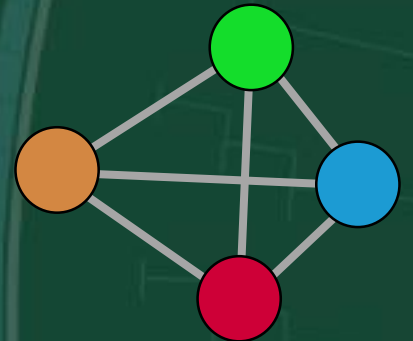
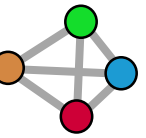


Social network analysis

Hector Marina



Cow Social Interaction: Disease Transmission



Social interactions



Essential feature of
cattle behavior

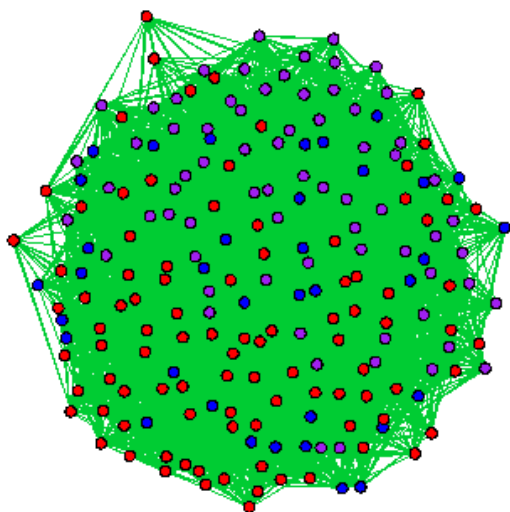
Meaningful social
relationships

Ultra-Wide Band technology



