Faculty of Agricultural and Nutritional Science

Christian-Albrechts-University Kiel
Institute of Animal Breeding and Husbandry

Static aggregation of a pig trade network in Northern Germany compared to its temporal counterpart

Kathrin Büttner and Joachim Krieter

Institute of Animal Breeding and Husbandry,
Christian-Albrechts-University, Kiel, Germany

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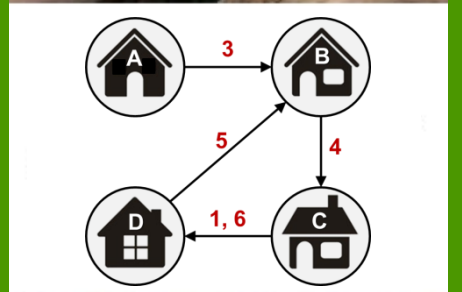
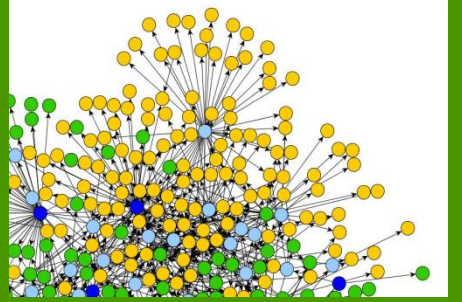
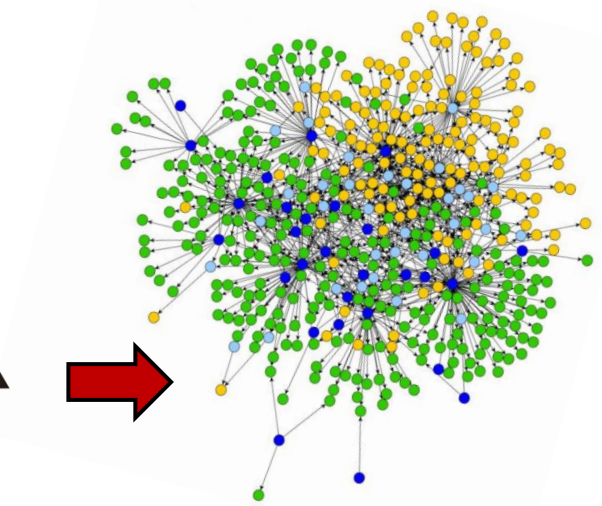




Introduction

- **Useful applications of network analysis in agricultural sciences**
  - → Behavioural research (social contacts, abnormal behaviour)
  - → Epidemiological studies (prediction and prevention of disease transmission)
- Network analysis has become a valuable framework to study the role of contact patterns in the case of an epidemic outbreak
- **Transport of live animals:** Major risk factor for the spread of infectious diseases
- **Trade network**
  - → Farms: Nodes
  - → Trade contacts: Edges



Introduction

- **But: Previous studies focused on the static network analysis**
  - → Contacts were aggregated over time windows of different length (i.e. monthly or yearly networks) and then analysed separately
  - → Temporal variation in the system is ignored
  - → Overestimation of the speed and the extent of an outbreak
- **Problematic**, if the static aggregation allows for the existence of more paths compared to the number of time-respecting paths (right chronological order)
- **Advantage of the static network analysis:** Huge toolbox of analytical and computational methods

