REM beyond dyads

relational hyperevent modeling with eventnet

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`https://github.com/juergenlerner/eventnet`

Relational hyperevent models (RHEM).

Relational hyperevent models are a family of statistical models

- for networks of **interaction events**,
- ordered in **time**,
- each may involve **any number of participants**,

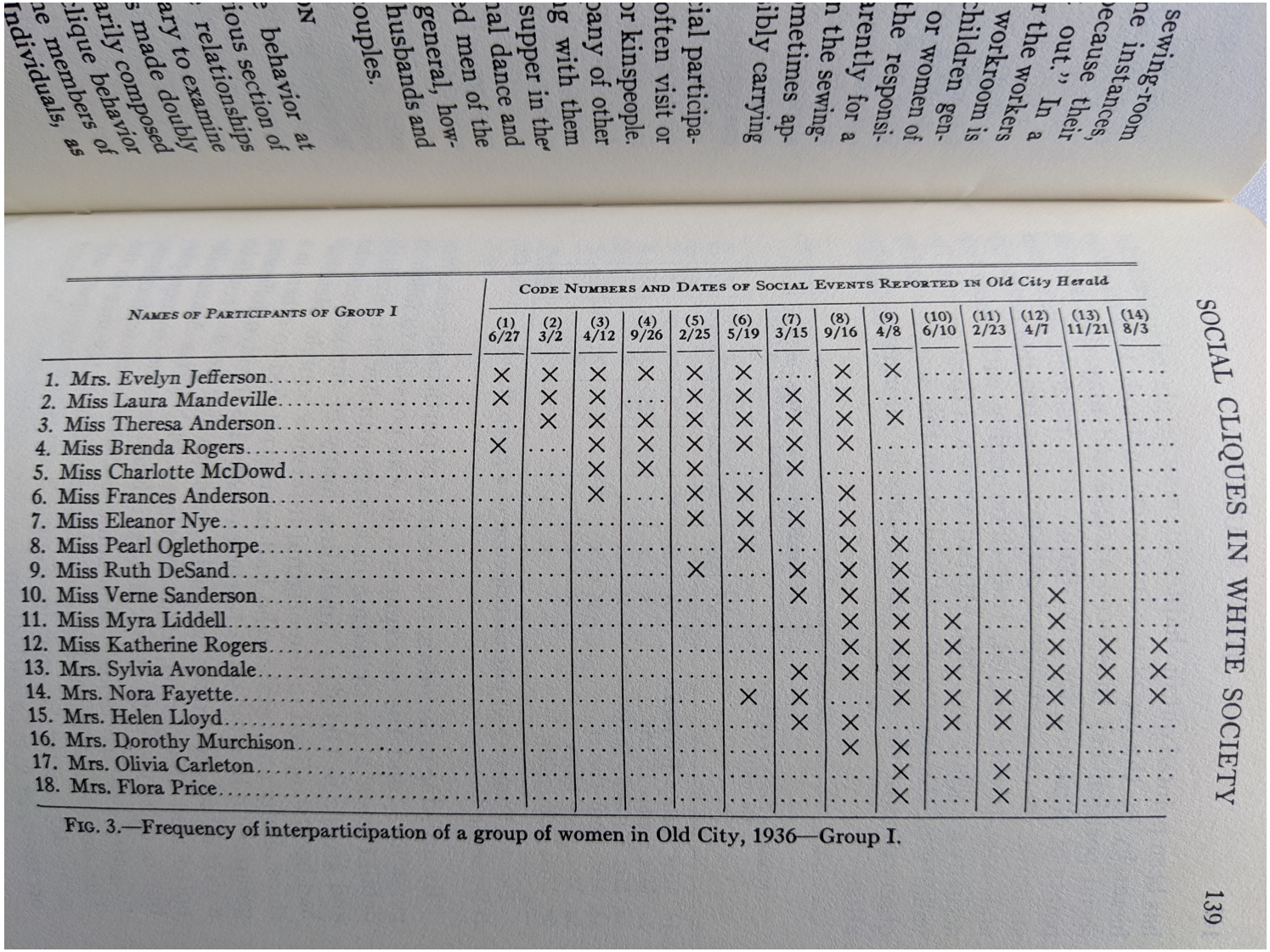
such as meetings, co-authoring, email communication, . . .

This workshop attempts to provide a

gentle introduction to RHEM.

Type of data: list of multi-actor events.

Davis, Gardner, and Gardner (1941). **Deep South.**



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SOCIAL CLIQUES IN WHITE SOCIETY 139

Names of Participants of Group I	Code Numbers and Dates of Social Events Reported in Old City Herald													
	(1) 6/27	(2) 3/2	(3) 4/12	(4) 9/26	(5) 2/25	(6) 5/19	(7) 3/15	(8) 9/16	(9) 4/8	(10) 6/10	(11) 2/23	(12) 4/7	(13) 11/21	(14) 8/3
1. Mrs. Evelyn Jefferson	×	×	×	×	×	×	.	×	×	.	.	.	.	.
2. Miss Laura Mandeville	×	×	×	.	×	×	×	×	.	.	.	.	.	.
3. Miss Theresa Anderson	.	×	×	×	×	×	×	×	×	.	.	.	.	.
4. Miss Brenda Rogers	×	.	×	×	×	×	×	×	.	.	.	.	.	.
5. Miss Charlotte McDowd	.	.	×	×	×	.	×	.	.	.	.	.	.	.
6. Miss Frances Anderson	.	.	×	.	×	×	.	×	.	.	.	.	.	.
7. Miss Eleanor Nye	.	.	.	.	×	×	×	×	.	.	.	.	.	.
8. Miss Pearl Oglethorpe	.	.	.	.	.	×	.	×	×	.	.	.	.	.
9. Miss Ruth DeSand	.	.	.	.	×	.	×	×	×	.	.	.	.	.
10. Miss Verne Sanderson	.	.	.	.	.	.	×	×	×	.	.	×	.	.
11. Miss Myra Liddell	.	.	.	.	.	.	.	×	×	×	.	×	.	.
12. Miss Katherine Rogers	.	.	.	.	.	.	.	×	×	×	.	×	×	×
13. Mrs. Sylvia Avondale	.	.	.	.	.	.	×	×	×	×	.	×	×	×
14. Mrs. Nora Fayette	.	.	.	.	.	×	×	.	.	×	×	×	.	.
15. Mrs. Helen Lloyd	.	.	.	.	.	.	×	×	.	.	.	.	.	.
16. Mrs. Dorothy Murchison	.	.	.	.	.	.	.	×	×	.	.	.	.	.
17. Mrs. Olivia Carleton	.	.	.	.	.	.	.	.	.	.	×	.	.	.
18. Mrs. Flora Price	.	.	.	.	.	.	.	.	.	.	×	.	.	.

Fig. 3.—Frequency of interparticipation of a group of women in Old City, 1936—Group I.

List of events – any number of participants – timestamps.

DGG data in famous SNA studies.

Breiger's duality

*The Duality of Persons and Groups**

RONALD L. BREIGER, *Harvard University*

ABSTRACT

A metaphor of classical social theory concerning the "intersection" of persons within groups and of groups within the individual is translated into a set of techniques to aid in empirical analysis of the interpenetration of networks of interpersonal ties and networks of intergroup ties. These techniques are useful in the study of director interlocks, clique structures, organizations within community and national power structures, and other collectivities which share members. The "membership network analysis" suggested in this paper is compared to and contrasted with sociometric approaches and is applied to the study by Davis *et al.* (1941) of the social participation of eighteen women.

Consider a metaphor which has often appeared in sociological literature but has remained largely unexploited in empirical work. Individuals come together (or, metaphorically, "intersect" one another) within groups, which are collectivities based on the shared interests, personal affinities, or ascribed status of members who participate regularly in collective activities. At the same time, the particular patterning of an individual's affiliations (or the "intersection" of groups within the person) defines his points of reference and (at least partially) determines his individuality.[1]

The following discussion consists of a translation of this metaphor into a set of techniques which aid in the empirical analysis of the interpenetration of networks of persons and networks of the groups that they comprise. My usage of the term "group" is restrictive in that I consider only those groups for which membership lists are available—through published sources, reconstruction from field observation or interviews, or by any other means. Such groups include corporation boards of directors (J. Levine, 1972), organizations within a community or national power structure (Lieberson, 1971; Perrucci and Pilisuk, 1970), cliques or organizations in a high school (Bonacich, 1972; Coleman, 1961), and political factions.

Donald Levine (1959:19–22) writes that "the concept of dualism" is a key principle "underlying Simmel's social thought." Levine explicates Simmel's dualism as "the assumption . . . that the subsistence of any aspect of human life depends on the coexistence of diametrically opposed elements." My own usage of the comparable term "duality" is specified with respect to Equations 3 and 4 below.[2]

THE BASIC CONCEPTION

Consider a set of individuals and a set of groups such that the value of a *tie* between any two individuals is defined as the number of groups of which they both are members. The value of a tie between any two groups is de-

* For their criticism and encouragement, I am indebted to Harrison White, Gregory Heil, François Lorrain, and Scott Boorman. For seminars which first introduced me to Simmel's thought, I am indebted to Kurt H. Wolff. Thanks are due Professor White for support through NSF Grant GS-2689.

[1] Simmel (1955) entitled one of his essays "The Intersection of Social Circles," but Reinhard Bendix changed the title in translation because "a literal translation of this phrase . . . is almost meaningless . . . Simmel often plays with geometric analogies; it has seemed advisable to me to minimize this play with words . . ." (Simmel, 1955:125). For an assertion that Simmel's original title is not at all inappropriate, see Walter's essay (1959). For a more complete explication of the "dualism" inherent in Simmel's thought, see the essays by D. Levine, Lipman, and Tenbruck in Wolff (1959). A similar metaphor was put forward in America by Charles H. Cooley (1902:148), who wrote that "A man may be regarded as the point of intersection of an indefinite number of circles representing social groups, having as many arcs passing through him as there are groups." Much later, Sorokin (1947:345) observed that "the individual has as many social egos as there are different social groups and strata with which he is connected." On the "much neglected" development of the concept of "social circle" since Simmel's writings, see Kadushin (1966).

[2] The "directional duality principle" enunciated by Harary *et al.* (1965) is to be distinguished from my conception. The former principle consists in reversing the directionality of lines in a graph; in the method of this paper, the lines in one graph are transformed into the points of its dual graph, and vice versa.

Freeman's meta analysis

Photograph by Ben Shahn, Natchez, MS, October, 1935

Finding Social Groups: A Meta-Analysis of the Southern Women Data[1]

Linton C. Freeman

University of California, Irvine

[1] The author owes a considerable debt to Morris H. Sunshine who read an earlier draft and made extensive suggestions all of which improved this manuscript.

surprisingly few studies use timing information

List of interaction events – ordered in time.

RHEM attempt to explain the participant list of each event

dependent on past events and exogenous covariates.

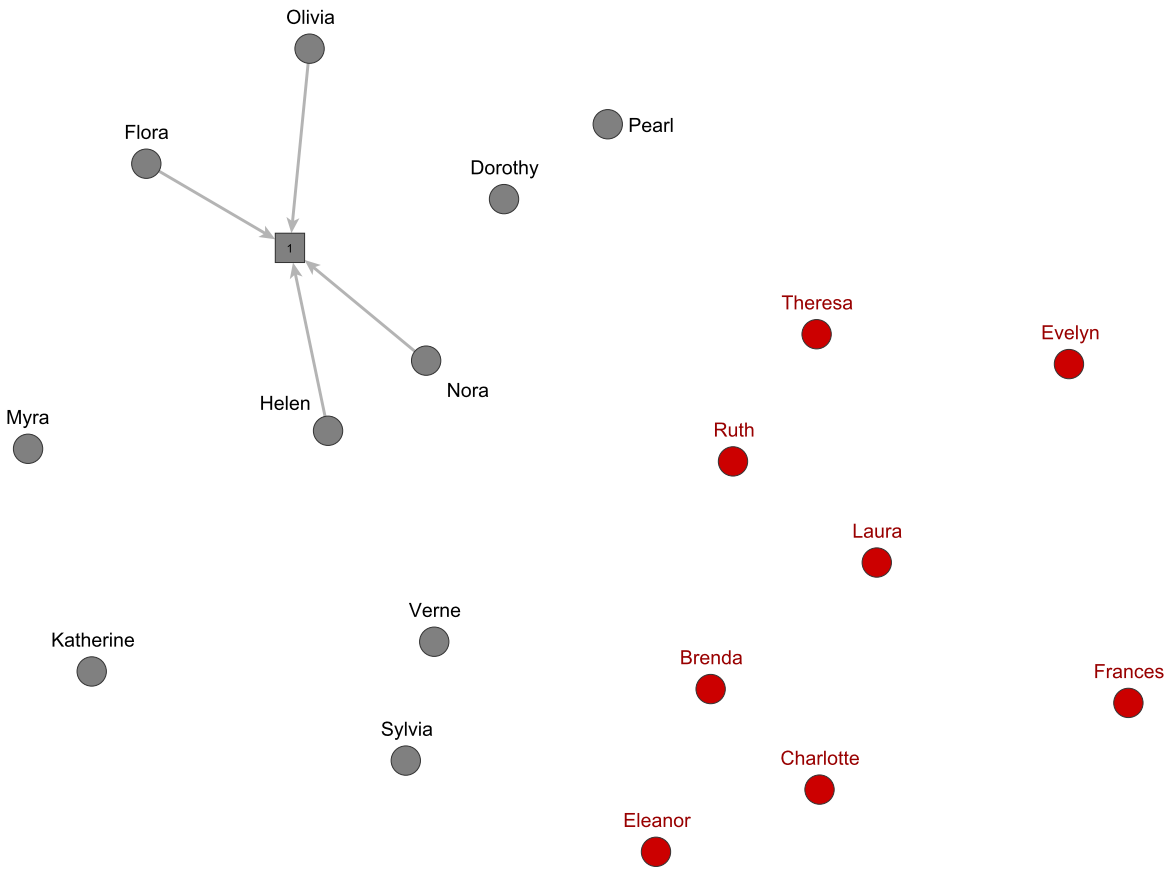
Participants of Event 1.

embedded in network of past events

events ordered in time (not DGG event index)

Participants of Event 2.

