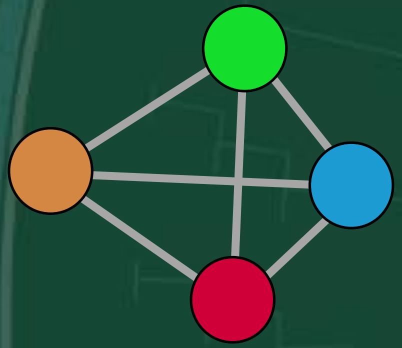
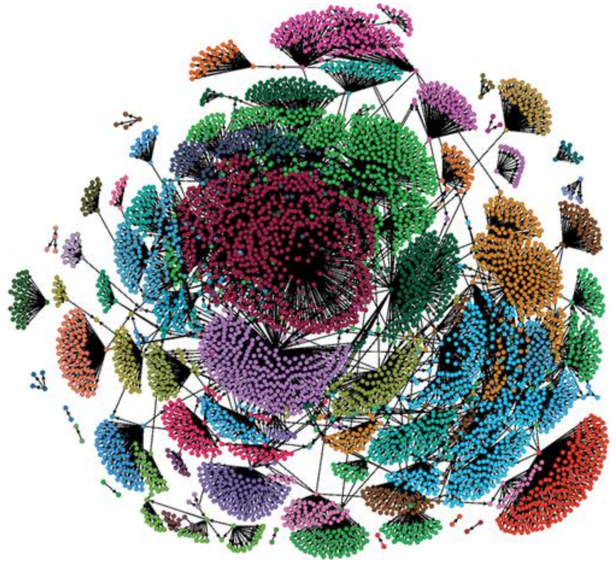
Social network analysis

Hector Marina



Social Networks

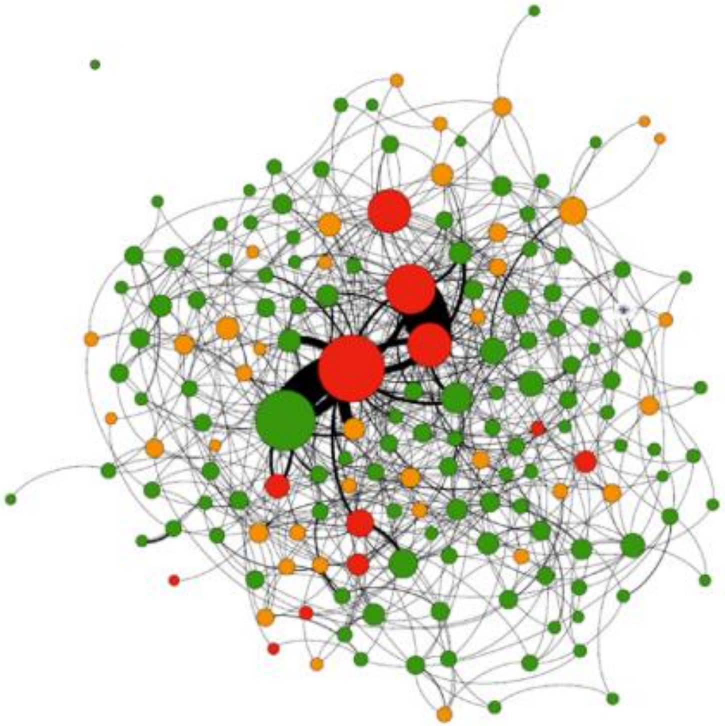
- A **social network** can be constructed from relational data and can be defined as a set of social entities, such as people, groups, and organizations, with some relationships or interactions between them. These networks are usually modelled by graphs, where vertices represent the social entities and edges represent the relationships established between them



(Tabassum et al., 2018)

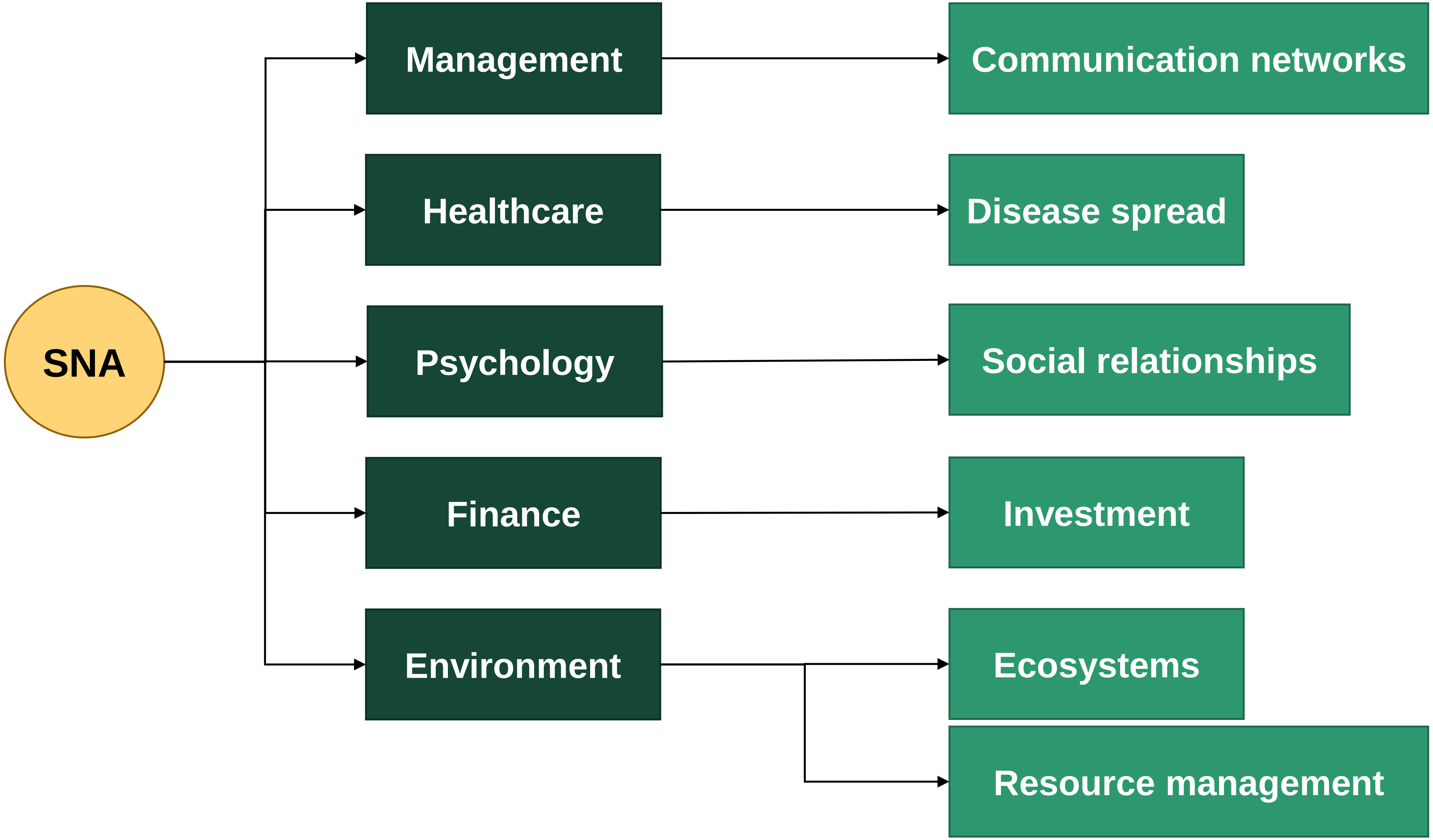
What is SNA?

- **Social network analysis** studies structures of relationships linking individuals and interdependencies in behaviour or attitudes related to configurations of social relations



(Freslon et al., 2019)

SNA applications

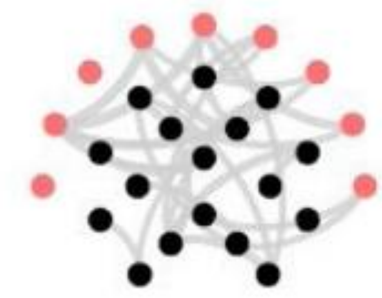


SNA applications in animals

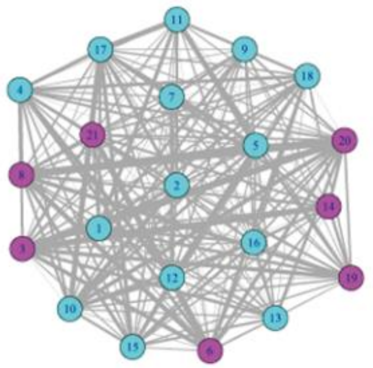
SNA

Behaviour

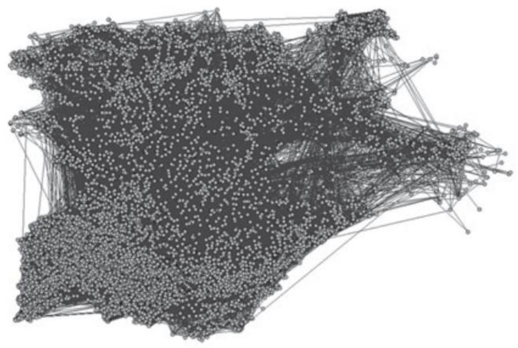
Disease



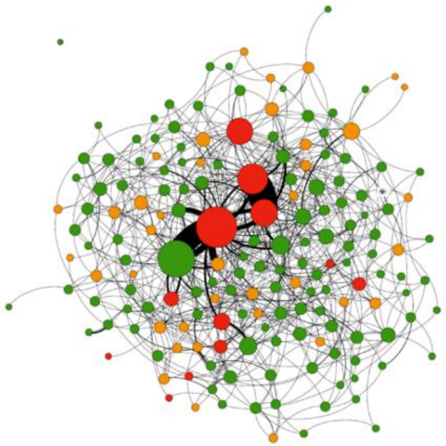
(Rocha et al., 2020)