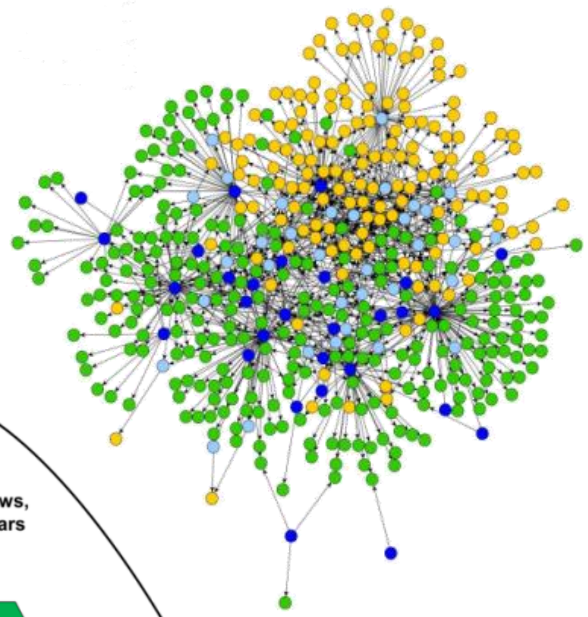
Aim of the study

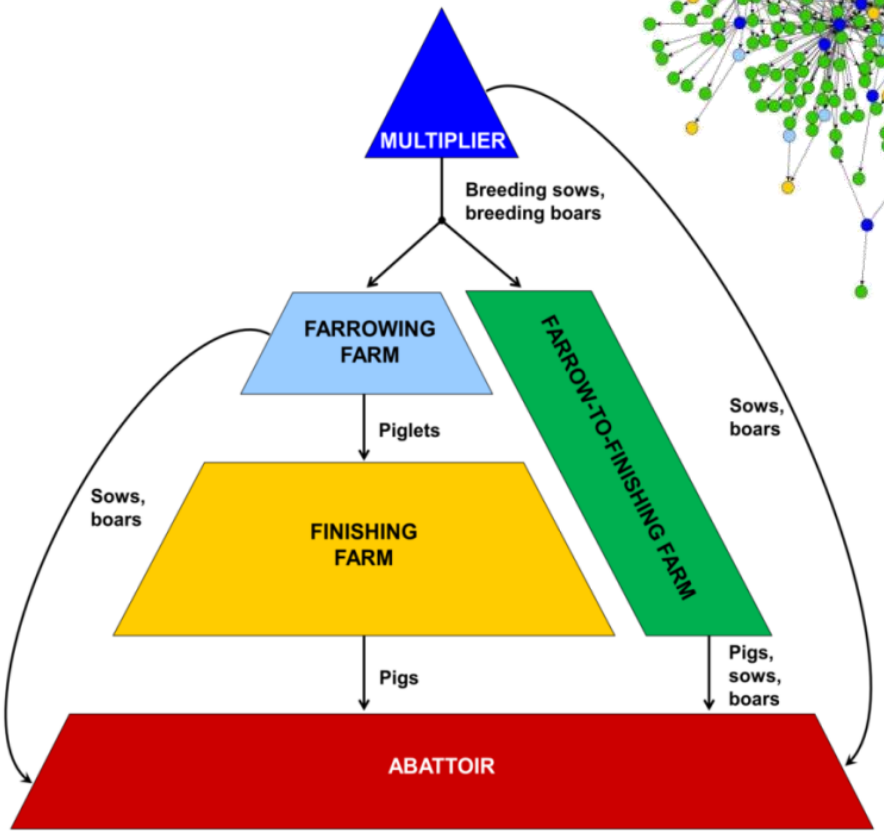
- **To reveal differences** between the static and the temporal representation of an animal trade network
- **To assess the quality** of the static aggregation in comparison to the temporal counterpart

Data basis

- Trade network of the pork supply chain from a producer community in Northern Germany
- **Observation period:** June 2006 to May 2009
- **Recorded data**
  - → Supplier
  - → Purchaser
  - → Number and type of delivered livestock
- **483 farms &**