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

Social networks



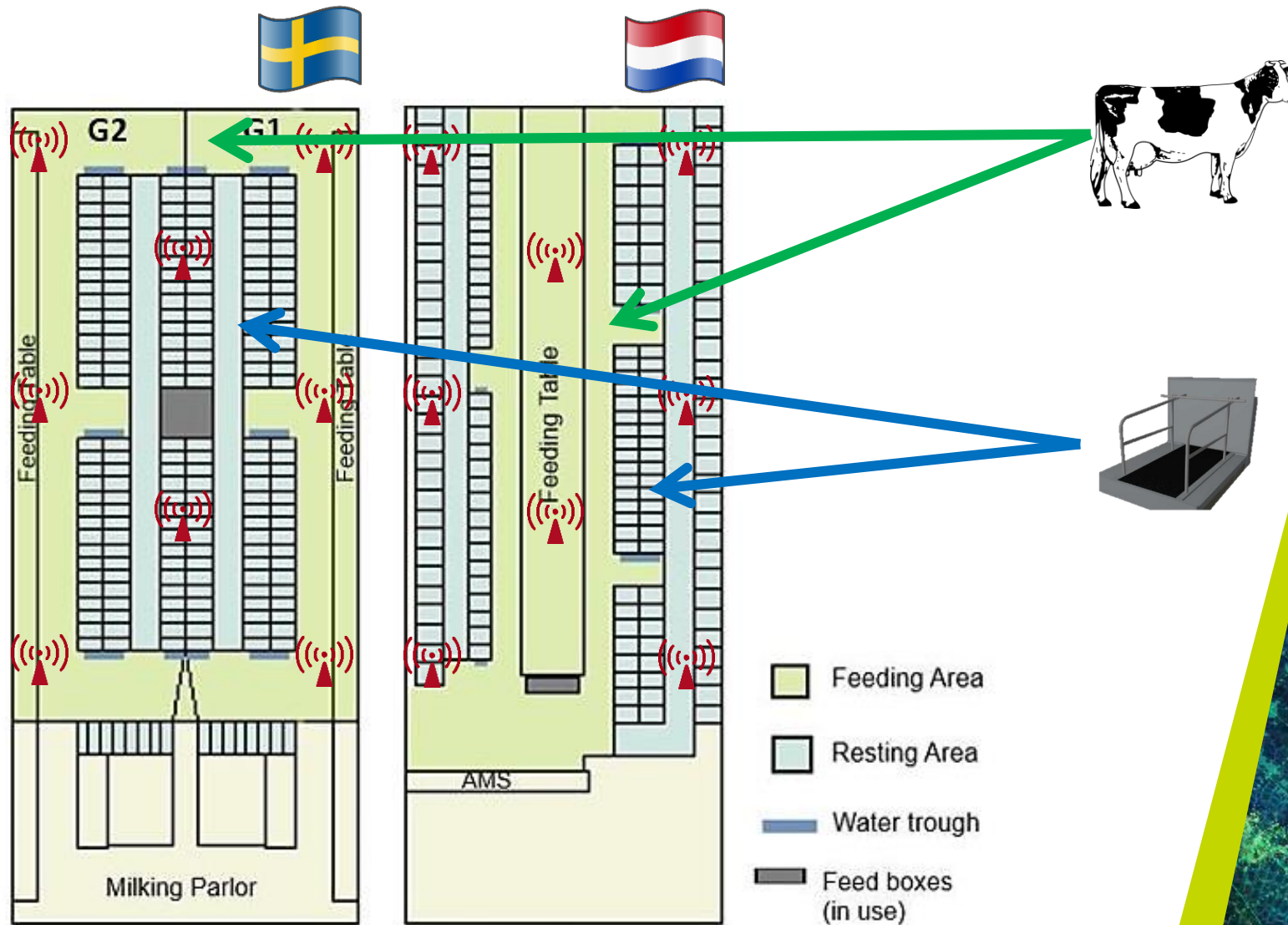
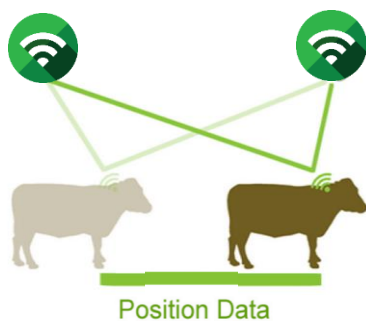
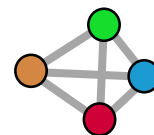
- Dynamics

- stERGM

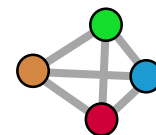
Separable Temporal








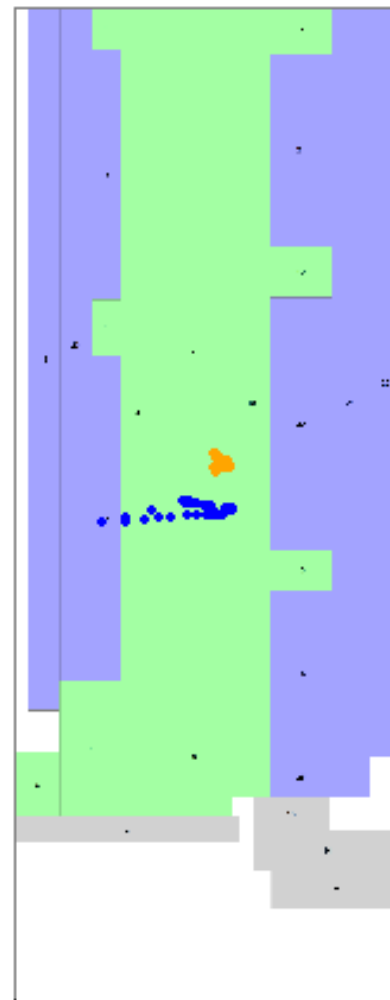
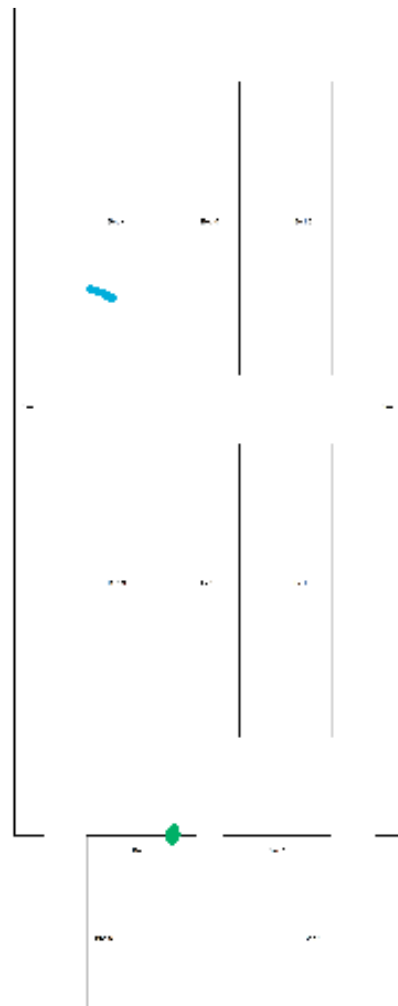
Spatial interactions