(Chen et al., 2015)

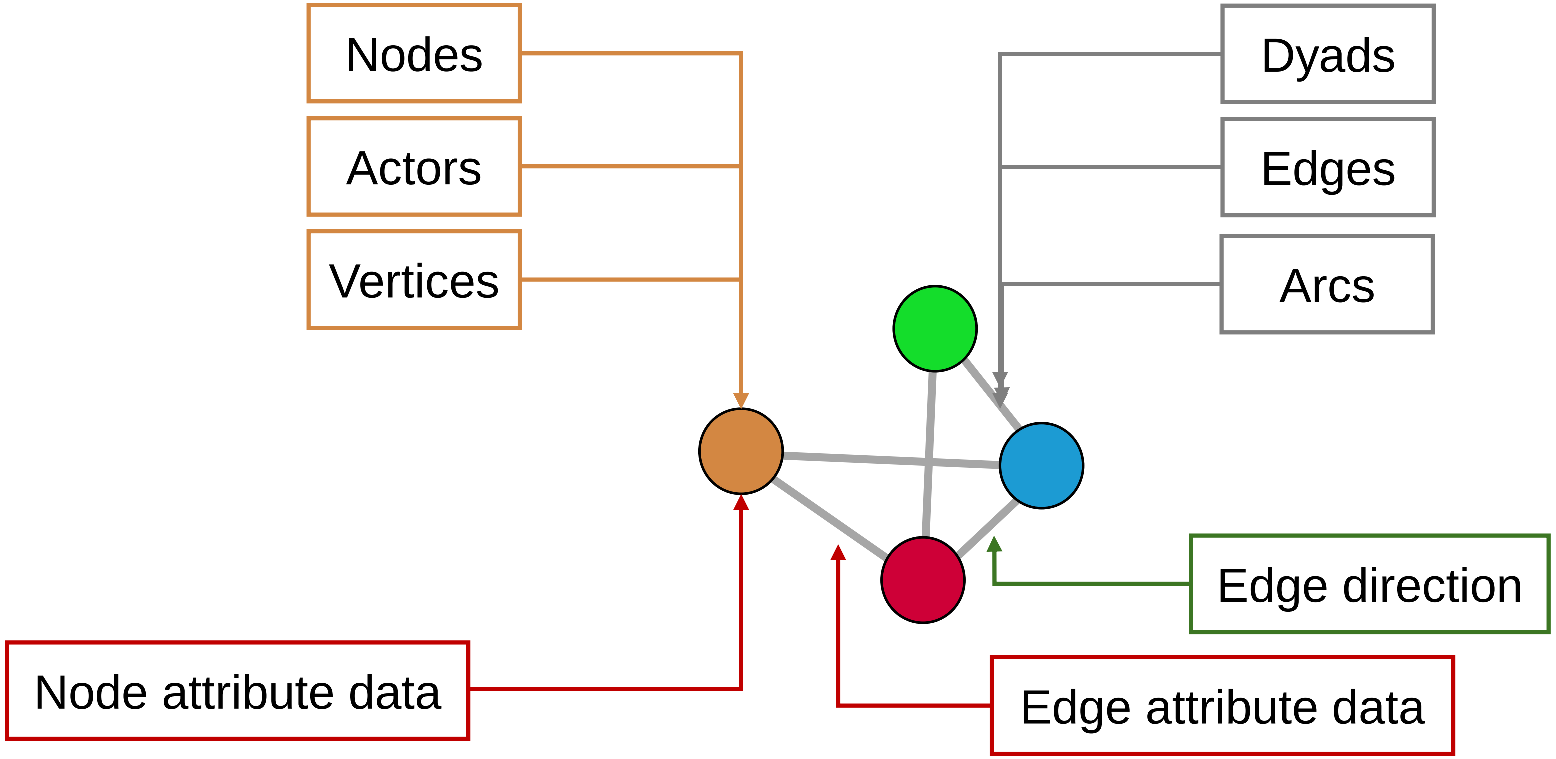


(Martínez-López et al., 2009)



(Freslon et al., 2019)

Part of the networks

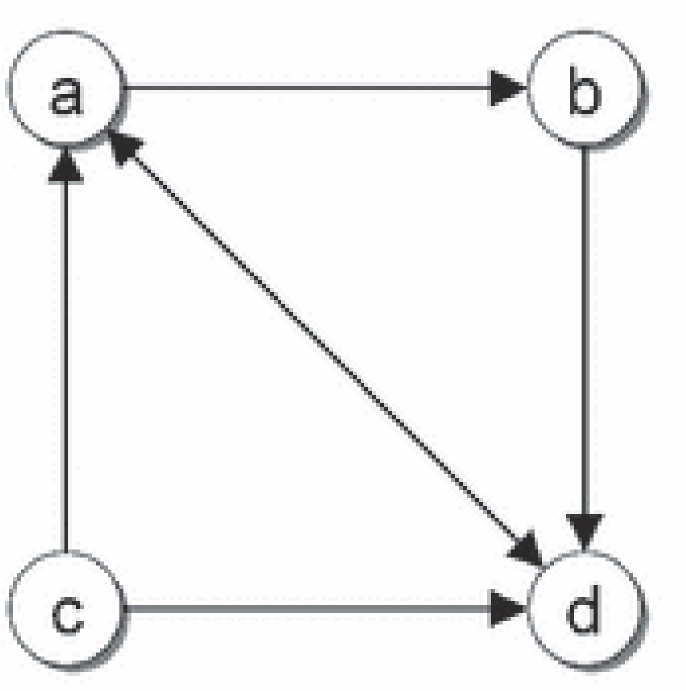


Ways to represent networks

Adjacency matrix

	a	b	c	d
a	0	1	0	1
b	0	0	0	1
c	1	0	0	1
d	1	0	0	0

Graph



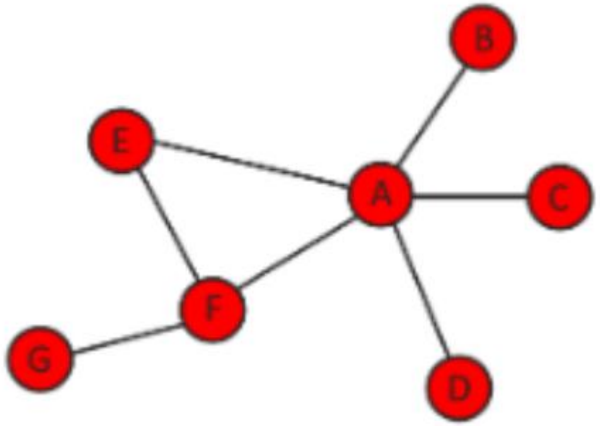
Notation

$$G = \{(a, b), (a, d), (b, d), (c, a), (c, d), (d, a)\}$$

(Martínez-López et al., 2009)