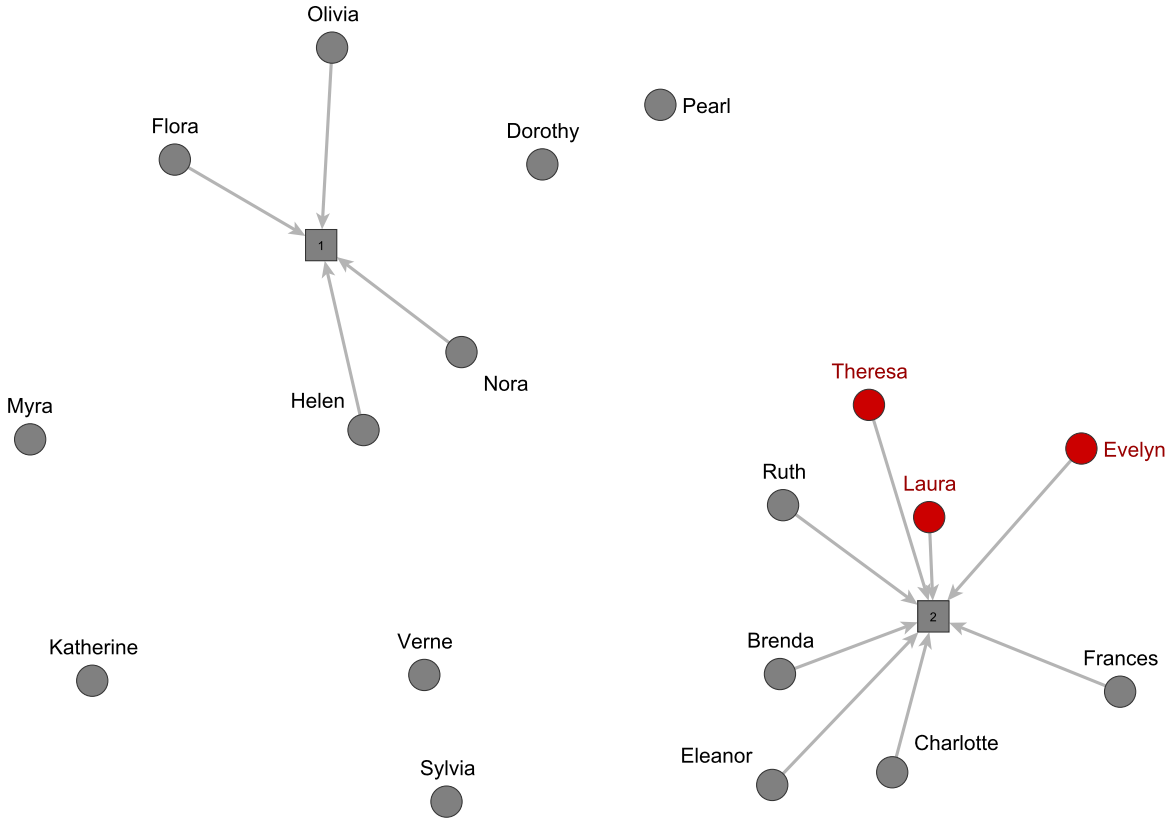
embedded in network of past events



events ordered in time (not DGG event index)

Participants of Event 3.

embedded in network of past events



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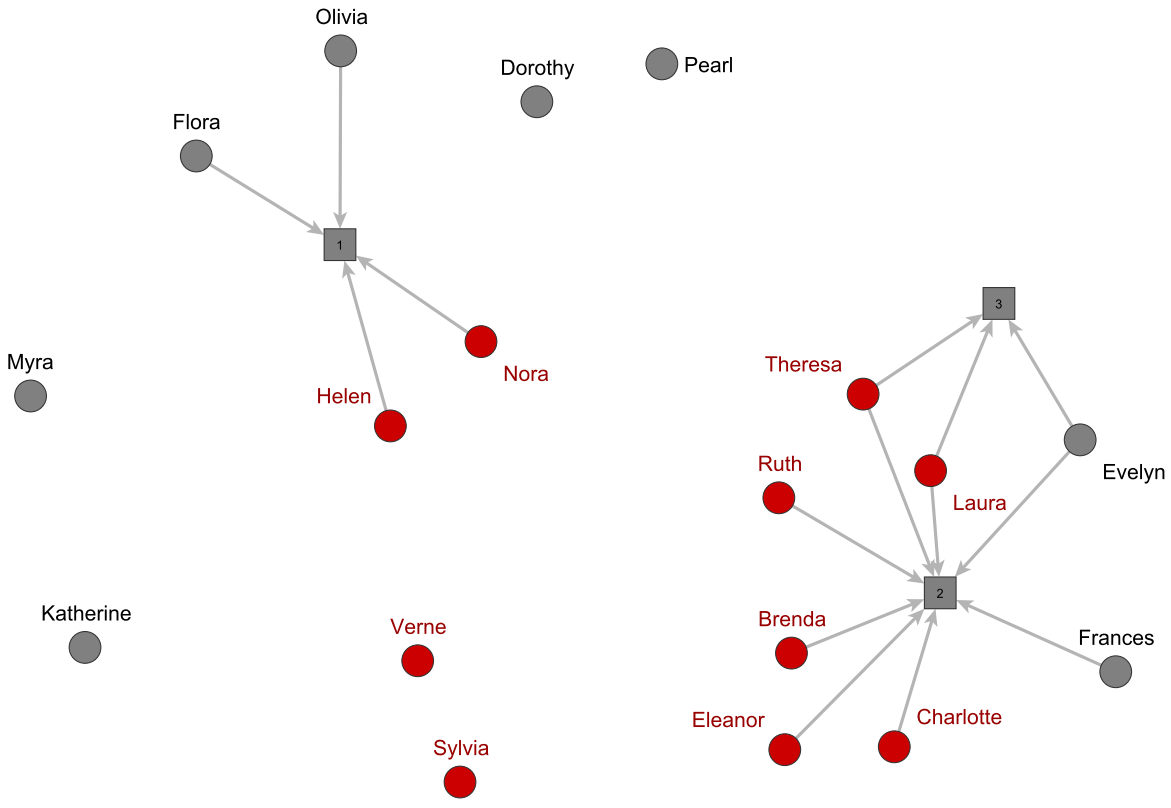
Participants of Event 4.

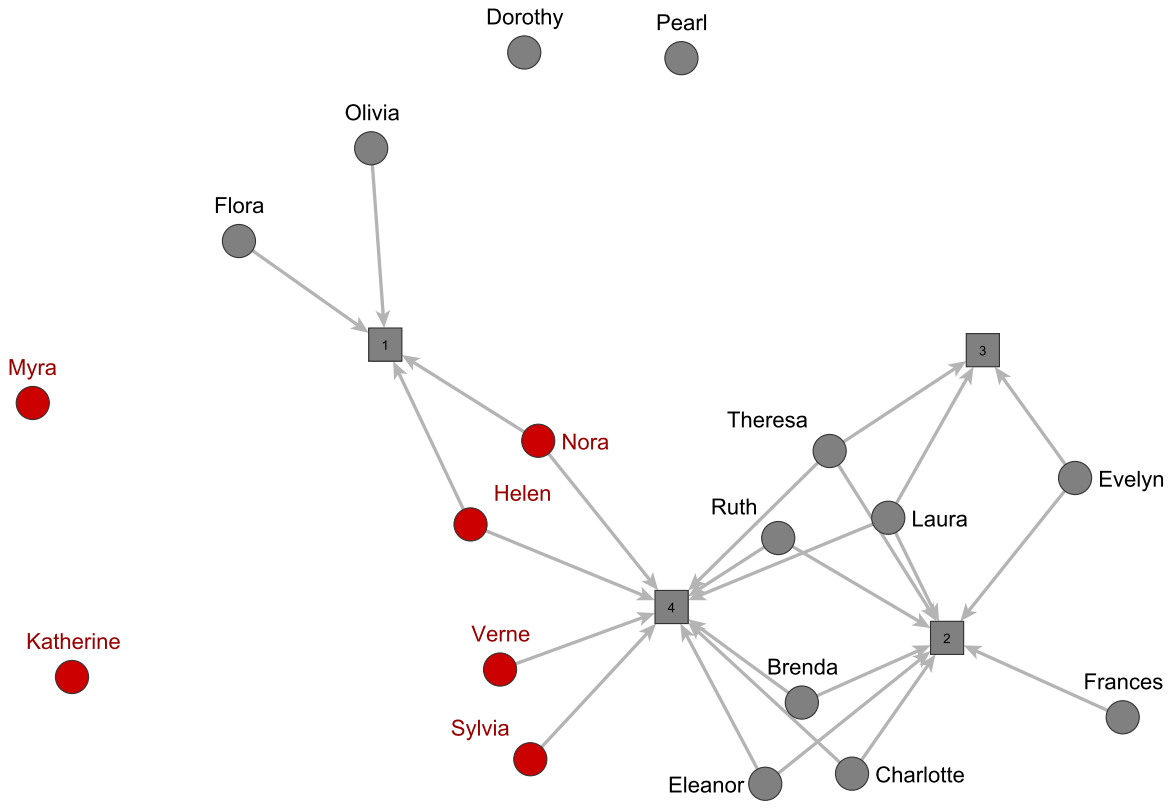
embedded in network of past events



events ordered in time (not DGG event index)

Participants of Event 5.

