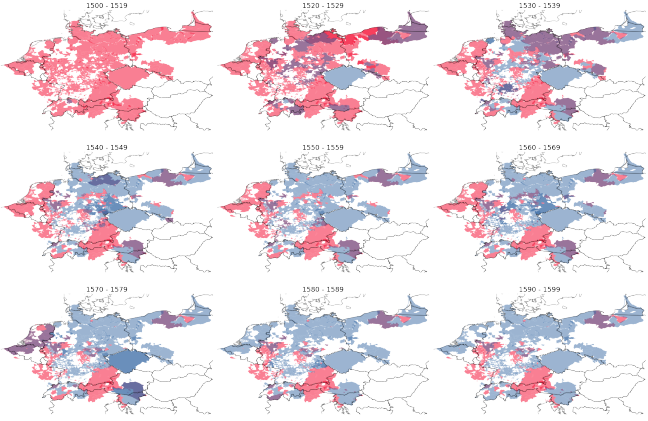
21st Juli 2023



The Adoption of Protestantism



- 16th-cent. Europe: Holy Roman Empire
- Territories become protestant
- Protestant ideas are transmitted

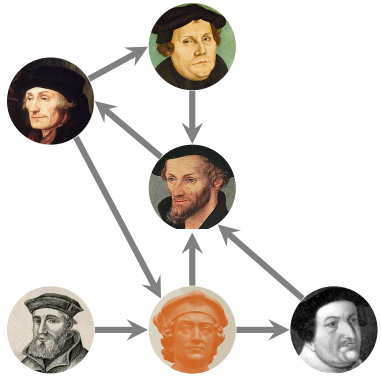
Catholic
Protestant

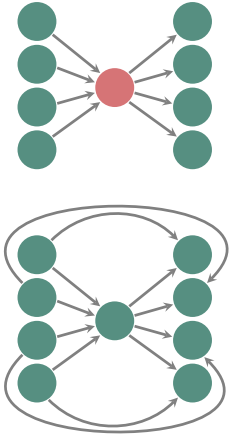
Research question

How can we characterise the transmission of protestant ideas?

- Important reformers

Letter Correspondence Networks for the Transmission of Ideas



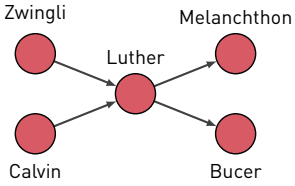


- Nodes: Reformers Edges: Letters
- N_V: 3,000 N_E: 30,000
- ✔ sending dates, locations
- ⊖ Topics, receiving dates

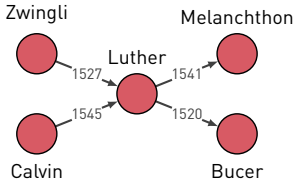
High betweenness Low betweenness

➔ Use node betweenness to identify important reformers for the transmission of ideas

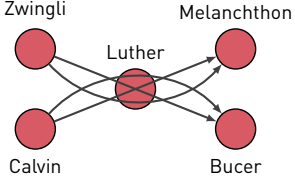
The Problem Scholtes, Wider & Garas, 2016



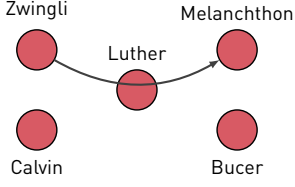
Aggregated network



Add time stamps



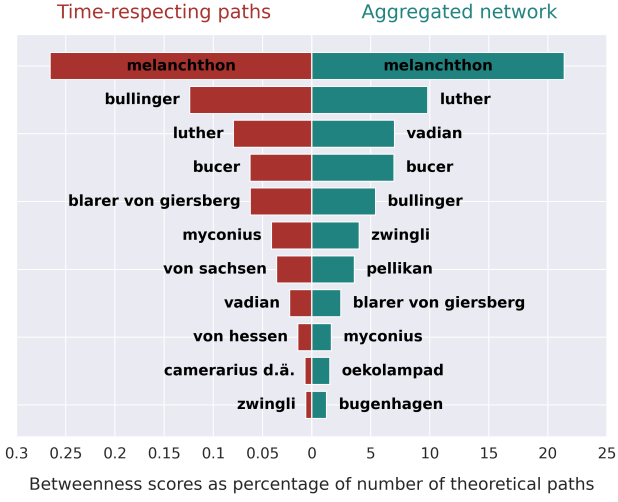
$btw_{Luther} = 4$



$btw_{Luther} = 1$

- In aggregated networks information can spread becakwards in time
- Topological network measures in aggregated networks are biased

Results

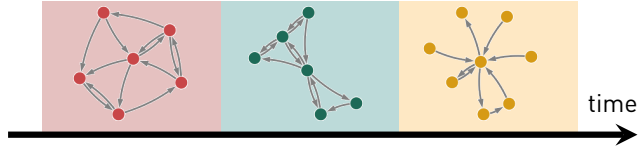


- Melanchthon contributed most
- Aggregated network measures overestimate importance of reformers

Solutions: Account for Time

- **Snapshots**
  - Automatic change points

    Darst et al., 2016; Peixoto & Gauvin, 2018
  - Theoretical all of us, I assume
  - Macro and meso scale