Ways to represent networks

A	B
A	C
A	D
A	E
A	F
E	F
F	G



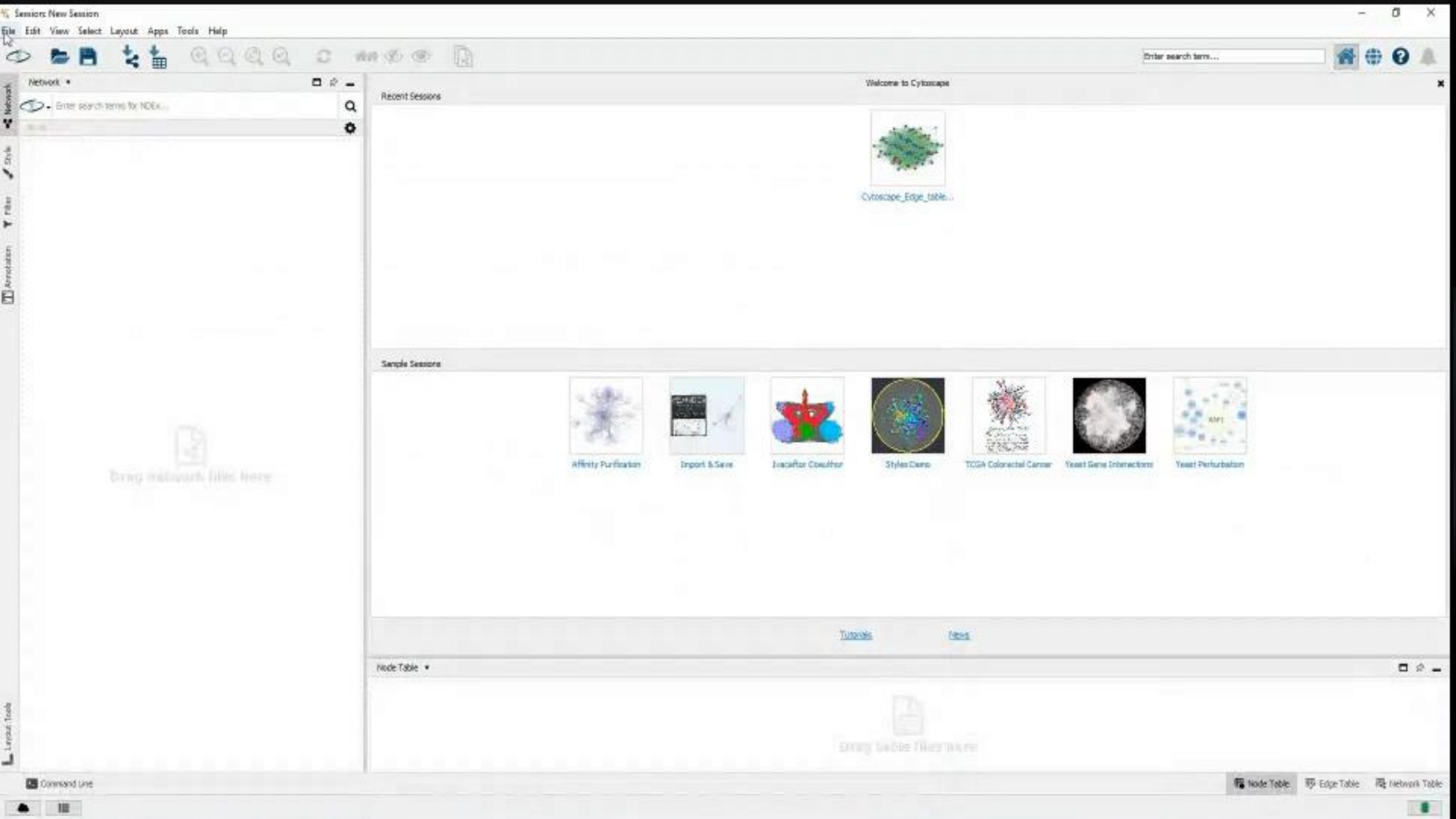
	A	B	C	D	E	F	G
A	0	1	1	1	1	1	0
B	1	0	0	0	0	0	0
C	1	0	0	0	0	0	0
D	1	0	0	0	0	0	0
E	1	0	0	0	0	1	0
F	1	0	0	0	1	0	1
G	0	0	0	0	0	1	0

Network analysis software

Cytoscape

sna igraph network

networkX igraph


Session: New Session
File Edit View Select Layout Apps Tools Help
Enter search term...
Network
Enter search terms for NDEx...
Drag network files here
Welcome to Cytoscape
Recent Sessions
Cytoscape_Edge_table...
Sample Sessions
Affinity Purification
Import & Save
Ivacaftor Coauthor
Styles Demo
TCGA Colorectal Cancer
Yeast Gene Interactions
Yeast Perturbation
Tutorials
News
Node Table
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Command Line
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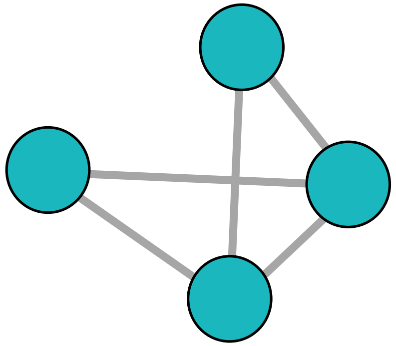
Edge Table
Network Table

Ways to analyze the information

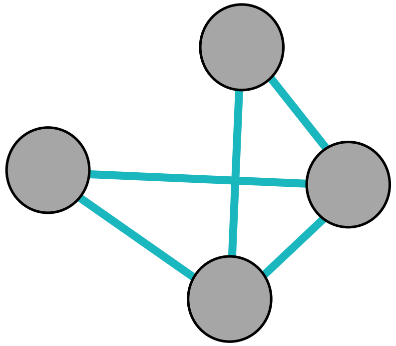
individual- level models

focuses on an **individual-level outcome, network data are used to define explanatory variables**



relational-level models

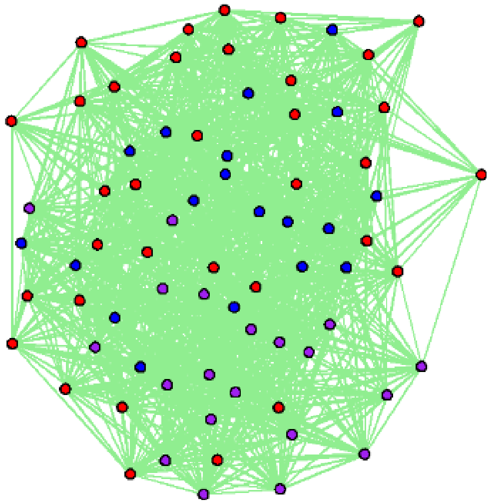
focuses on an **dyad-level,** analyse the **relationship** rather than a characteristic of particular individuals



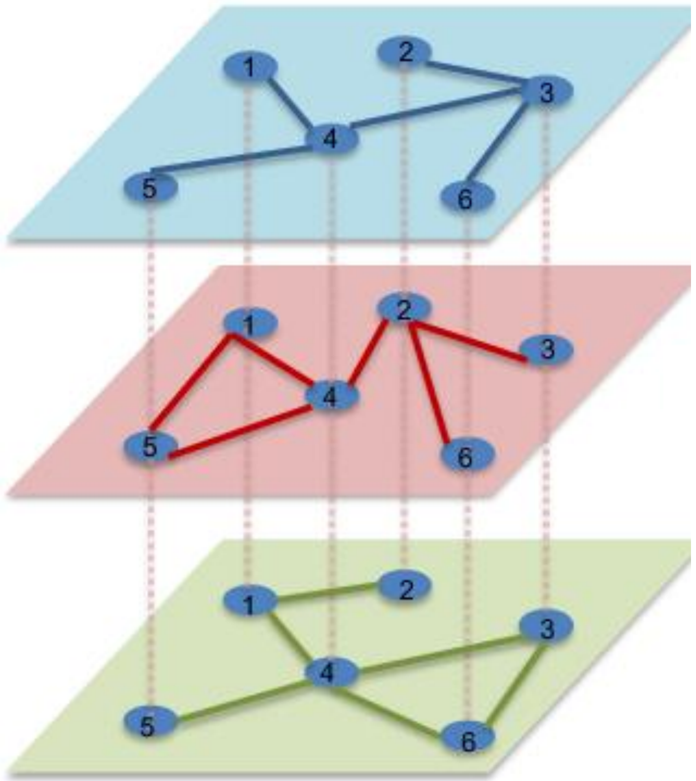
(O´Malley et al., 2008)

Network dimensions

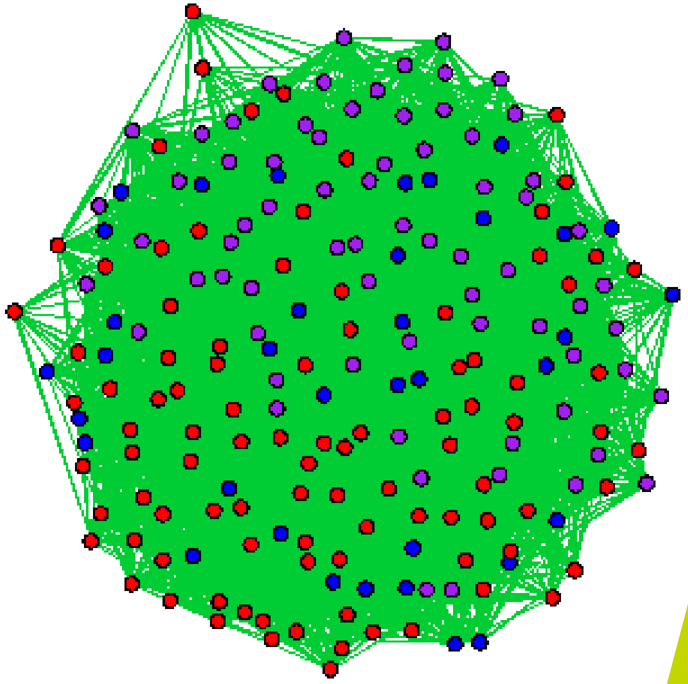
Unidimensional data



Multidimensional data



Longitudinal data



Time

Descriptive properties of networks

y_{ij}

$$
\begin{array}{c c}
 & \begin{array}{ccccccccc} & j & & & & & & & \end{array} \\
i & \left[\begin{array}{ccccccccc}
0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\
1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 1 \\
0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\
1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \\
1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0
\end{array}\right]
\end{array}
$$