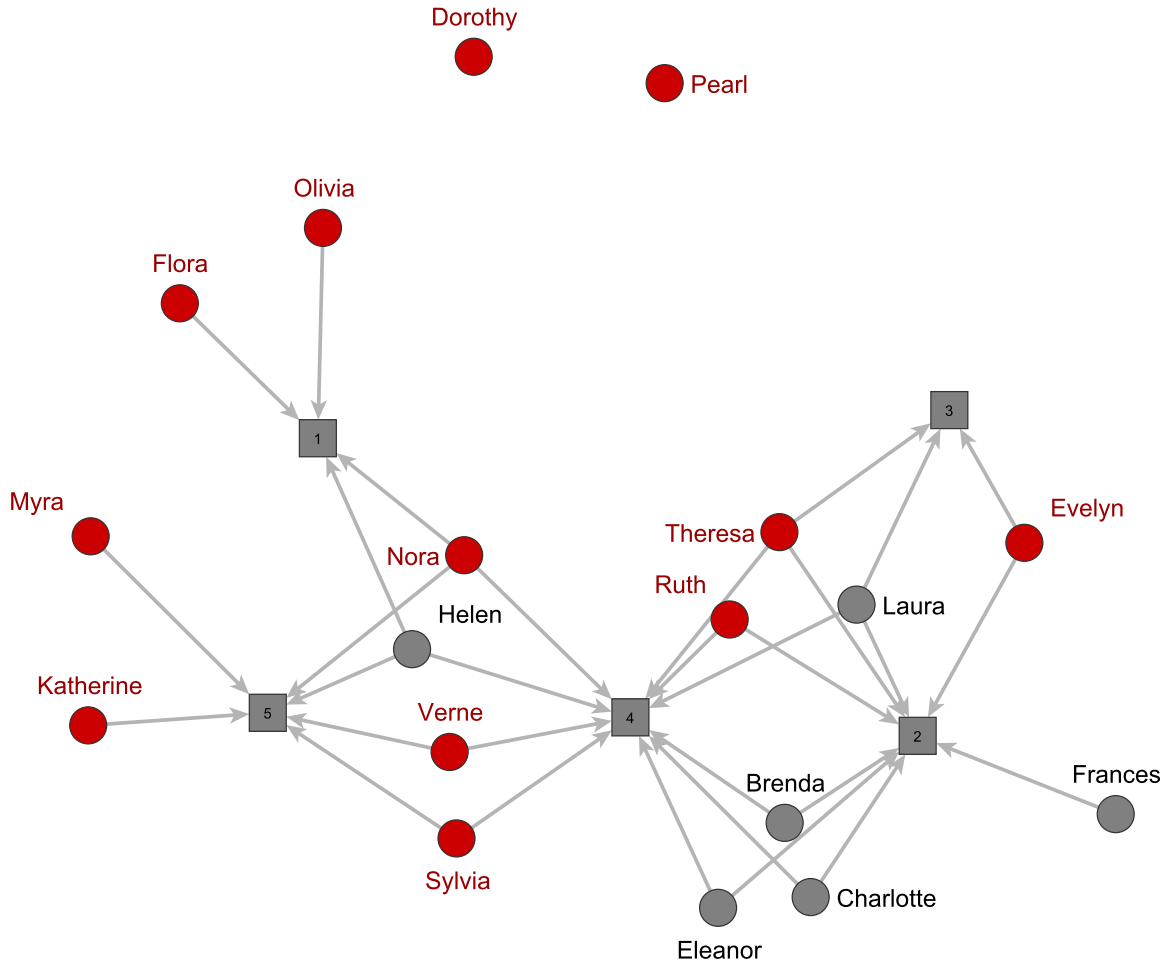
embedded in network of past events



events ordered in time (not DGG event index)

Participants of Event 6.

embedded in network of past events



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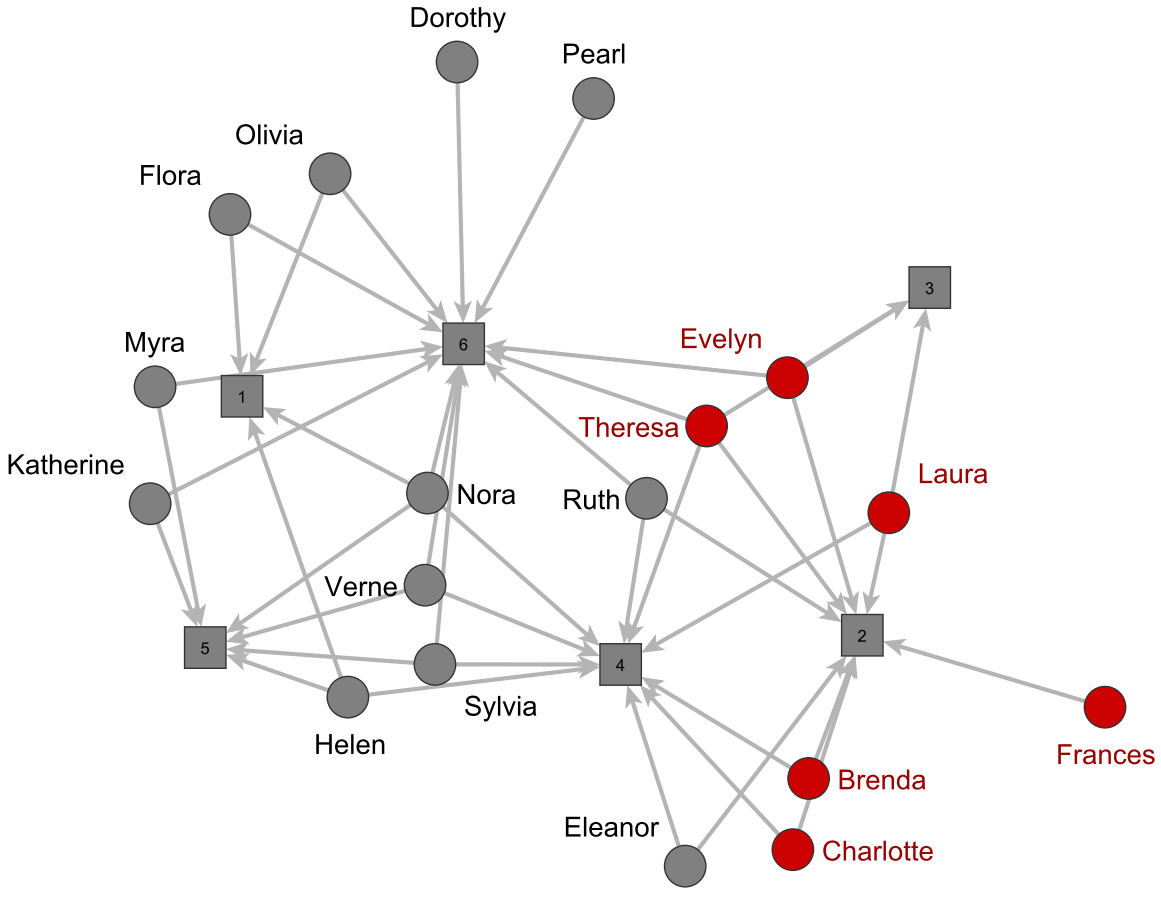
Participants of Event 7.

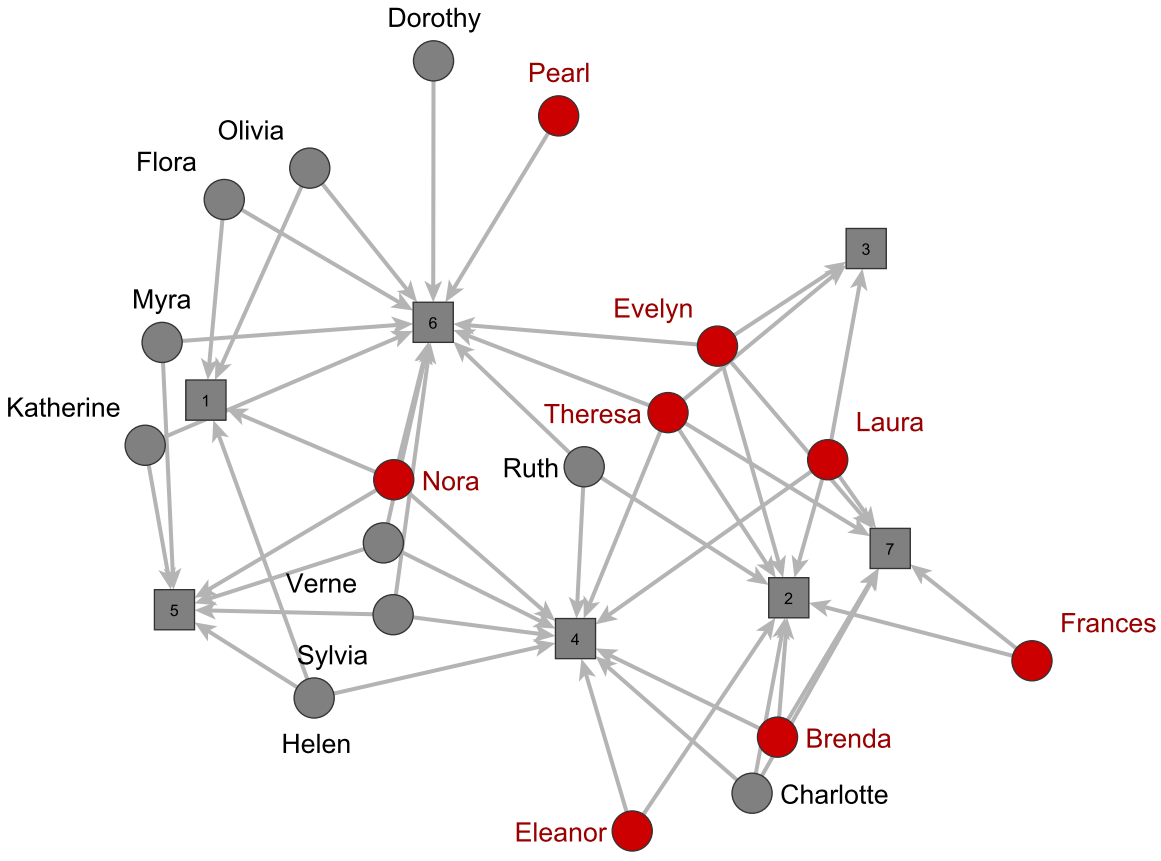
embedded in network of past events



events ordered in time (not DGG event index)

Participants of Event 8.

embedded in network of past events



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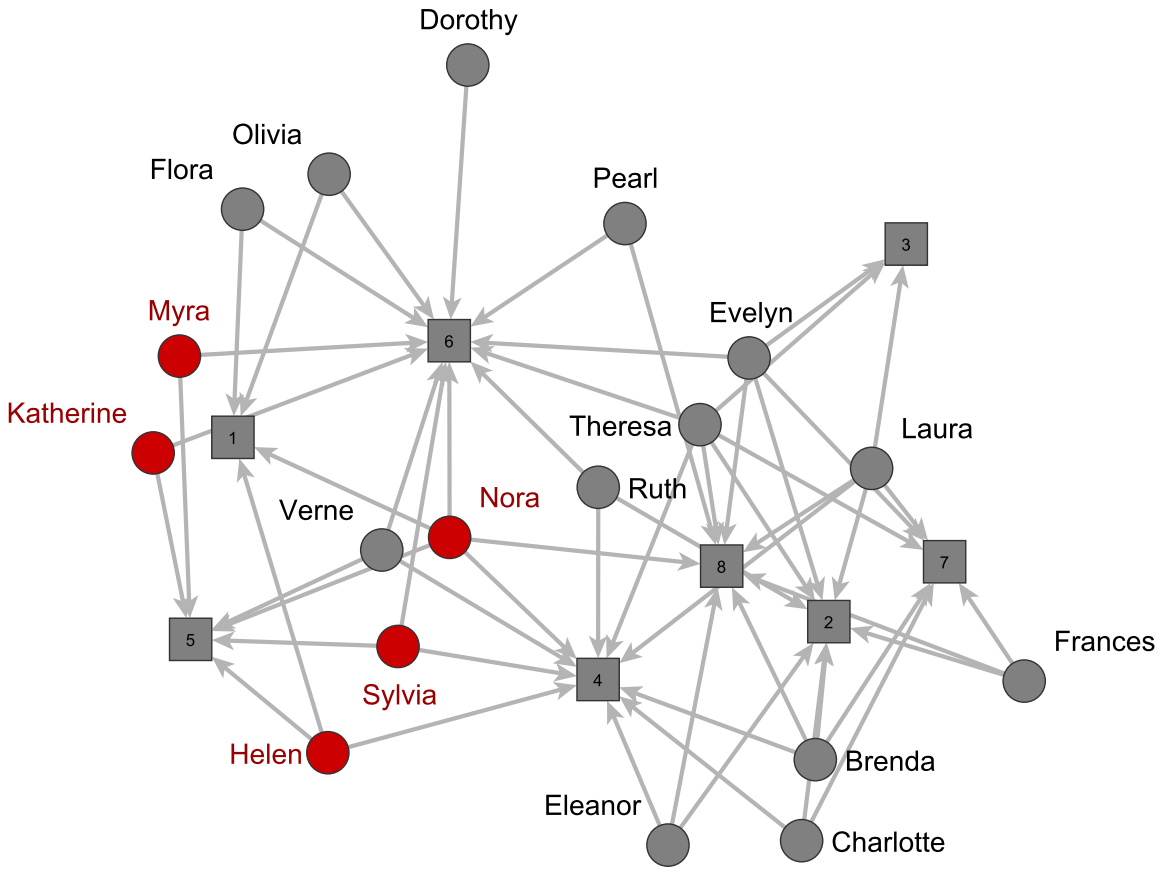
Participants of Event 9.