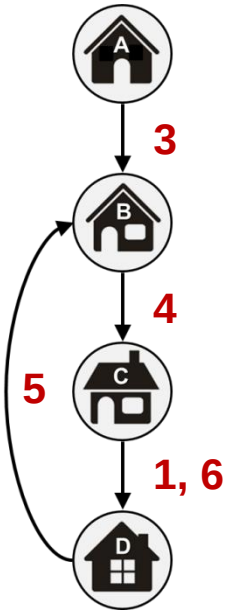
  4,635 trade contacts





Static vs. temporal representation – An example

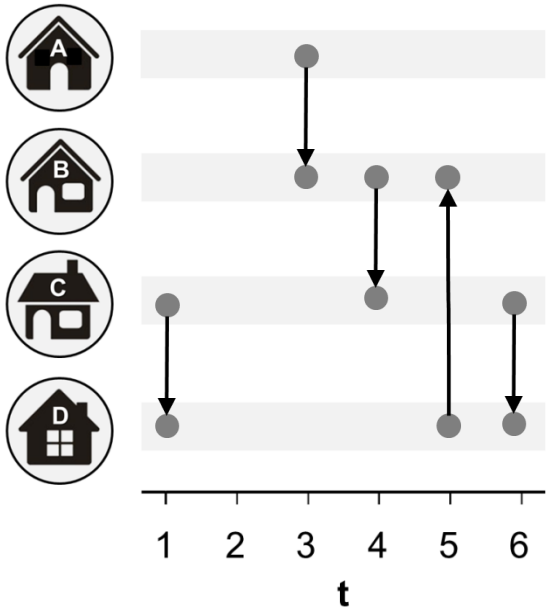
Static representation



	Topological distance
A → B	1
A → B → C	2
A → B → C → D	3
B → C	1
B → C → D	2
C → D	1
C → D → B	2
D → B	1
D → B → C	2

9 static paths

Temporal representation



	Temporal distance
A → B	1
A → B → C	2
A → B → C → D	4
B → C	1
B → C → D	3
C → D	1
C → D → B	5
D → B	1
D → B → C	

8 time-respecting paths

Causal fidelity

- Measurement of how closely a static aggregated network reproduces the path properties of the temporal information

$$c = \frac{Number\ of\ time\text{-}respecting\ paths}{Number\ of\ static\ paths}$$

- **Range of the parameter: $0 \leq c \leq 1$**

  → **Large values:** The static aggregation gives a good approximation from a causal point of view (right chronological order of paths)

  → **Low values:** The majority of paths in the static network are not in the right chronological order and thus do not exist in the temporal network

- **Example network:** $\frac{8\ time\text{-}respecting\ paths}{9\ static\ paths} = 0.889$

  → 88.9 % of the time-respecting paths exist in both representations

  → Good approximation

Causal fidelity

Median, minimum and maximum number of paths and causal fidelity

	Total network	Yearly networks	Monthly networks
Static paths	3,005	795 (760 to 1,114)	153 (116 to 203)
Time-respecting paths	1,999	693 (669 to 910)	141 (111 to 175)
Causal fidelity	**0.67**	**0.87 (0.82 to 0.88)**	**0.92 (0.81 to 0.98)**

- **Good approximation:** In all three observation windows, the static aggregation captured its temporal characteristics sufficiently well

  → Comparable to other pig trade networks (Lentz et al., 2013)

- **Explanation:** Stable production rhythm of the pork supply chain

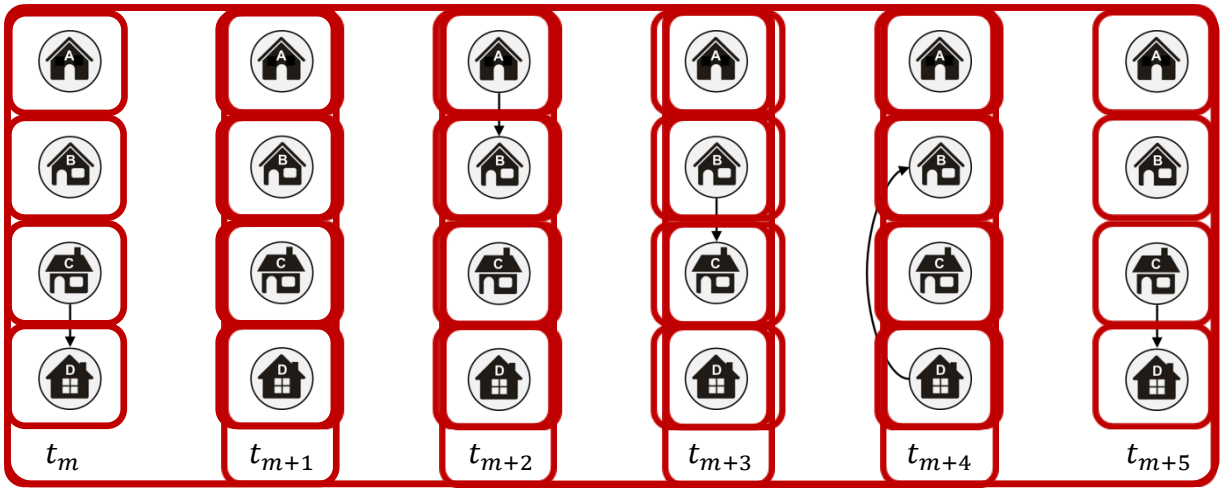
- **But:** Increasing causal fidelity with shorter aggregation window