Spatial contacts

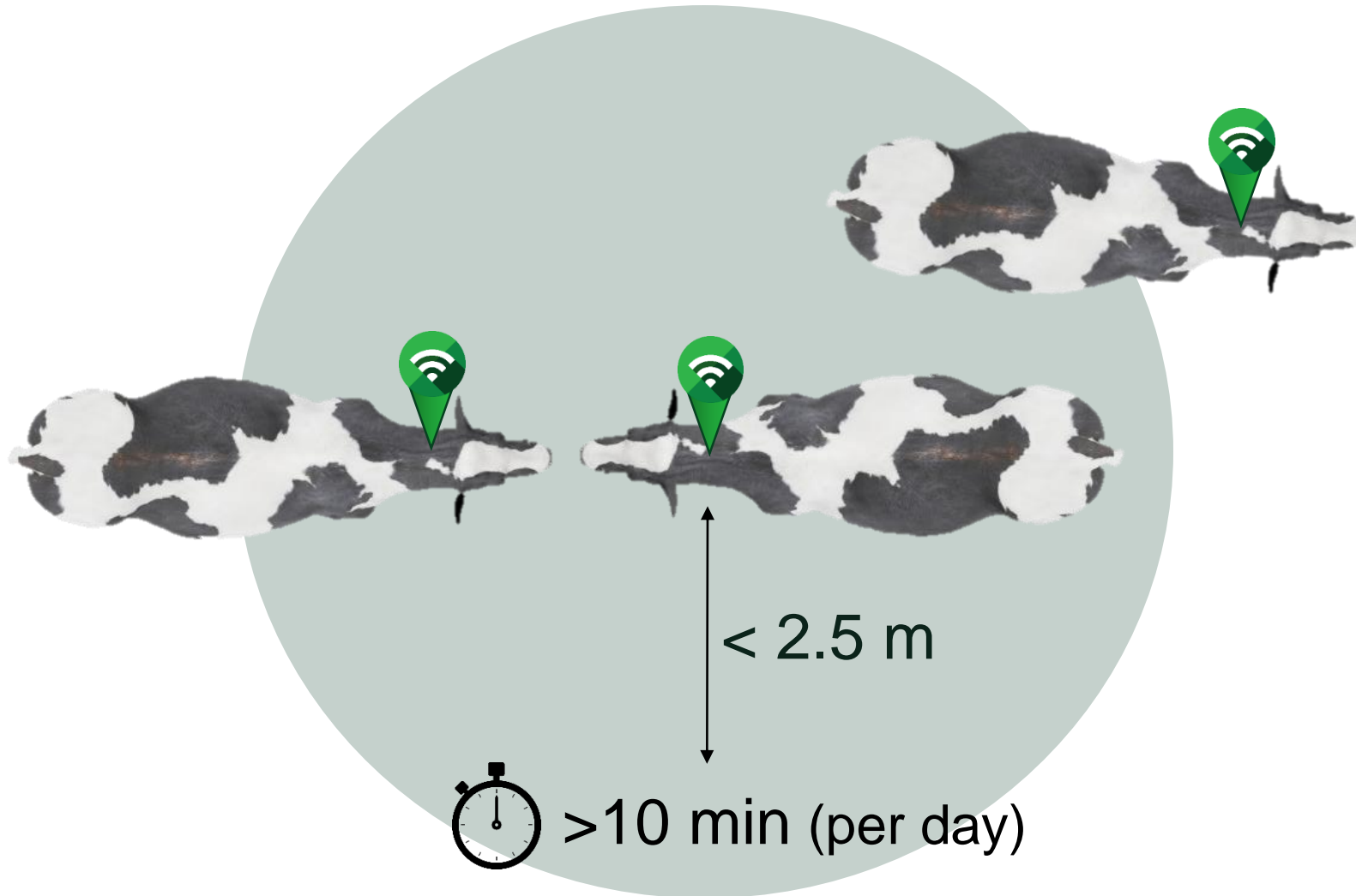


-  Cow: 1
-  Cow: 2
-  Cow: 3
-  Cow: 4
-  Spatial interaction

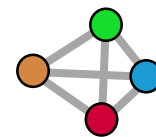


Spatial contacts

What was consider as social contact?

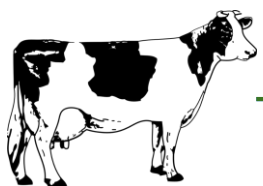


Spatial contacts



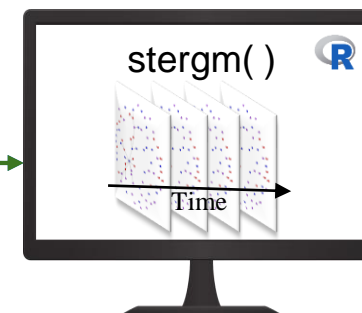
14 consecutive days:

- 2020-10-16
- 2020-10-29



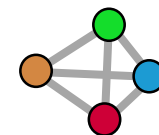
Information available:

- Parity
- Lactation stage
- Claw health
- Breed
- Early life experience
- Dried off experience
- Pedigree

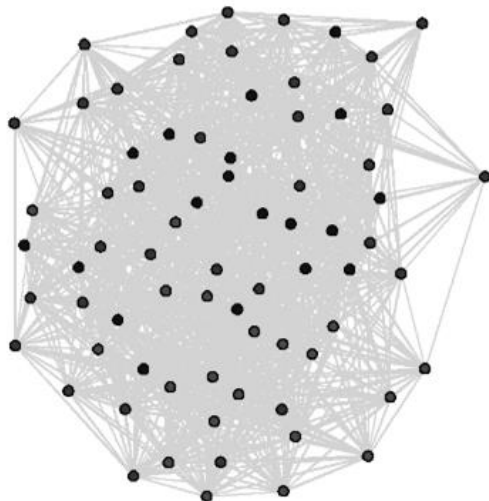


Separate temporal exponential random graph models (STERGM)