embedded in network of past events



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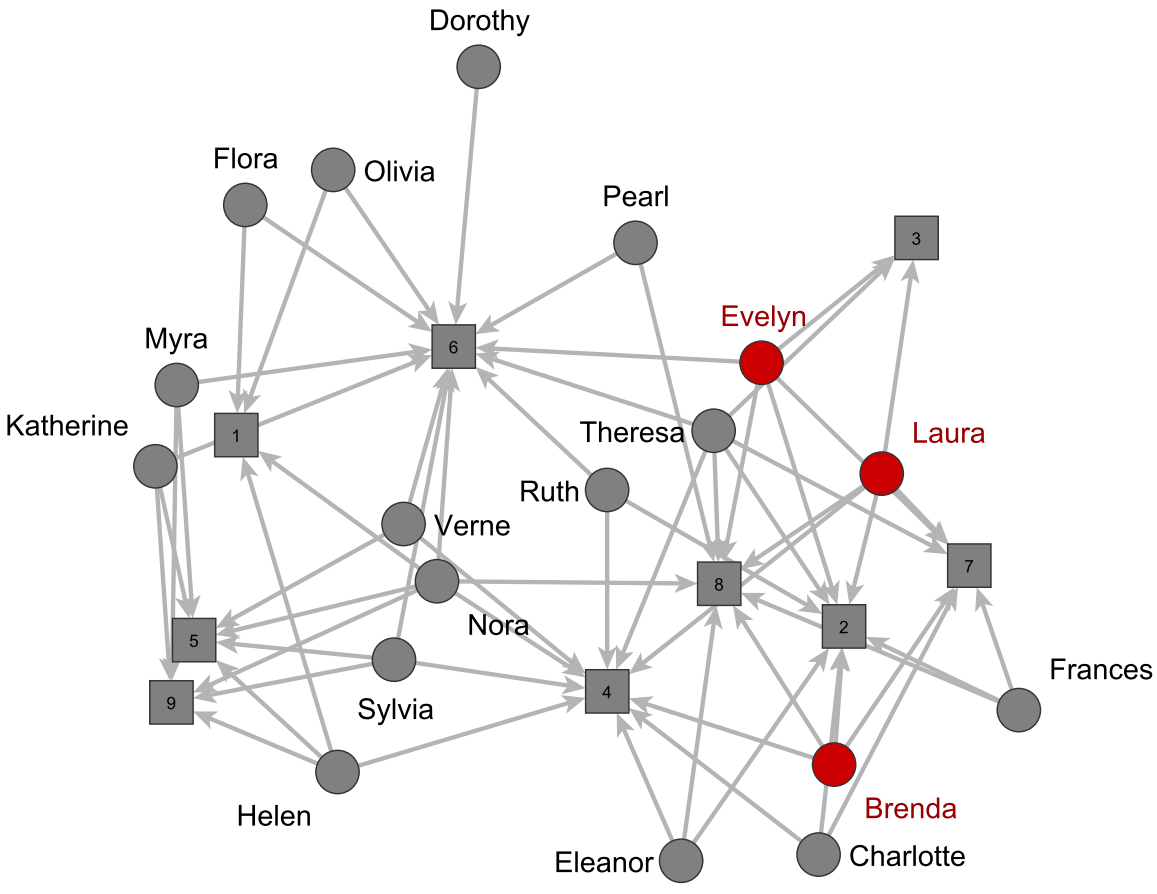
Participants of Event 10.

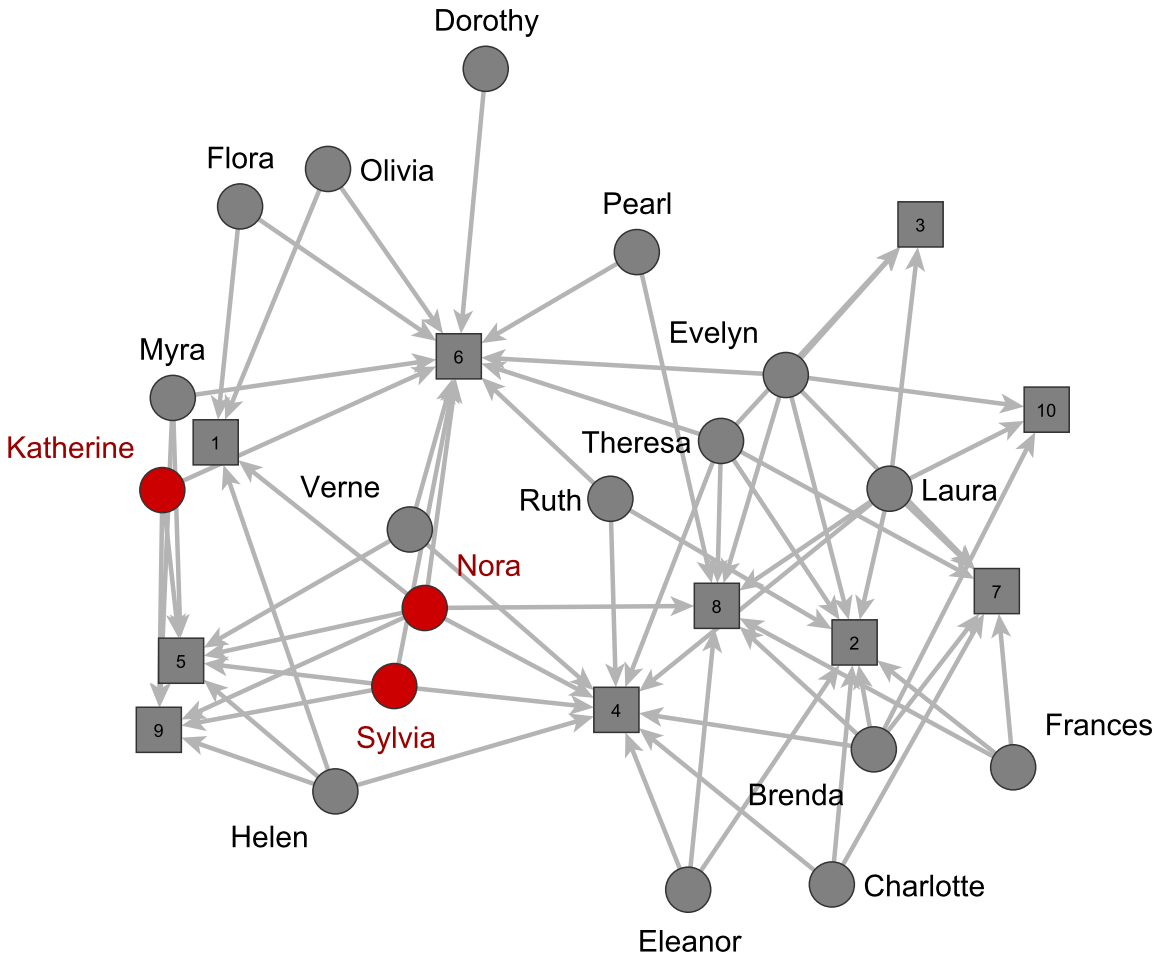
embedded in network of past events



events ordered in time (not DGG event index)

Participants of Event 11.

embedded in network of past events



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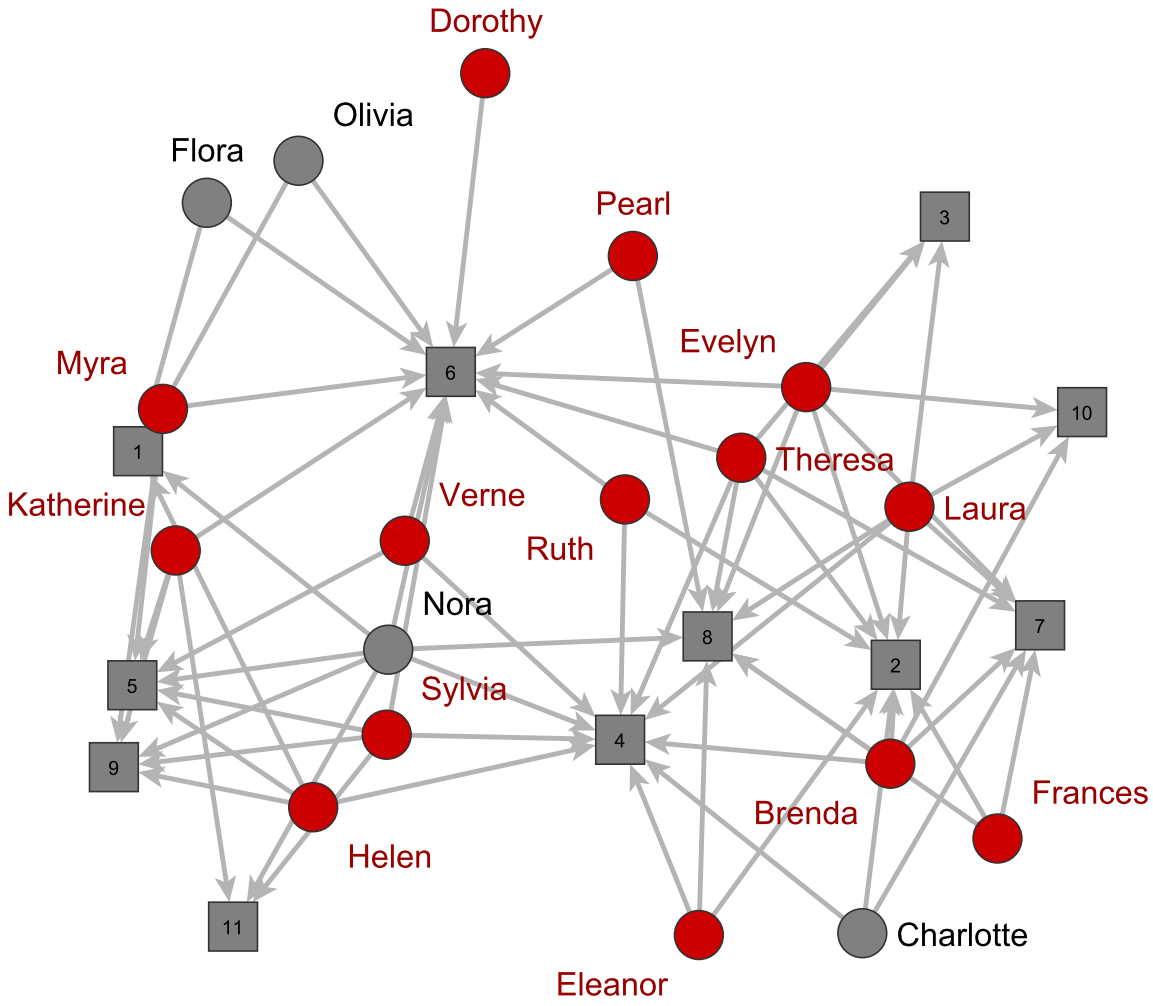
Participants of Event 12.

embedded in network of past events



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Participants of Event 13.