- ***Y*** is the adjacency matrix
- $\mathbf{y_{ij}}$: relationship from actor *i* to actor *j*
- Binary-valued
- Self-relations are usually undefined

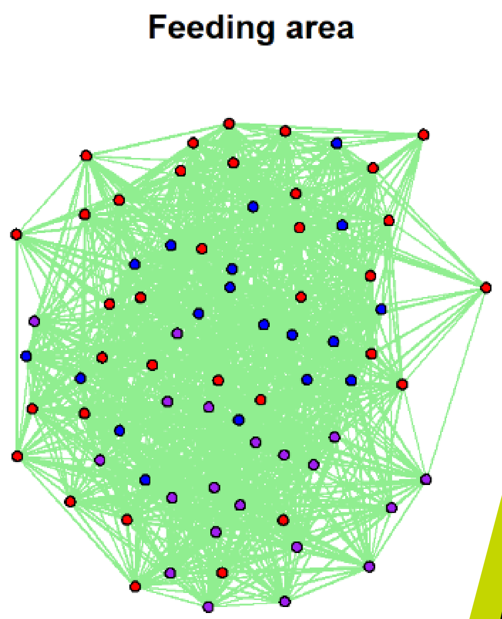
(O´Malley et al., 2008)

Descriptive properties of networks

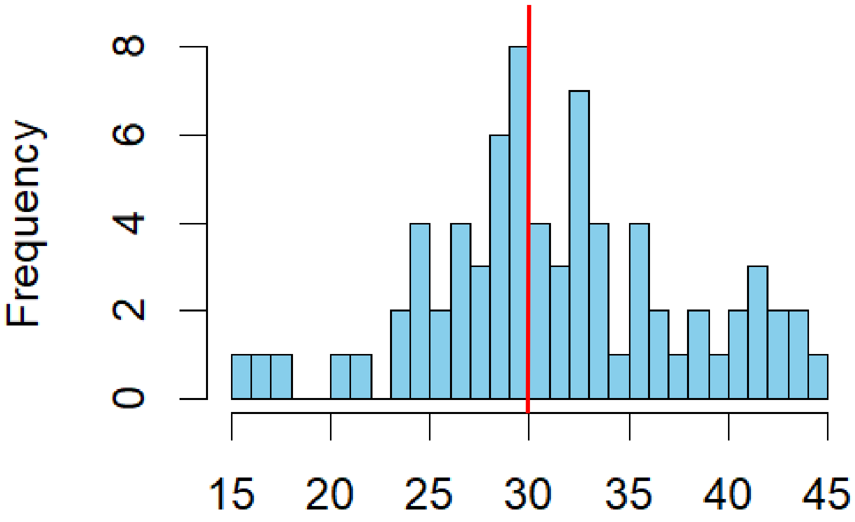
1) Size and density of the network

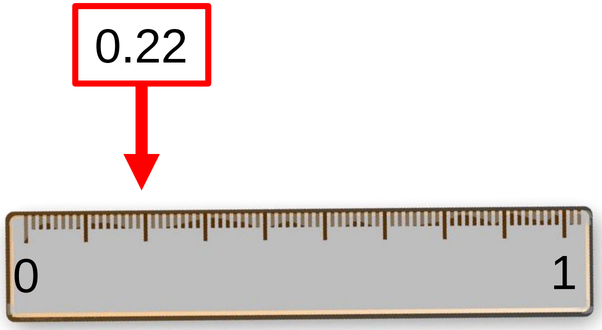
$$\boxed{(L = \sum_{i,j} y_{ij})}$$

$$\boxed{L/(N(N-1))}$$



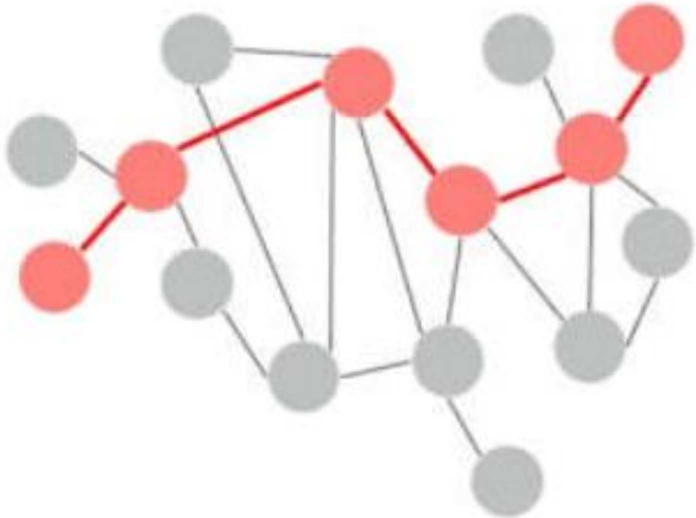
2) Degree and the degree distribution

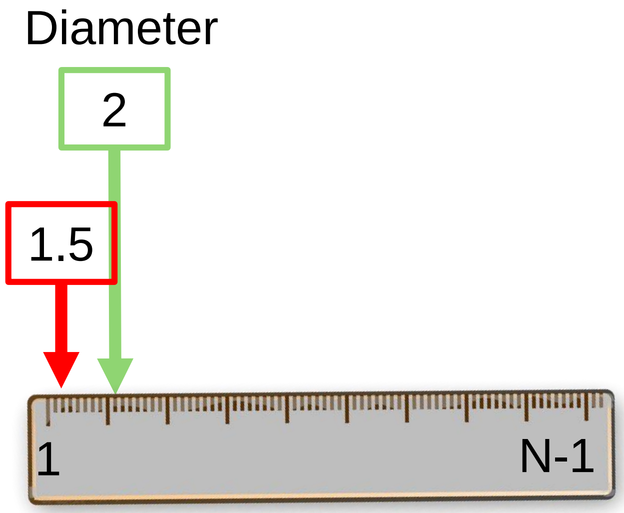




Descriptive properties of networks

3) Geodesic distance:



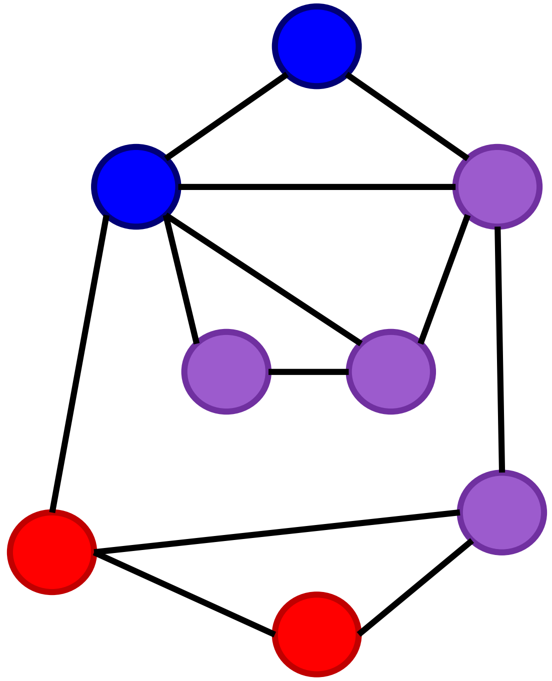


Descriptive properties of networks

4) Centrality parameters:

Degree:

- The simplest is based on an actor’s degree
- Reflects an actor’s level of network activity or involvement



Descriptive properties of networks

4) Centrality parameters:

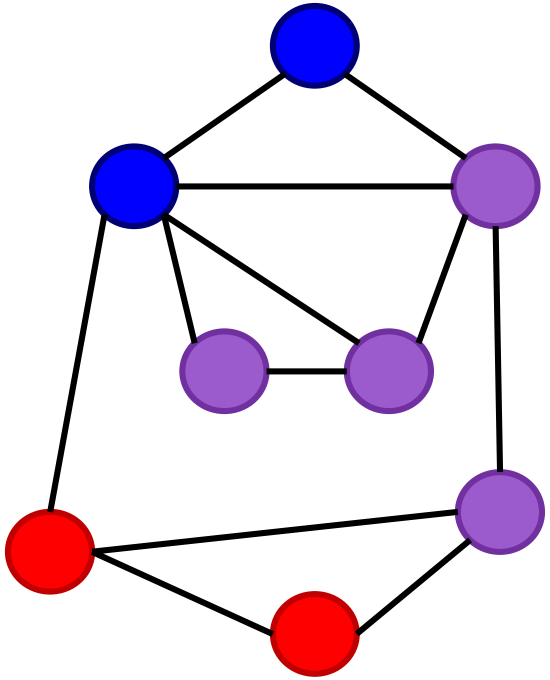
Betweenness:

- Number of times a node acts as a bridge along the shortest path between two other nodes

Shortest path from s->t
that cross through v

$$g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

Shortest path from s->t



Descriptive properties of networks

4) Centrality parameters:

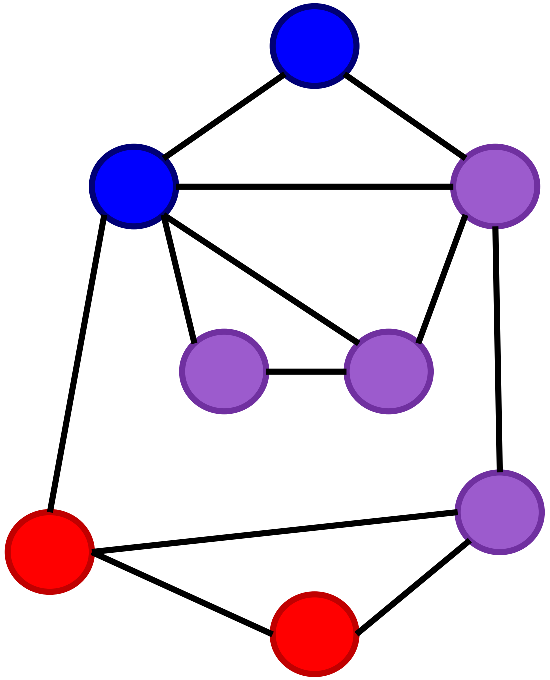
Closeness:

- Sum of the length of the shortest paths between the node and all other nodes in the graph

$$C(v) = \frac{N-1}{\sum_u d(u,v)}.$$

Number of nodes in the graph

Distance between vertices u and v

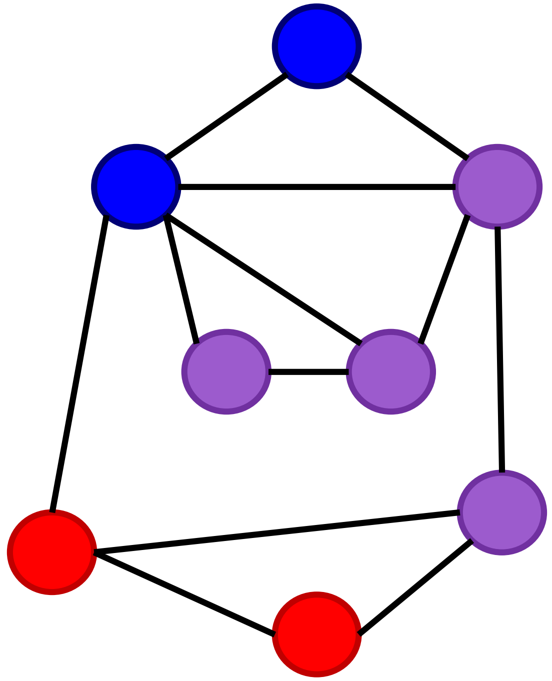


Descriptive properties of networks

4) Centrality parameters:

Eigenvector:

- Principal eigenvector using the adjacency matrix
- Measures a node’s importance while giving consideration to the importance of its neighbors

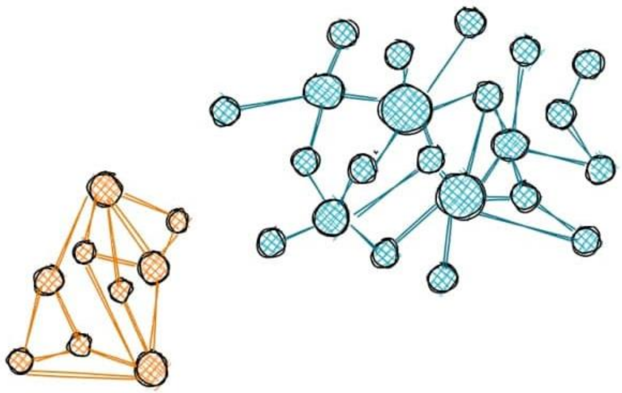


Descriptive properties of networks

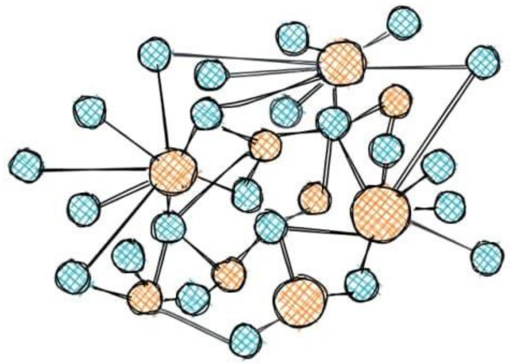
5) Homophily:

- Represents the propensity of individuals to interact with others of similar characteristics

Homophily

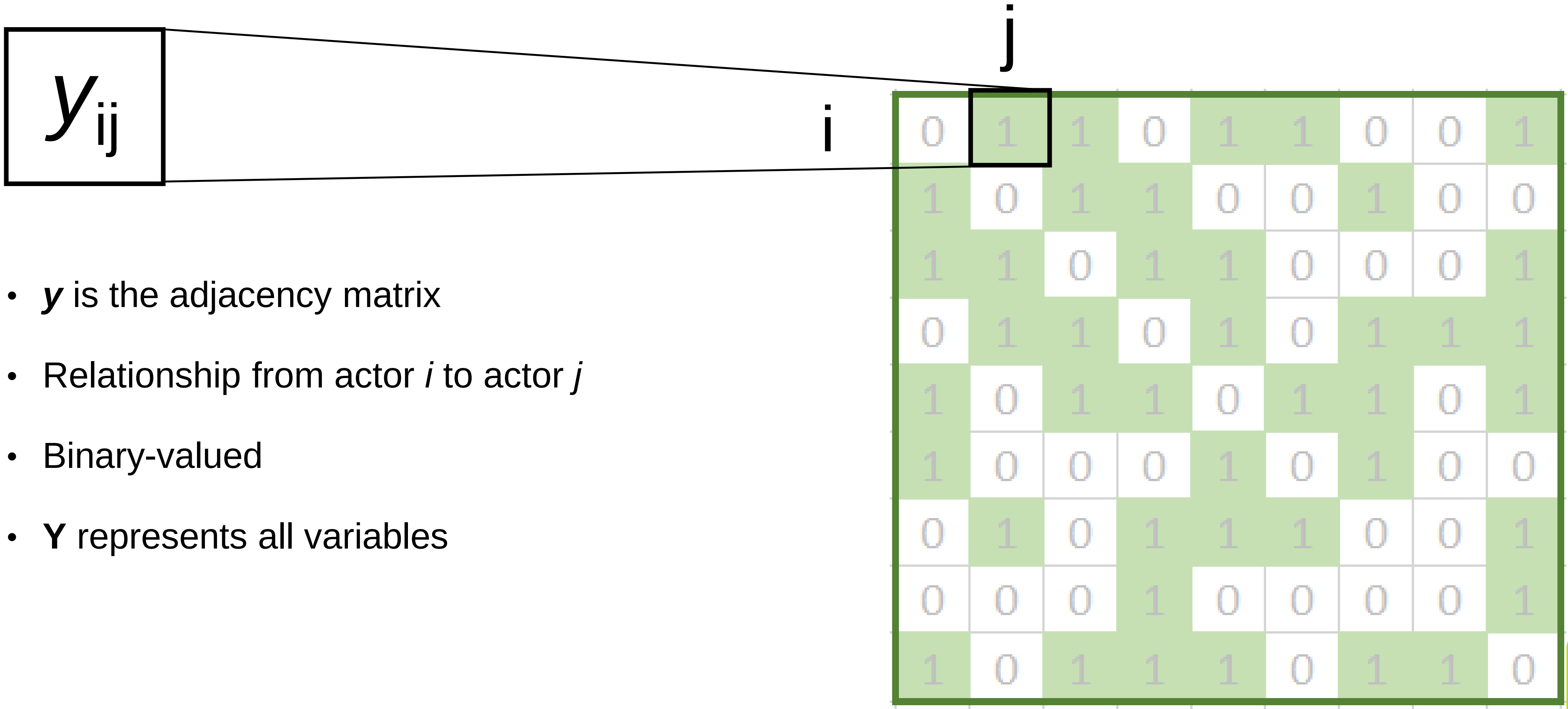


Heterophily



Relational or dyad-level models

- Exponential random graph models (ERGMs):

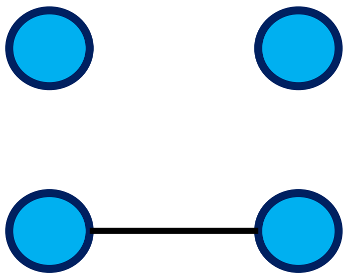


- ***y*** is the adjacency matrix
- Relationship from actor *i* to actor *j*
- Binary-valued
- **Y** represents all variables