  → Strong dependency according to the chosen aggregation window

Temporal correlation coefficient (TCC)

- Average possibility for an edge to persist across two consecutive time steps
- **Three calculation steps**

1. Topological overlap of the neighbourhood of node i	$C_i(t_m, t_{m+1}) = \frac{\sum_j a_{ij}(t_m) a_{ij}(t_{m+1})}{\sqrt{[\sum_j a_{ij}(t_m)][\sum_j a_{ij}(t_{m+1})]}}$
2. Average topological overlap of the graph	$C_m = \frac{1}{max[A(t_m), A(t_{m+1})]} \sum_{i=1}^{N} C_i(t_m, t_{m+1})$
3. Temporal correlation coefficient	$TCC = \frac{1}{M-1} \sum_{m=1}^{M-1} C_m$



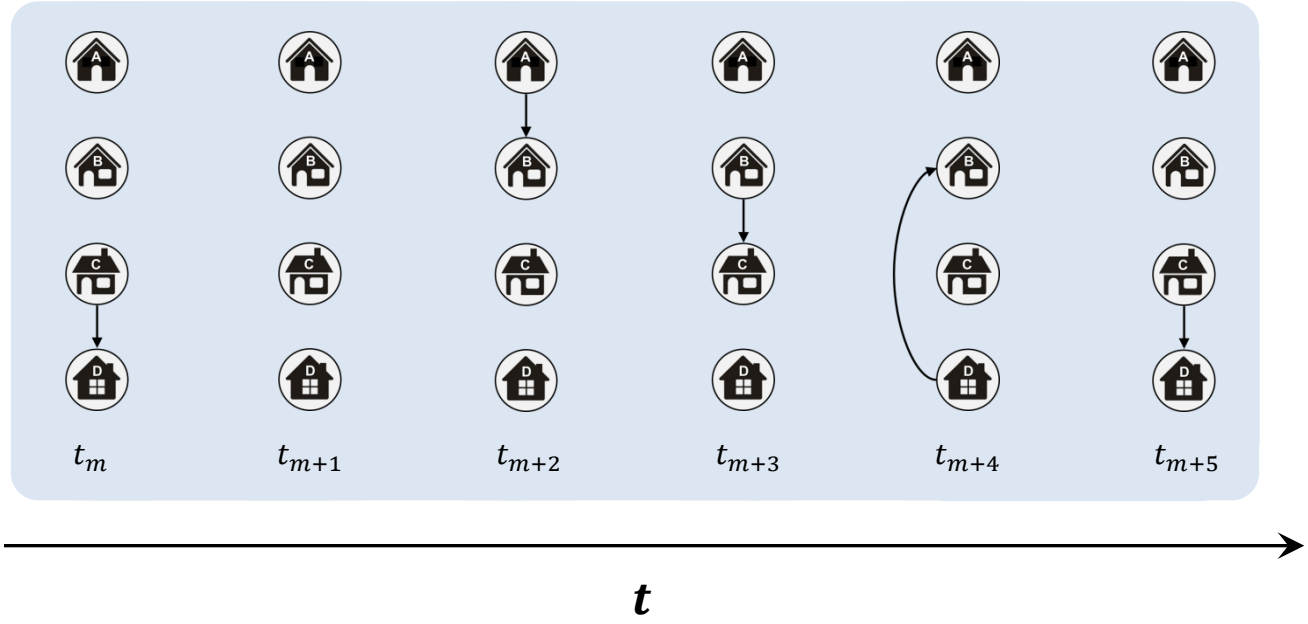
Temporal correlation coefficient (TCC)