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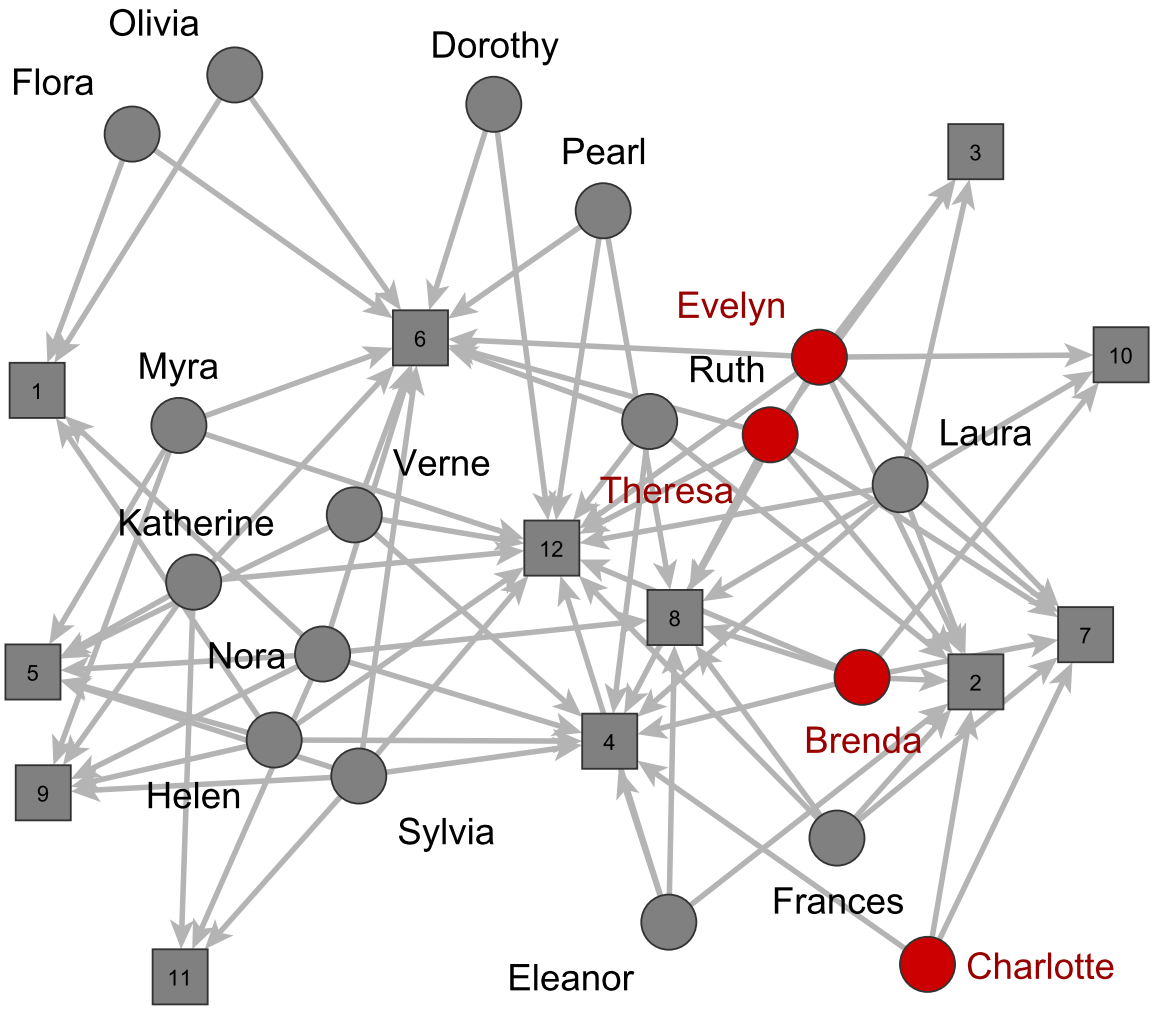
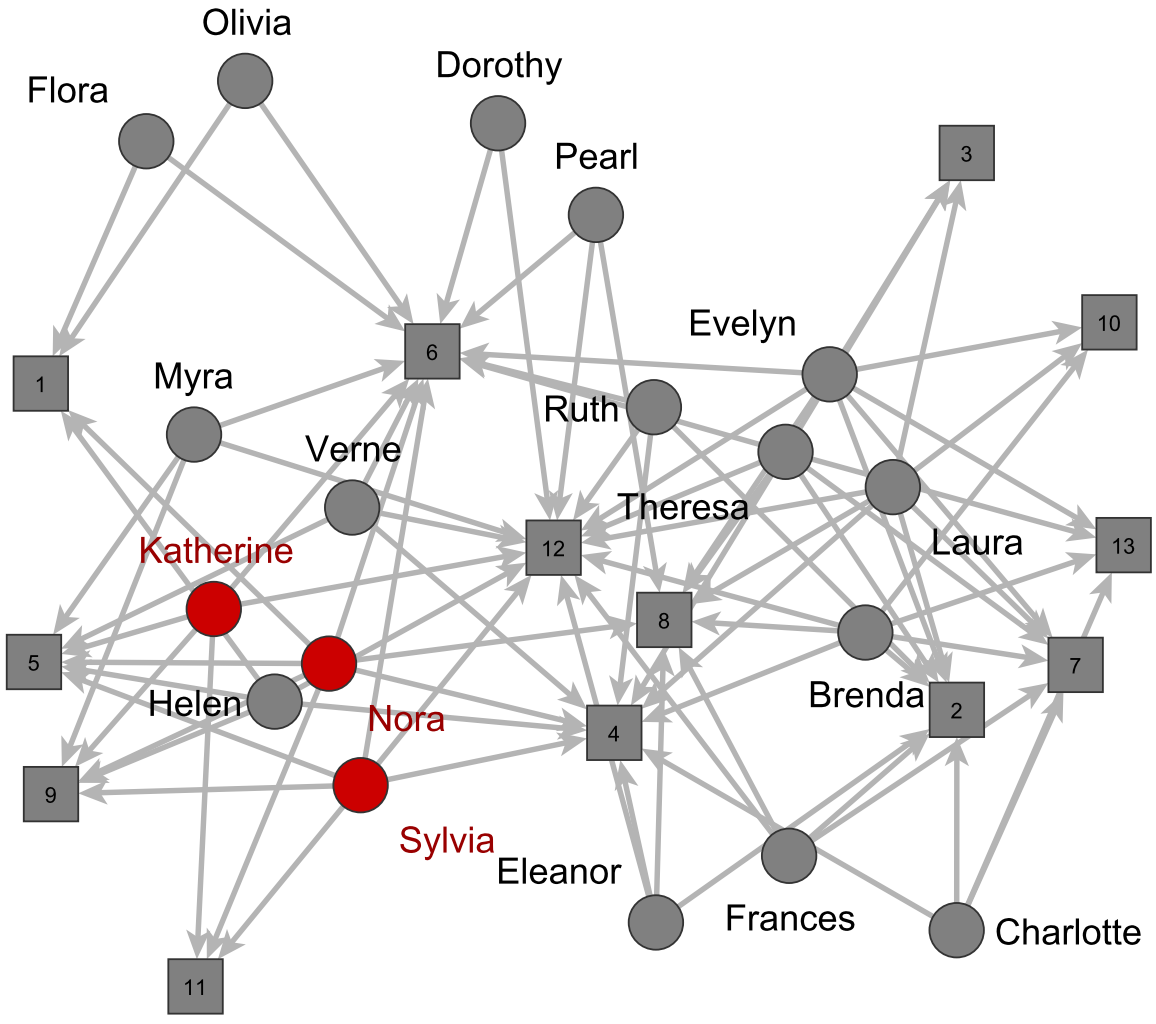


events ordered in time (not DGG event index)

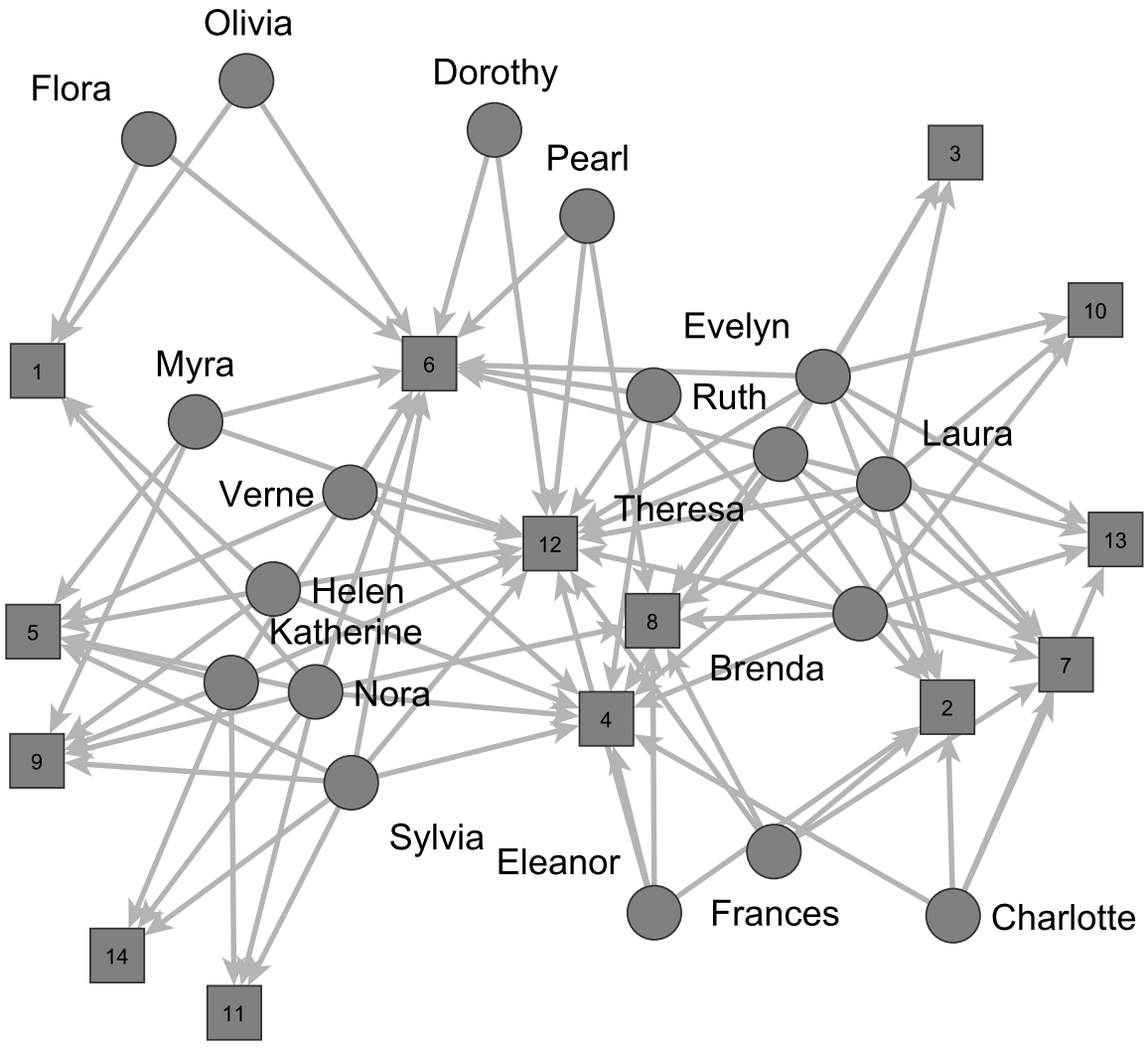
Participants of Event 14.

embedded in network of past events



events ordered in time (not DGG event index)

Network of all 14 events.



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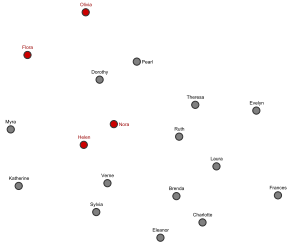
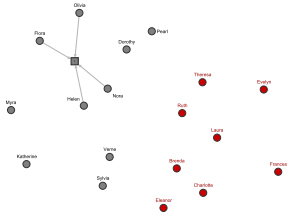
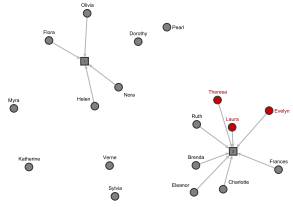
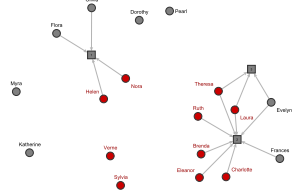
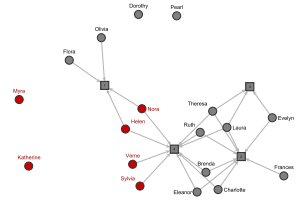
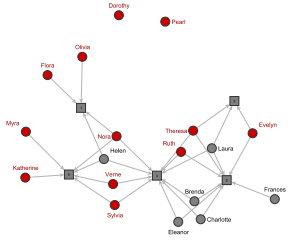
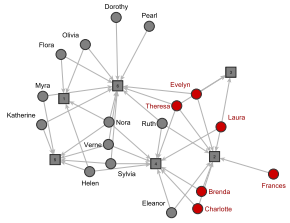
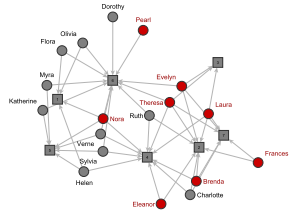
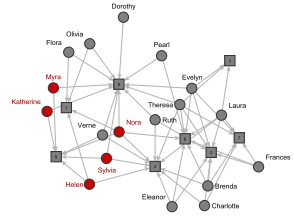
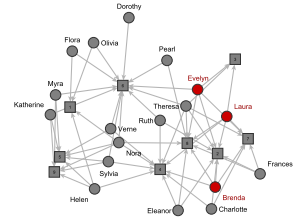
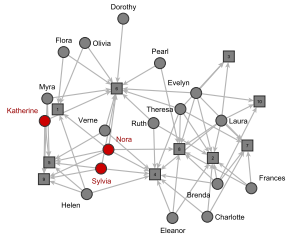
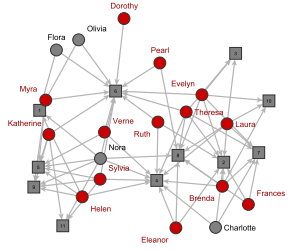
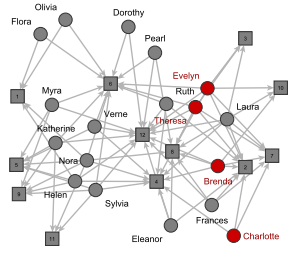
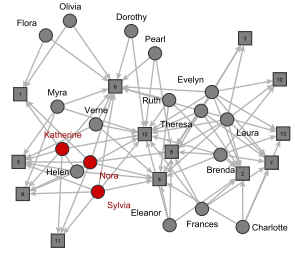
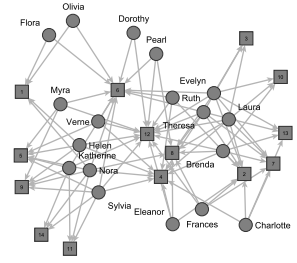
All 14 events.