Relational or dyad-level models

- Exponential random graph models (ERGMs):

y_{ij}



Absence

Presence

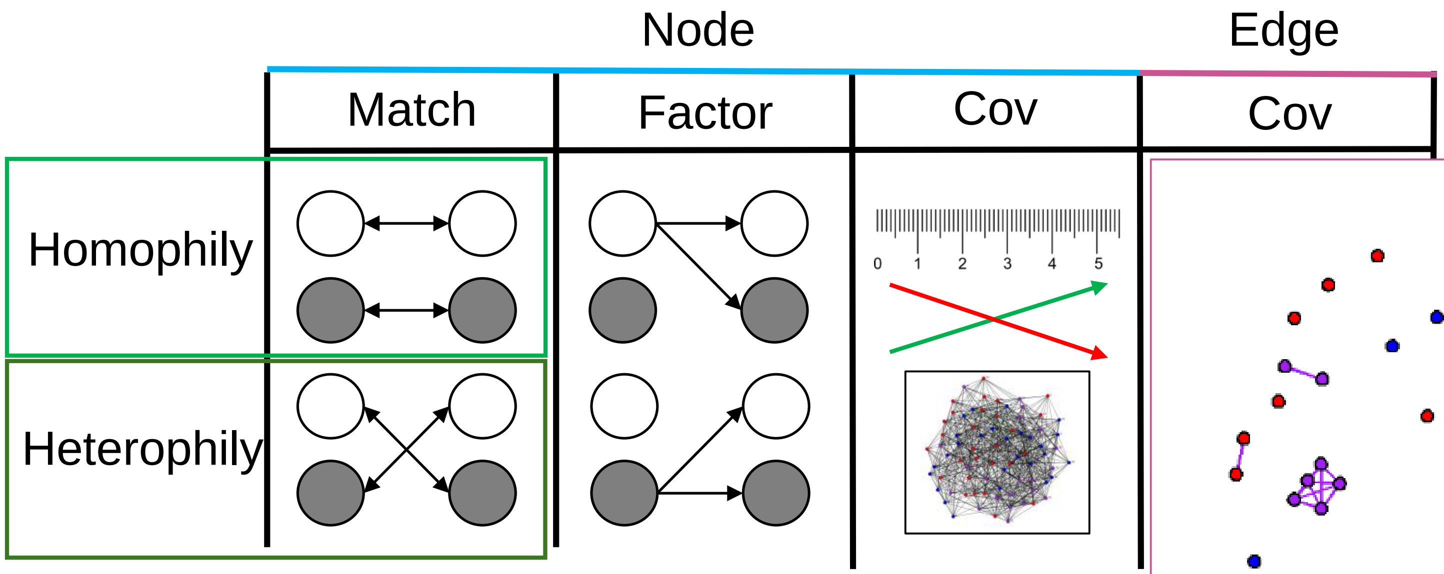
Intercept

$$\operatorname{logit}P\left(Y_{ij}=1\right)=\mu+\beta x_{ij}$$

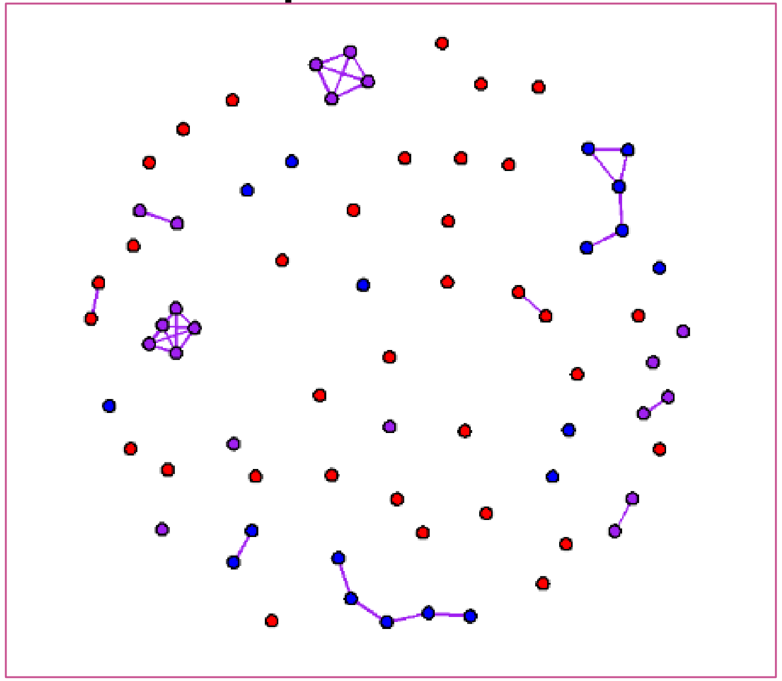
Logistic regression

Covariable

Relational or dyad-level models



- **Born 7 days apart**

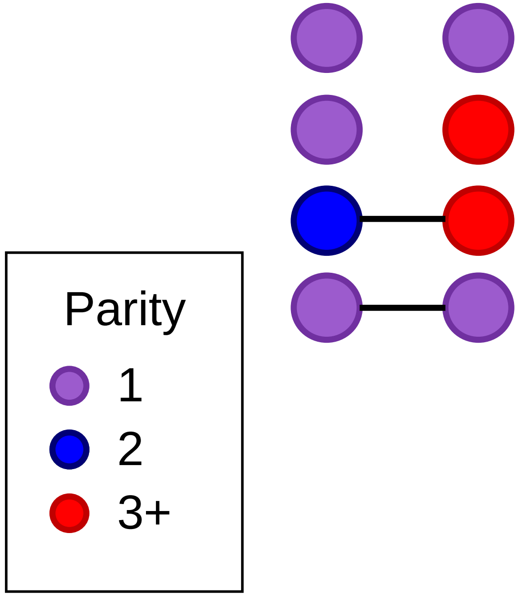


Parity [1, 2 or 3+]
Days in milk [Early, Mid or Late]
Breed [Holstein, Red Dairy Cattle or Crossbred]

Time spent per Area

Relational or dyad-level models

- Exponential random graph models (ERGMs):



	Parity		TimeInArea	AGEnet
	Match	Factor	Cov	Cov
$Y_{ij} = 0$	1	0	0.22+0.43	1
$Y_{ik} = 0$	0	2	0.22+0.33	0
$Y_{jk} = 1$	0	3	0.56+0.33	0
$Y_{im} = 1$	1	0	0.22+0.13	0