- **Range of the parameter:** $\mathbf{0} \leq \boldsymbol{TCC} \leq \mathbf{1}$

  → **Large values:** Nearly all snapshots have the same configuration

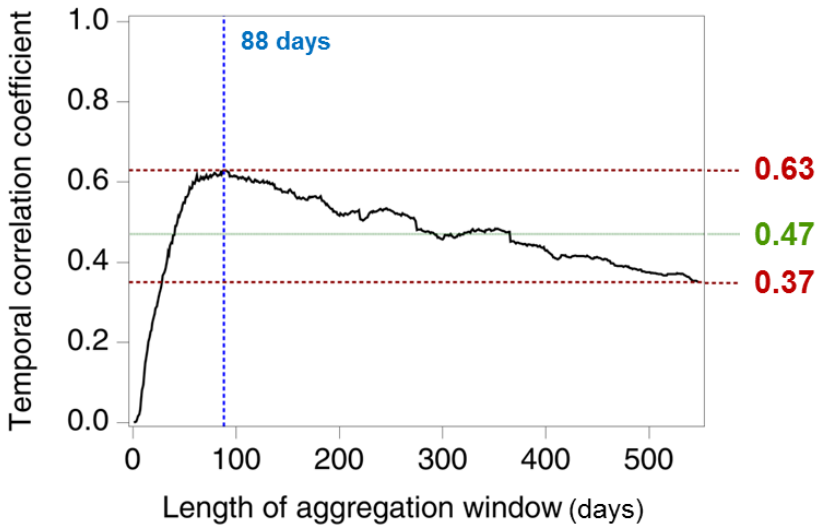
  → **Low values:** Only a small number of edges has ever been observed in two consecutive snapshots

- **Length of aggregation window** = 1

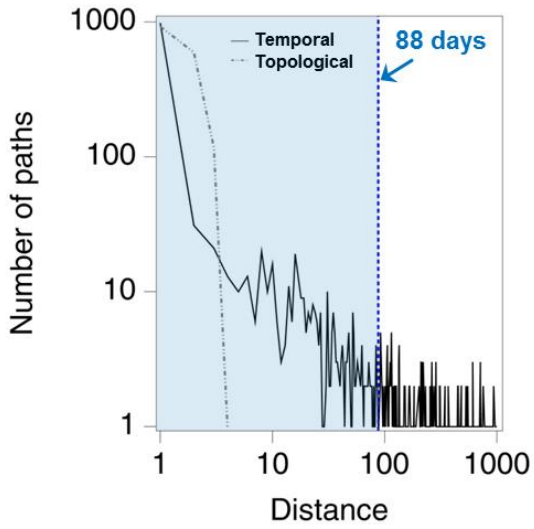


Temporal correlation coefficient (TCC)

TCC depending on the length of the aggregation window



Topological and temporal distances



- **Maximum value of TCC at day 88**
  - → Periodical patterns every three months
  - → Most of the time-respecting paths had a temporal length < 88 days
- **But:** Strong dependency according to the chosen aggregation window

Conclusion

- **Sufficient representation of the temporal dynamics by the static aggregation**
  - → Relatively high causal fidelity
  - → Median temporal correlation coefficient
- **Important: Choice of the appropriate time window length**
  - → Parameters rely on it

If the appropriate time window length is chosen, the methodology of the static network analysis can be used instead of performing the temporal approach for the present pig trade network without losing too much information

Thank you for your attention!

Deutsche Forschungsgemeinschaft

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