Settings that often produce multi-actor events.

Interaction events are often not dyadic but may involve any number of nodes (**polyadic interaction**).

Undirected polyadic interaction:

- meetings, co-attendance at events
- team work, coauthoring
- countries signing international treaties

Directed polyadic interaction:

- multicast (one-to-many) communication, email, texting
- citation networks: papers citing lists of references
- virus spreading from persons to several contacts

Treating polyadic events as collections of dyadic events is invalid in general and often creates structural artefacts.

Types of effects in RHEM.

RHEM may reveal or test different types of effects, potentially explaining the participant lists of events.

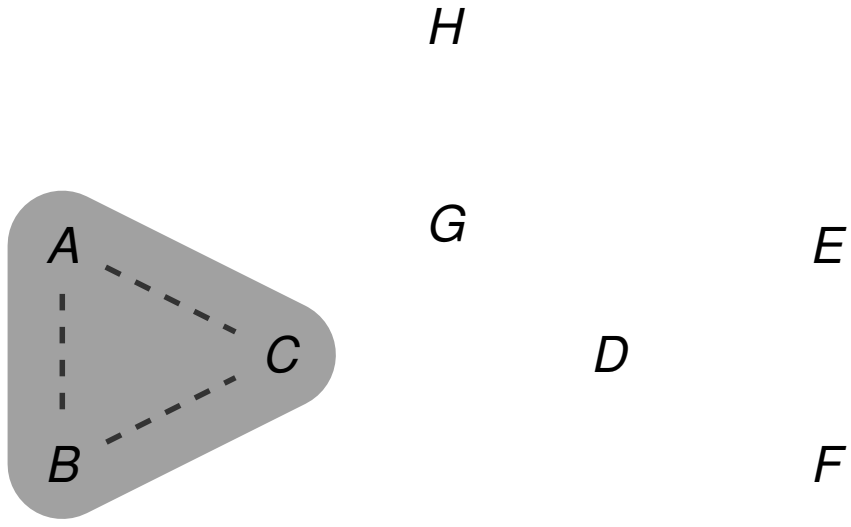
- **(partial) repetition** of participant lists
- **(shared) activity and popularity:** events beget events
- **closure:** indirectly connected actors becoming connected
- **reciprocation** (in directed hyperevent networks)
- **covariate effects:** first-order, second-order (homophily, diversity)
- ...

Data: relational hyperevents (here: undirected).

meetings, social gatherings, coauthorship, project teams, ...

Hyperevent: $e = (t, h)$ with **time stamp** t
and $h \subseteq V$ a set of event **participants**.

$e_1 = (t_1, \{A, B, C\})$



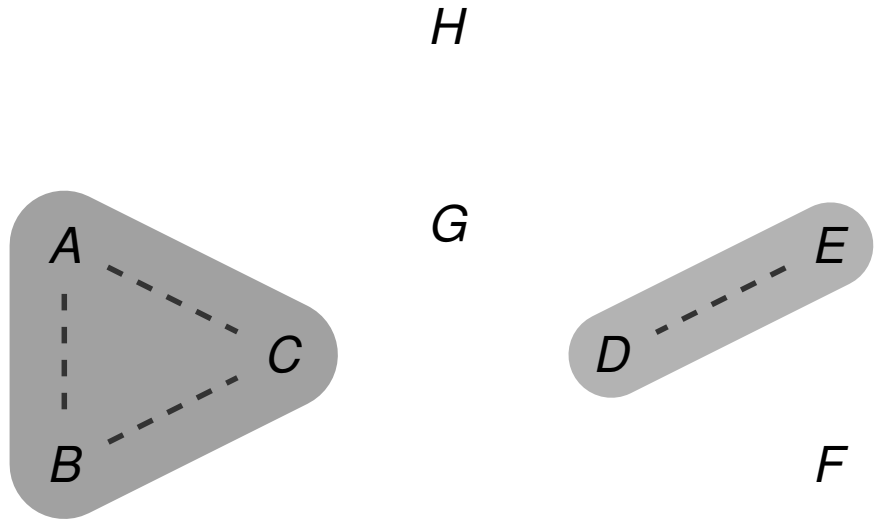
Events are ordered in time and may involve any number of participants.

Data: relational hyperevents (here: undirected).

meetings, social gatherings, coauthorship, project teams, ...

Hyperevent: $e = (t, h)$ with **time stamp** t
and $h \subseteq V$ a set of event **participants**.

$e_1 = (t_1, \{A, B, C\})$
$e_2 = (t_2, \{D, E\})$



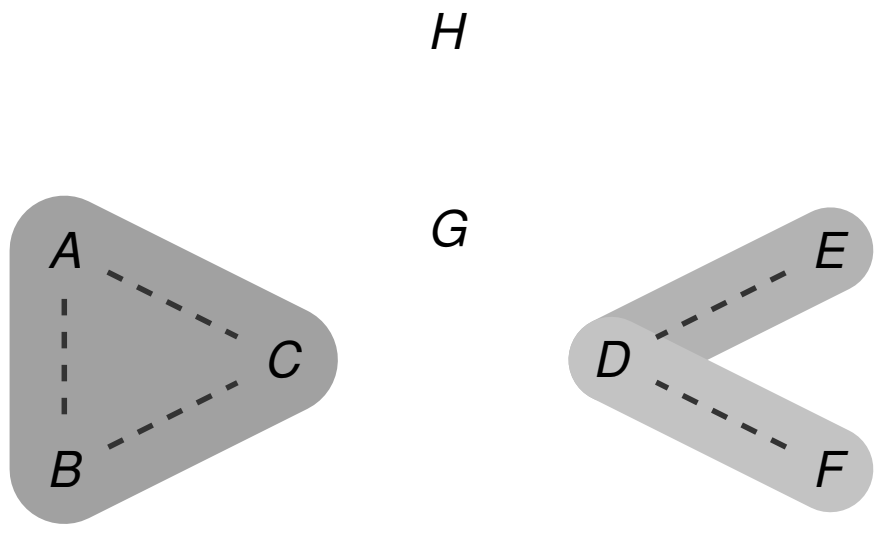
Events are ordered in time and may involve any number of participants.

Data: relational hyperevents (here: undirected).

meetings, social gatherings, coauthorship, project teams, ...

Hyperevent: $e = (t, h)$ with **time stamp** t and $h \subseteq V$ a set of event **participants**.

$e_1 = (t_1, \{A, B, C\})$
$e_2 = (t_2, \{D, E\})$
$e_3 = (t_3, \{D, F\})$



Events are ordered in time and may involve any number of participants.

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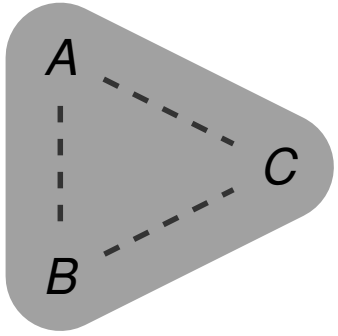
Hyperevent: $e = (t, h)$ with **time stamp** t and $h \subseteq V$ a set of event **participants**.

$e_1 = (t_1, \{A, B, C\})$
$e_2 = (t_2, \{D, E\})$
$e_3 = (t_3, \{D, F\})$
$e_4 = (t_4, \{E, F\})$

H



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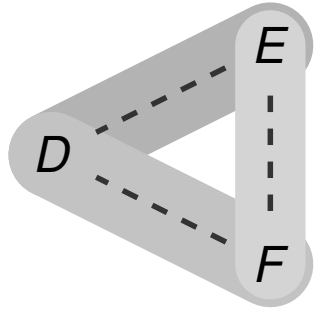


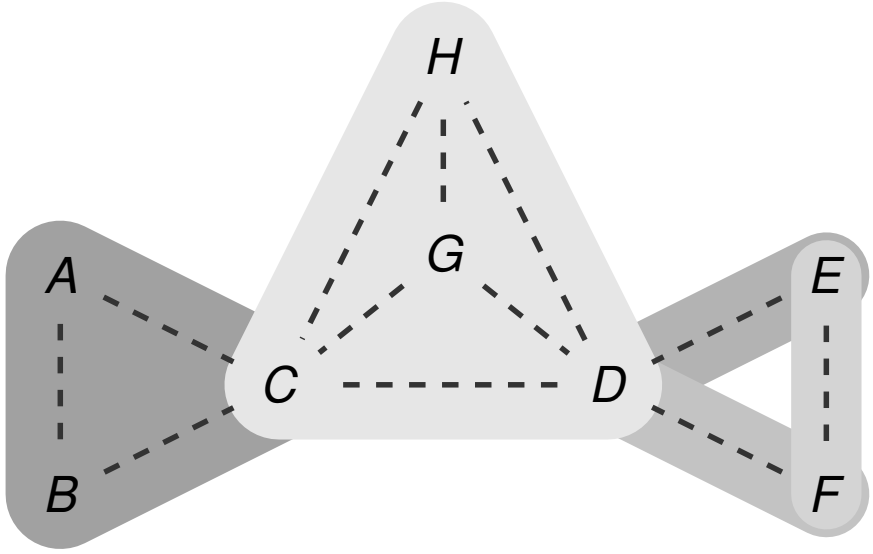
Events are ordered in time and may involve any number of participants.

Data: relational hyperevents (here: undirected).

meetings, social gatherings, coauthorship, project teams, ...

Hyperevent: $e = (t, h)$ with **time stamp** t and $h \subseteq V$ a set of event **participants**.

$e_1 = (t_1, \{A, B, C\})$
$e_2 = (t_2, \{D, E\})$
$e_3 = (t_3, \{D, F\})$
$e_4 = (t_4, \{E, F\})$
$e_5 = (t_5, \{C, D, G, H\})$



Events are ordered in time and may involve any number of participants.

Relational hyperevent models (RHEM).

For every **set of possible event participants** $h \subseteq V$ and point in time t,

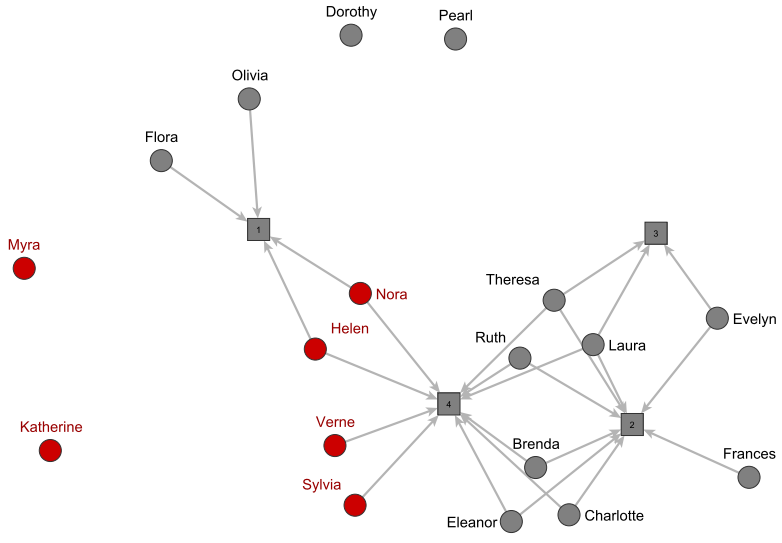
RHEM estimate the **rate of events** on h at t as a function of explanatory variables.

- Which factors explain that actors $\{A, B, C\}$ meet at a higher/lower rate than actors $\{C, D, E\}$?
- Explanatory variables can be functions of exogenous actor attributes;
- or functions of previous events.

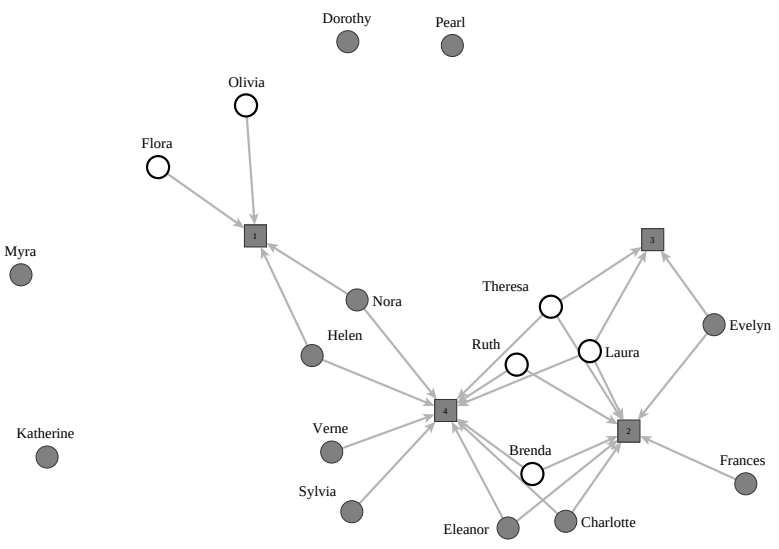
RHEM generalize dyadic relational event models (Butts, 2008).