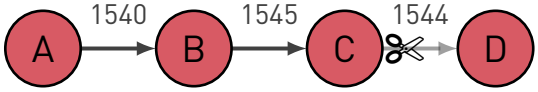


- **Correlations between consecutive node pairs**
  - Time-respecting paths Pfitzner et al., 2013
  - Micro scale

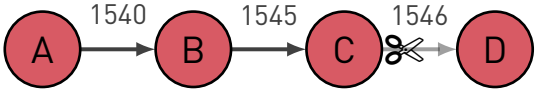
➔ Snapshots and time-respecting paths represent times at different scales: macro vs micro

Time-respecting Paths Pfitzner et al., 2013

1. Sequence of nodes that are connected by time-consecutive edges (**chronology**)..
2. ..with the inter-edge time being restricted by a lower (**minimum reaction time**) and an upper bound (**memory**)



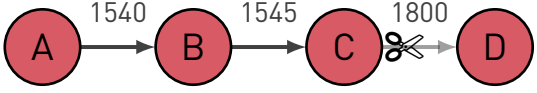
1. Chronology is broken



2a. Inter-edge time $<$ minim reaction time

Assumptions

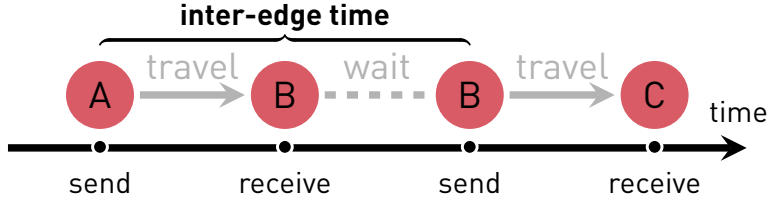
1. Time-consecutive edges deal with the same topic
2. Time scale is global



2b. Inter-edge time $>$ memory

- Accounting for chronology is easy, choosing the correct inter-edge time is not
- Time scale at which temporal edges influence each other is unknown

Inter-edge Time for Letters



- Minimum inter-edge time: 1 day (min. reaction time)
- Maximum inter-edge time: δt (memory)

Real life

- Only waiting time is relevant
- Refresh memory: Repeatedly read letter
- Continuous waiting↑ → Forgetting↑

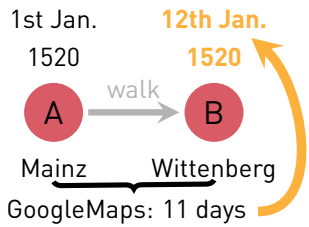
Data

- Missing receiving dates:
  cannot disentangle travel and waiting times
- No data on repeated reading
- Total waiting↑ → Forgetting↑

Estimating δt from data is hard

Estimating δt from data

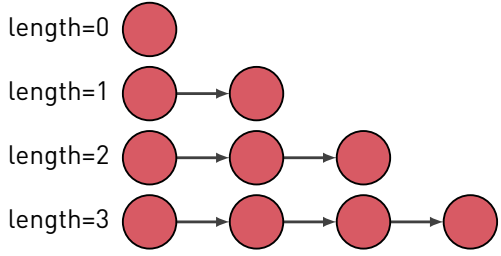
Waiting time



- $\delta t =$ typical (travel + waiting time)
- Keep 1% of reformers, 24% of edges

➔ Not representative to draw conclusion

Path lengths Petrovic, Wagner & Scholtes, 2023

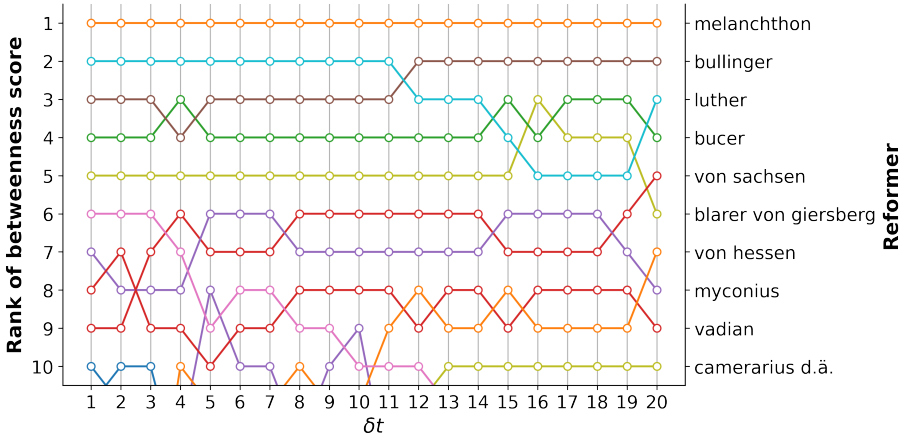


- Optimal δt: only one path length dominates
- No paths for some lengths → no variation for statistical inference

➔ Measure is not informative

➔ Sparseness poses problems to data-driven approaches

Robustness Checks



- Robust result: Melanchthon is always the most important reformer
- But other reformers change their scores

Summary

- **Aggregated network ignore time**
  - Information spreads backwards in time
  - Biased topological network measures
- **Time-respecting paths**
  - Temporal ordering of edges
  - Challenge: parameter calibration (δt)
  - Calibration methods: problem with data sparseness
  - Strict assumptions
- **Outlook**
  - Validate topological paths with topic-based paths