Social interactions

Essential feature of cattle behavior

Meaningful social relationships

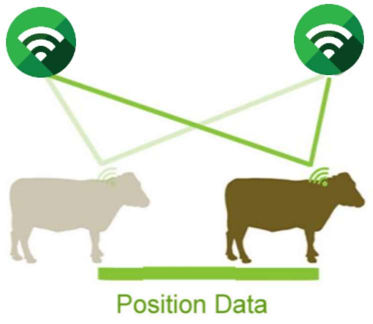
Social interactions

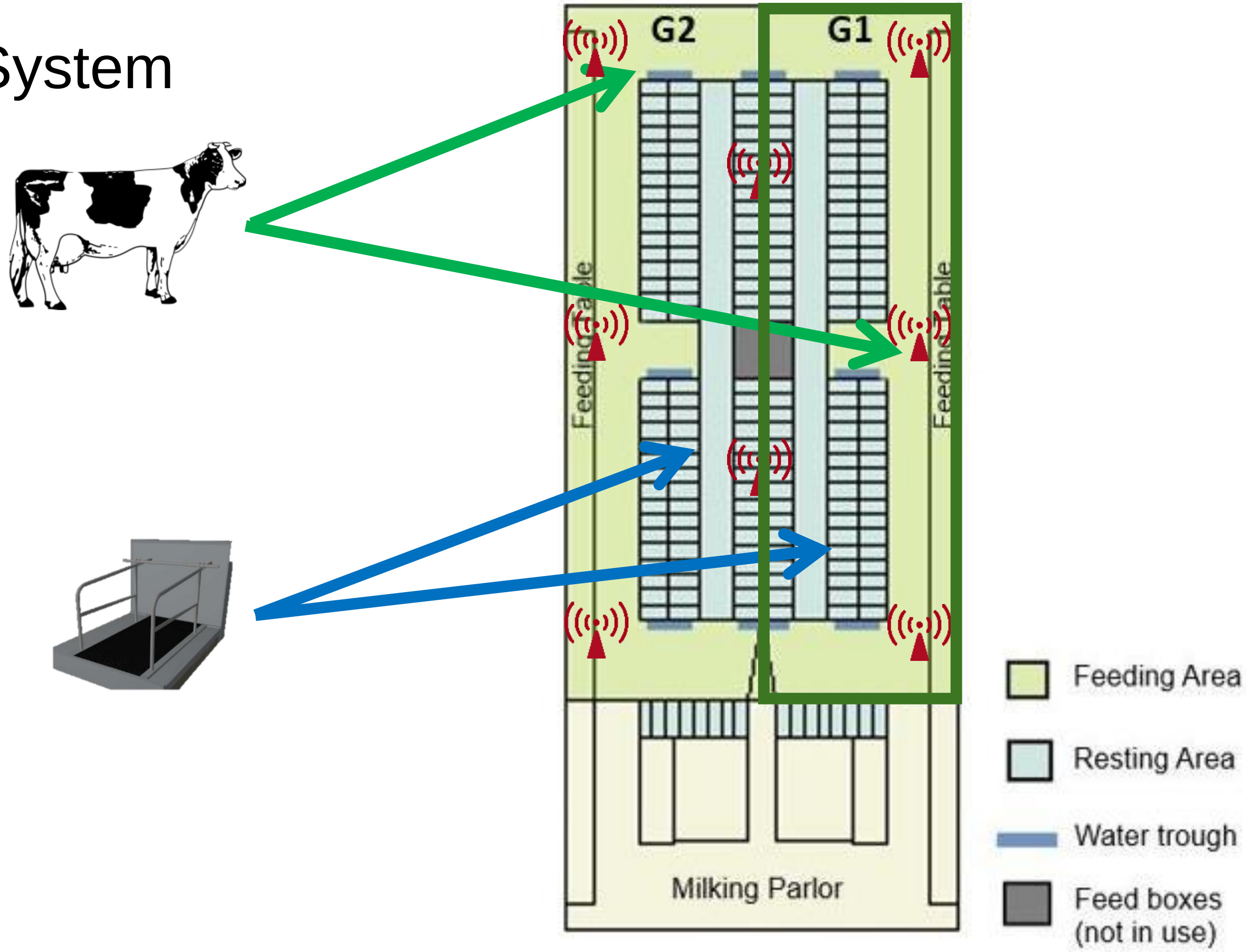
Ultra-Wide Band technology

- Collecting positions of all cows every second
- Spatial interactions
- Real time information

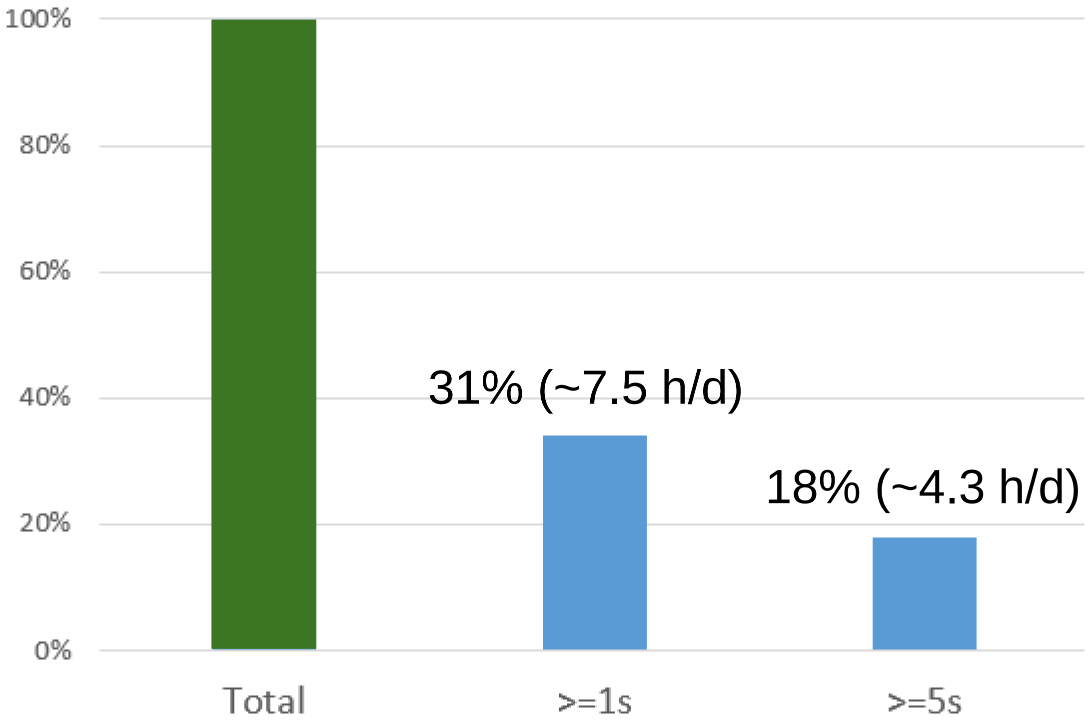
Spatial interactions

Real-time Location System

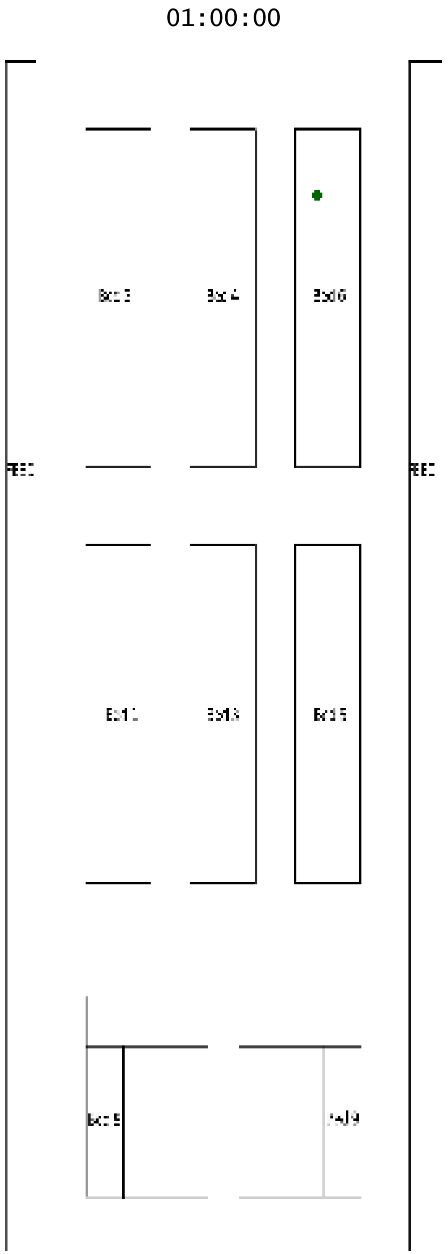




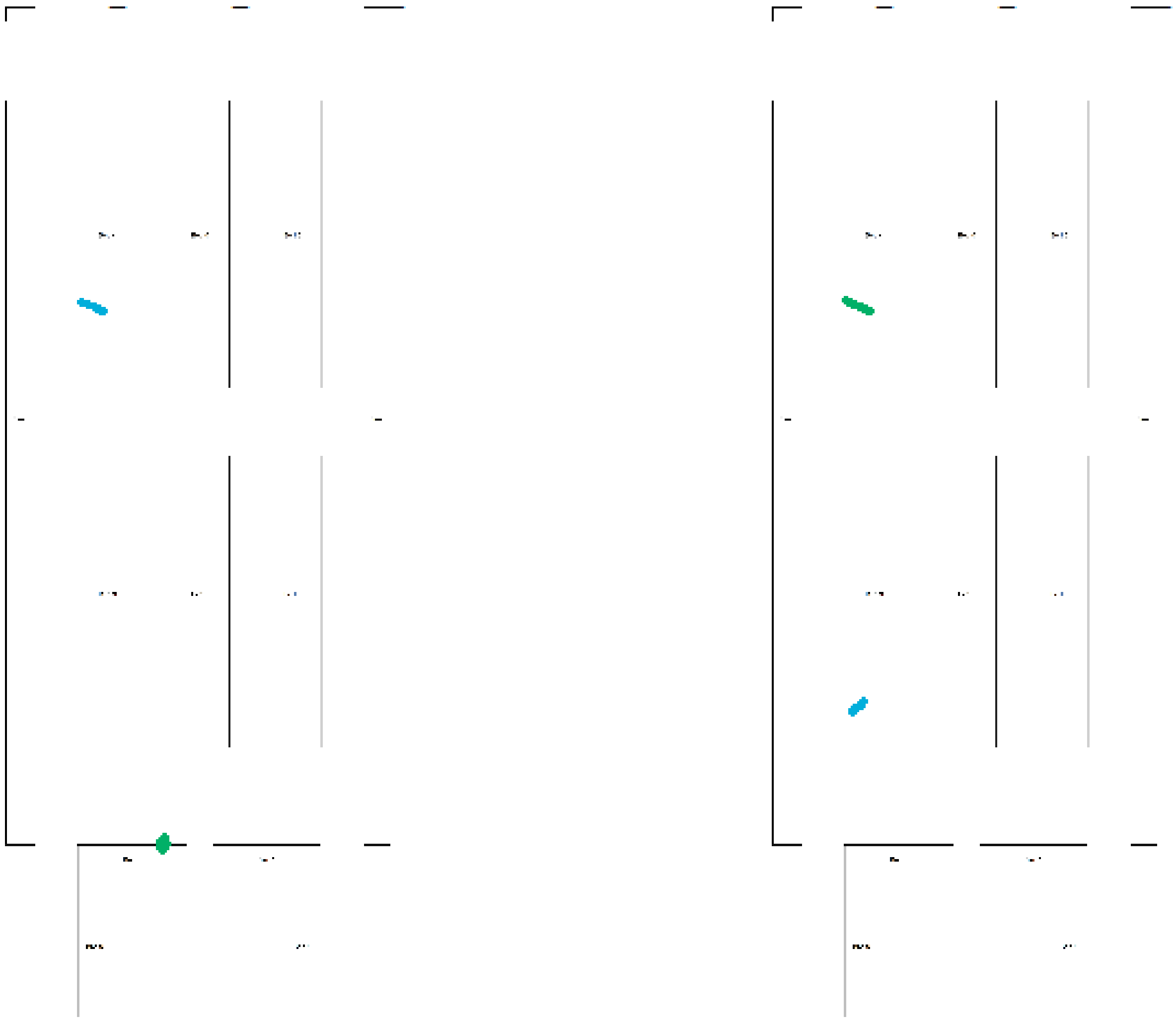
Interpolation



(Ren et al., 2021)