Events that happened vs. events that could have happened.

True Event 5



alternative (non-event).

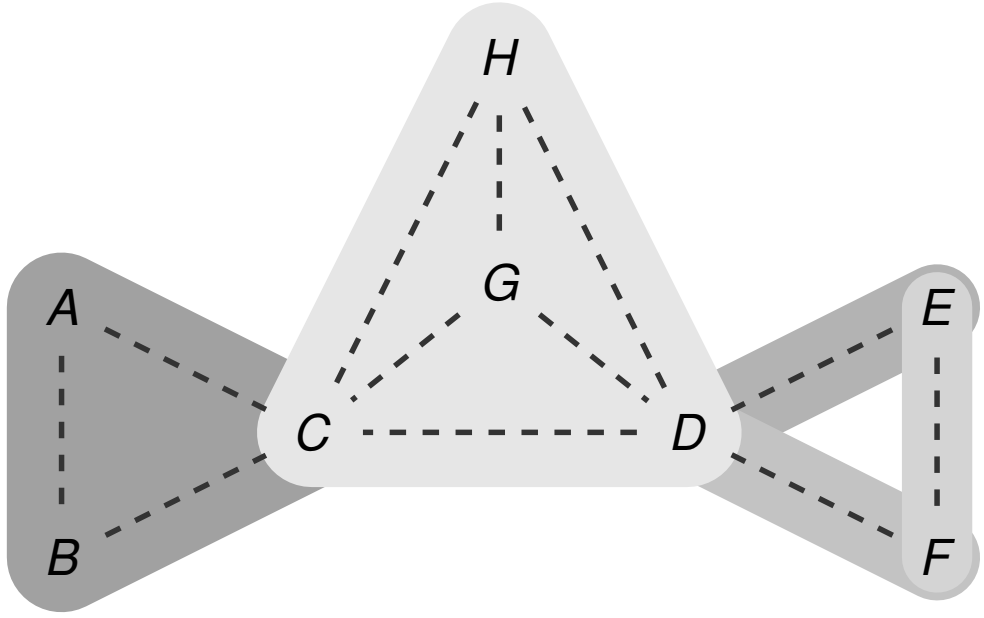


RHEM attempt to explain which events – out of the space of all possible events – are more likely to happen.

Some effects: triadic closure vs. partial repetition.

Gray-shaded areas are past events.

Actor *C* is in a “broker position” (member of several groups).



Positive triadic closure would imply that *C* is going to loose her broker position.

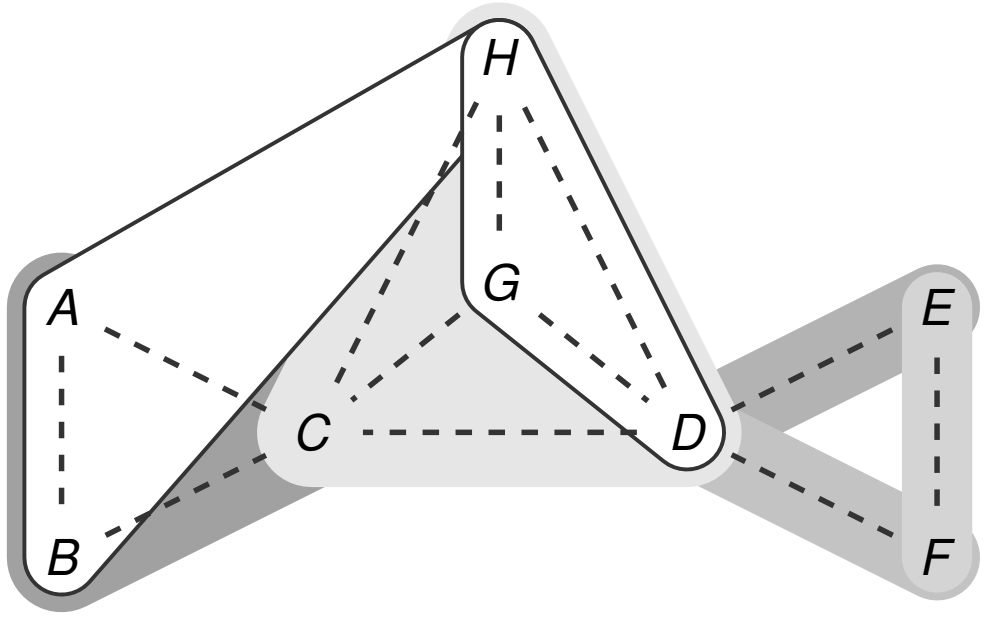
Negative triadic closure: stable broker positions.

Some effects: triadic closure vs. partial repetition.

Gray-shaded areas are past events.

White areas are possible future events.

Actor *C* is in a “broker position” (member of several groups).



Positive triadic closure would imply that *C* is going to loose her broker position.

Negative triadic closure: stable broker positions.

Selected findings on the DGG Southern Women data.

Lerner & Lomi (2022). **A dynamic model for the mutual constitution of individuals and events.** *Journal of Complex Networks*.

DGG results: estimated parameters.

Data: 14 events – each compared with all elements from the size-constrained risk set.

Model: closure and prior (shared) activity of order 1, 2, 3.

	Model 1	Model 2	Model 3
individual.activity	−0.44 (0.83)	−3.71 (1.19)**	−4.11 (1.76)*
dyadic.shared.activity		7.32 (1.70)***	8.33 (3.67)*
triadic.shared.activity			−0.68 (2.17)
closure	0.41 (0.17)*	−0.52 (0.26)*	−0.52 (0.26)*
AIC	234.83	208.55	210.45

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

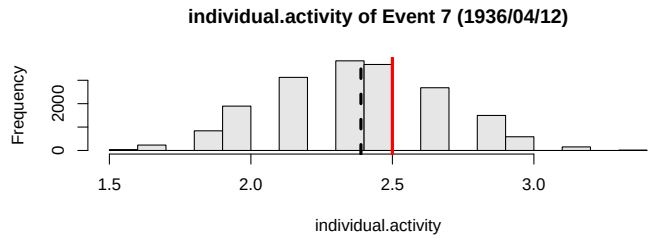
Main findings: (1) interaction is clustered; (2) clusters do not merge over time (stable broker positions).

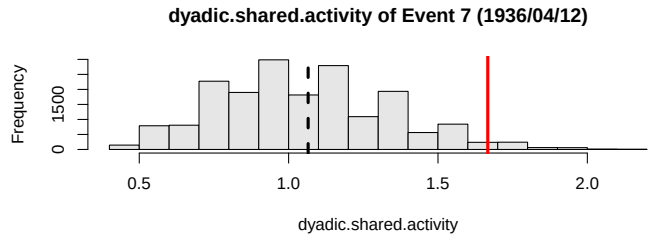
Descriptive quantitative analysis.

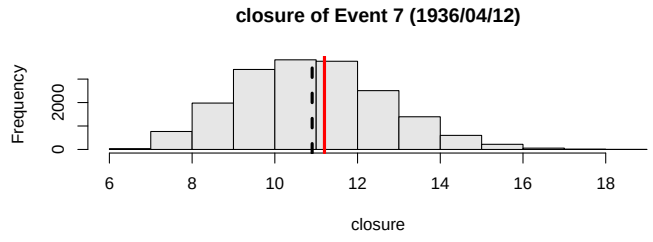
Statistics of observed event in relation to values over all possible events.

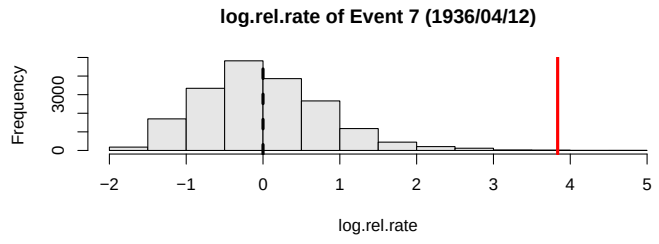
For each statistic and for the predicted log hazard ratio (according to Model 2)

- gray bars: histogram of values over the entire risk set;
- vertical dashed line: mean value;
- vertical red line: value of observed event



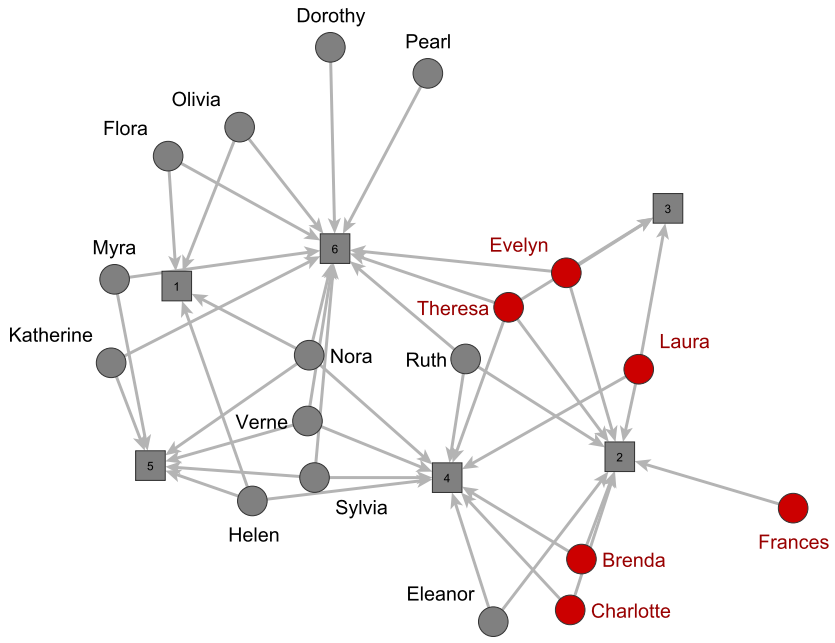


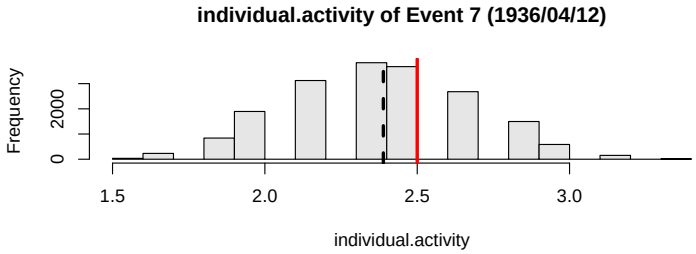


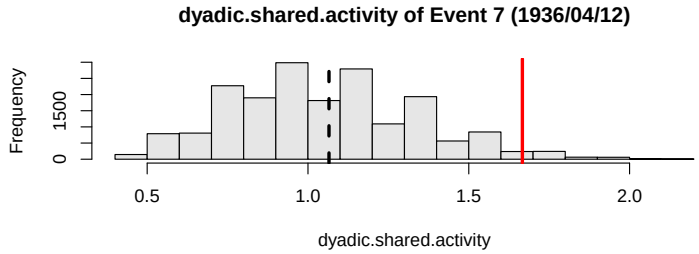


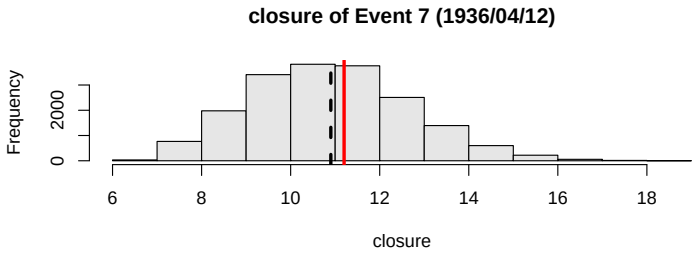
DGG results: discussing Event 7.

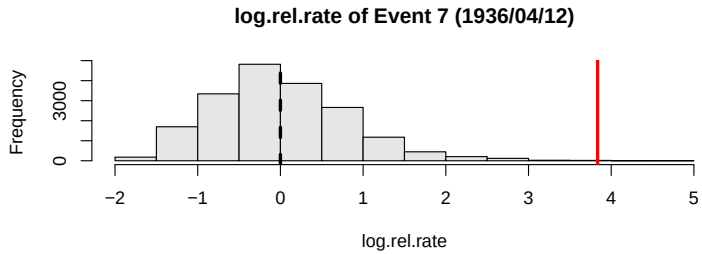
one of the most likely events, according to the model





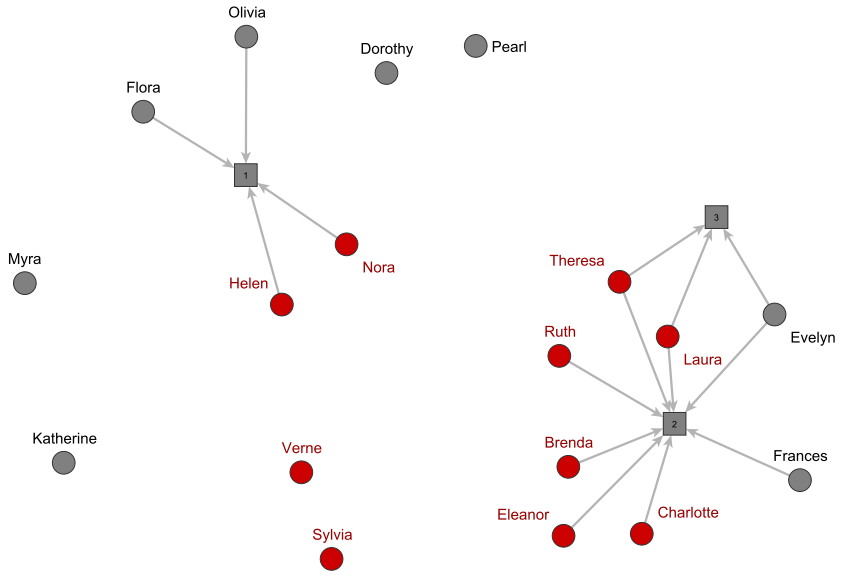


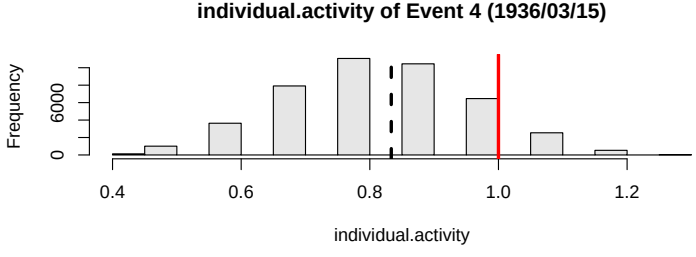


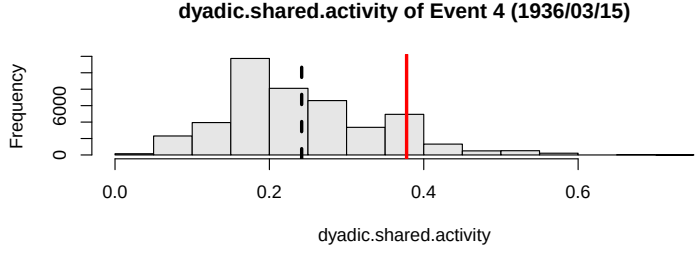


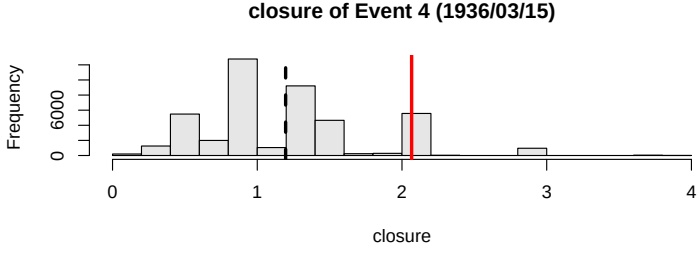
DGG results: discussing Event 4.

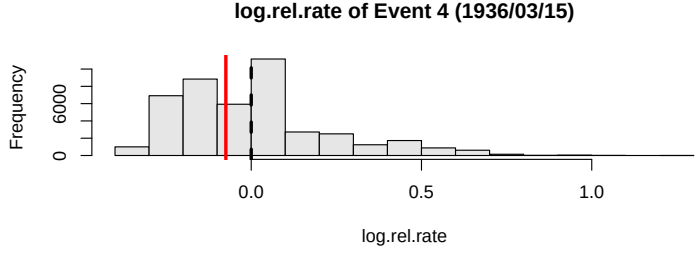
the most unlikely event in the whole sequence, according to the model







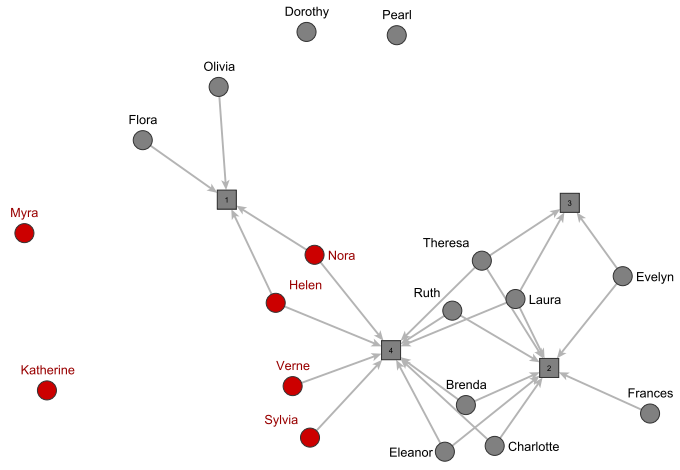




DGG results: discussing Event 5.

the most tricky event to explain

True Event 5



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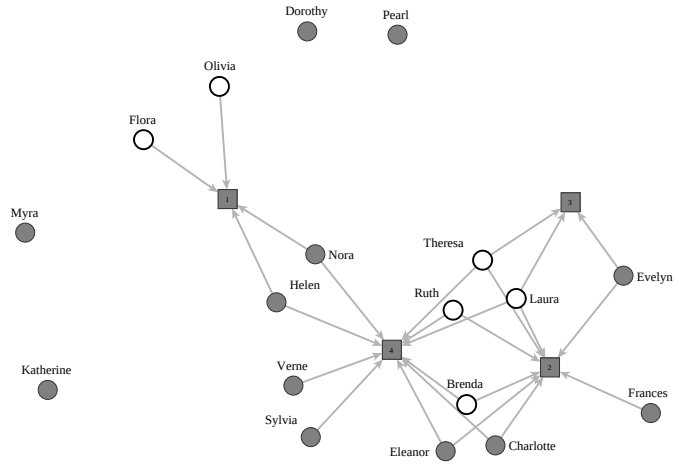

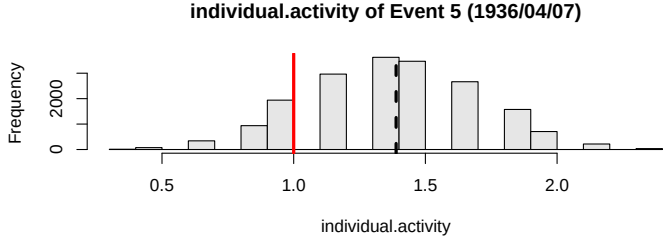

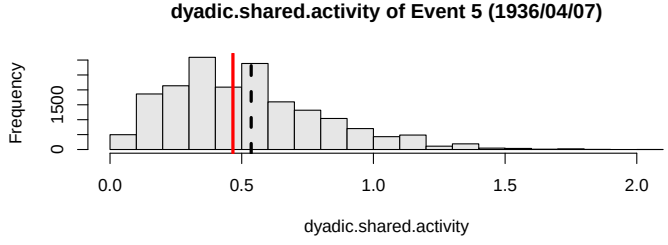

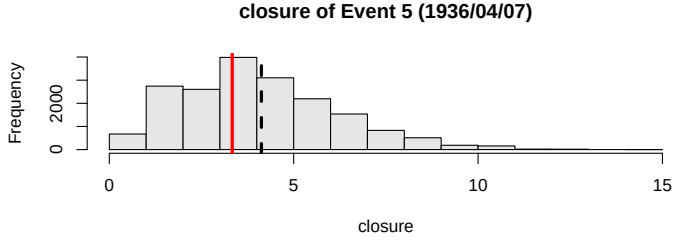

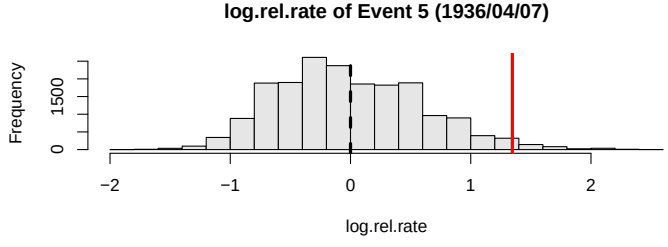

Practical aspects:

what do we have to do to specify and estimate RHEM?

Relational hyperevent models (RHEM).

For every **set of possible event participants** $h \subseteq V$
and point in time t,

RHEM estimate the **rate of events** on h at t as a function of explanatory variables.

The good news: statistical software (free or commercial) has powerful packages for time-to-event / survival analysis.

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However, it does not understand dependencies in hyperevent networks (cannot compute explanatory variables).

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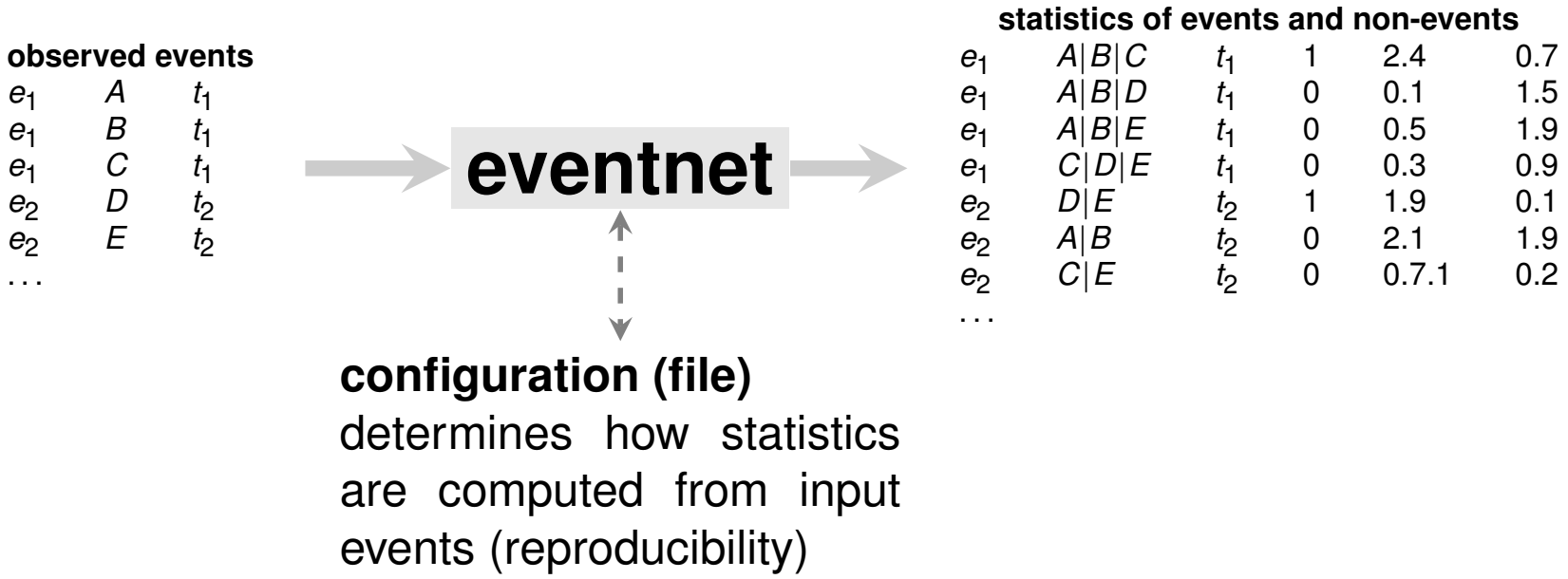
This gap is filled by the **eventnet software**.

Workflow of eventnet.

https://github.com/juergenlerner/eventnet

Computes specified statistics for events and non-events; models can be fitted with standard software (`coxph`, ...).



Configurations can be specified with a graphical user interface (still limited for RHEM) or via a configuration file (XML).

Eventnet configurations (six main parts).

correspond to six tabs in the eventnet GUI

(files) specify input event files (or directories) in CSV format.

(events) specify which column holds which event component (event id, actors, . . .) and whether networks are one-mode or multi-mode.

(time) specify how time is encoded and interpreted.

(attributes) specify network attributes recording past events.

(statistics) specify statistics explaining future events.

(observations) specify risk sets and sampling (if applies).

eventnet demo

Conclusion.

Relational hyperevent models (RHEM) are a general model for time-ordered multi-actor events: meetings, team-work, communication, ...

`https://github.com/juergenlerner/eventnet`