Spatial contacts



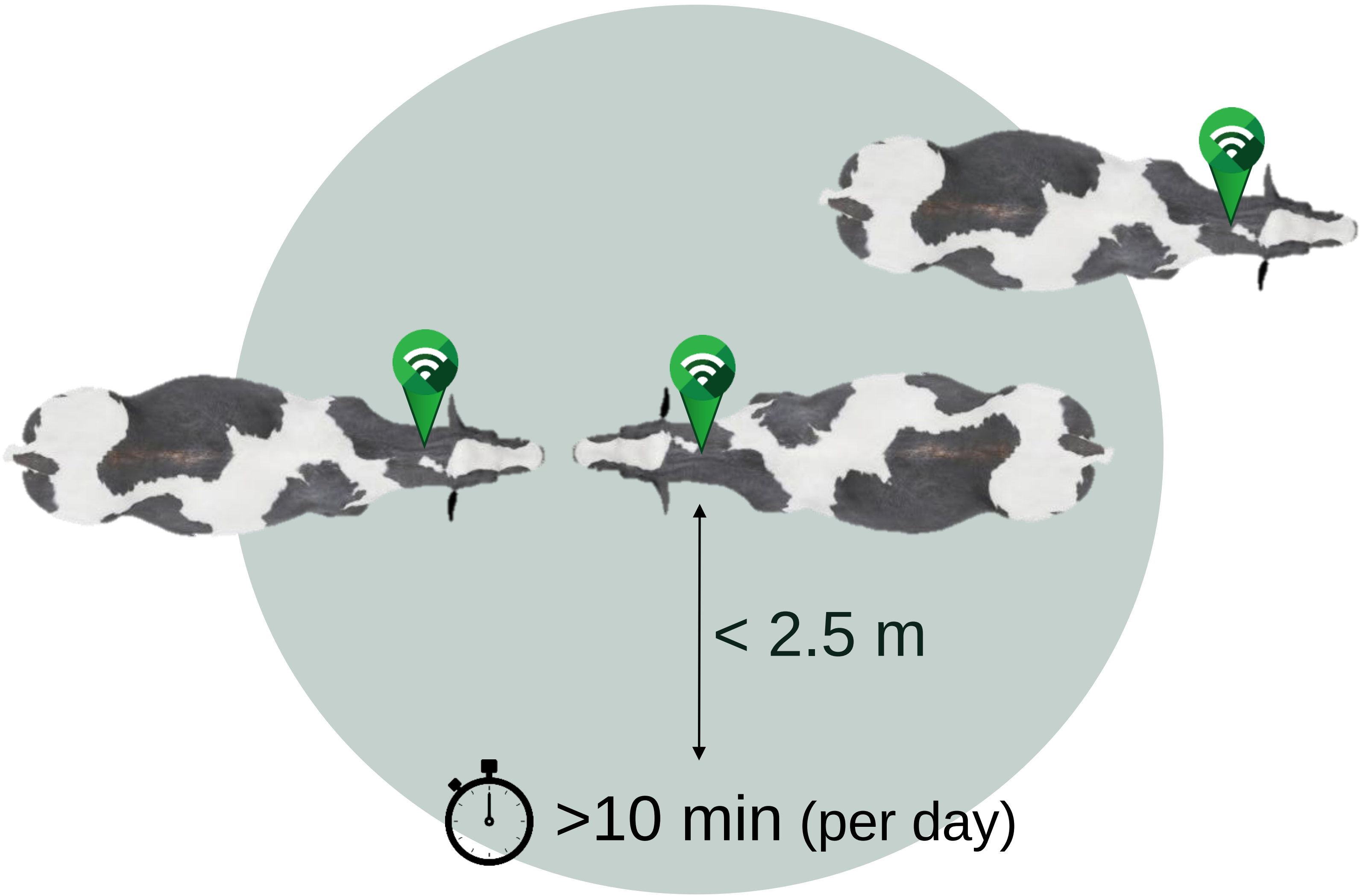
Cow: 1

Cow: 2

Spatial interaction

Spatial contacts

What was consider as social contact?

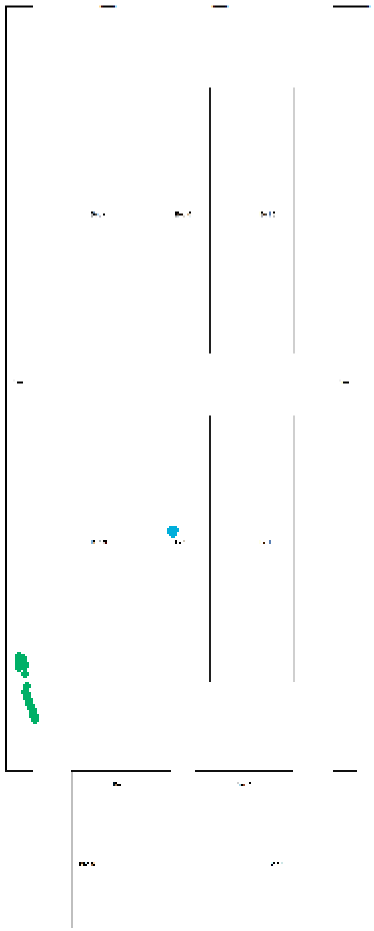


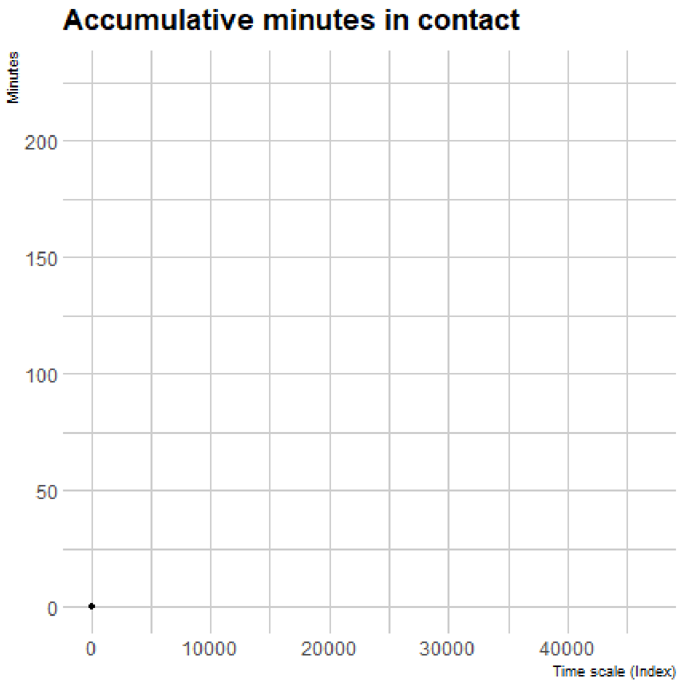
Spatial contacts

Cow: 1

Cow: 2

Spatial interaction





Spatial contacts

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

Absence

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

Presence


hands
on

Recommended literature

1. O'Malley, A.J., and P. V. Marsden. 2008. The Analysis of Social Networks. Health Serv. Outcomes Res. Methodol. 8:222. doi: https://doi.org/10.1007/S10742-008-0041-Z
2. de Freslon, I., Martínez-López, B., Belkhiria, J., Strappini, A., Monti, G., 2019. Use of social network analysis to improve the understanding of social behaviour in dairy cattle and its impact on disease transmission. Appl. Anim. Behav. Sci. 213, 47–54. https://doi.org/10.1016/J.APPLANIM.2019.01.006
3. Tabassum, S, Pereira, FSF, Fernandes, S, Gama, J. Social network analysis: An overview. WIREs Data Mining Knowl Discov. 2018; 8:e1256. https://doi.org/10.1002/widm.1256
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5. Chen, S., Ilany, A., White, B.J., Sanderson, M.W., Lanzas, C., 2015. Spatial-Temporal Dynamics of High-Resolution Animal Networks: What Can We Learn from Domestic Animals? PLoS One 10, e0129253. https://doi.org/10.1371/JOURNAL.PONE.0129253
6. Rocha, L.E.C., Terenius, O., Veissier, I., Meunier, B., Nielsen, P.P., 2020. Persistence of sociality in group dynamics of dairy cattle. Appl. Anim. Behav. Sci. 223, 104921. https://doi.org/10.1016/J.APPLANIM.2019.104921

Publications