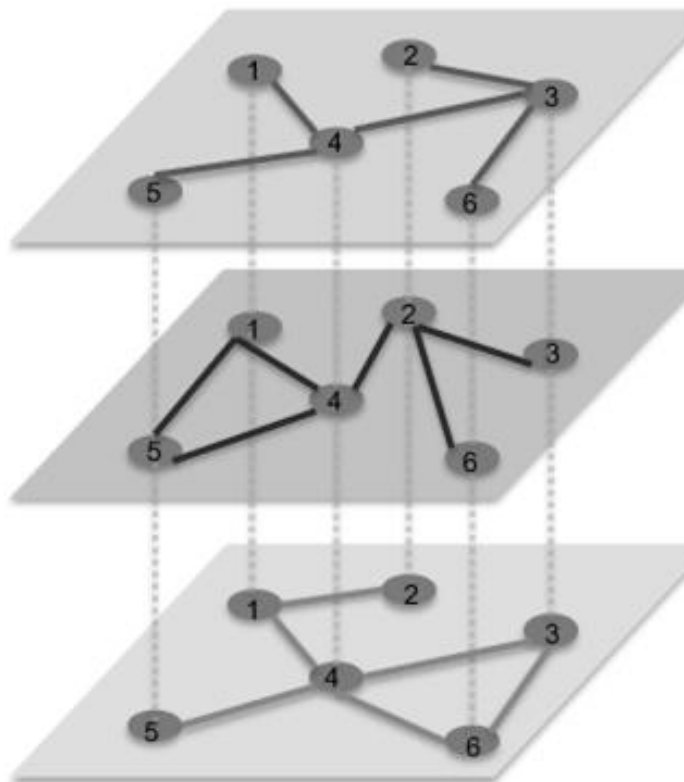
Network dimensions



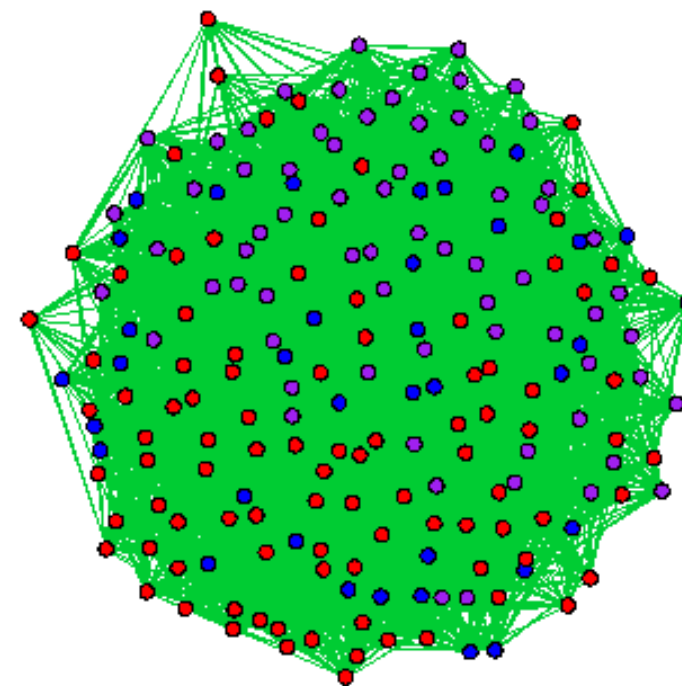
Unidimensional
data



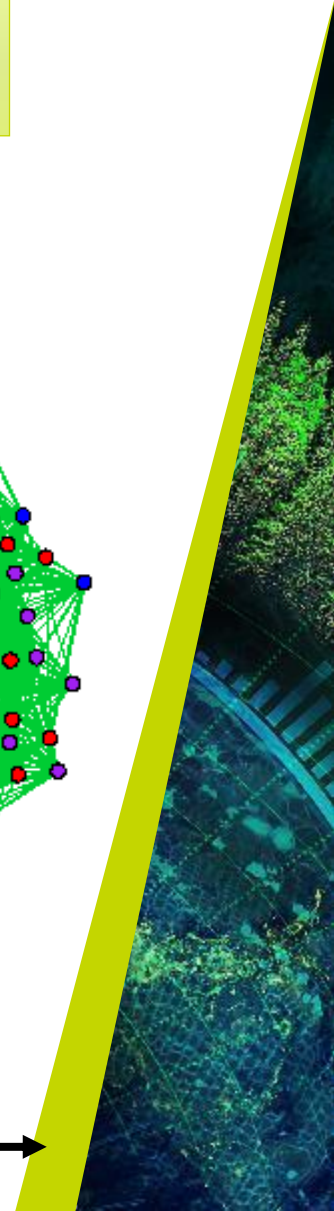
Multidimensional
data



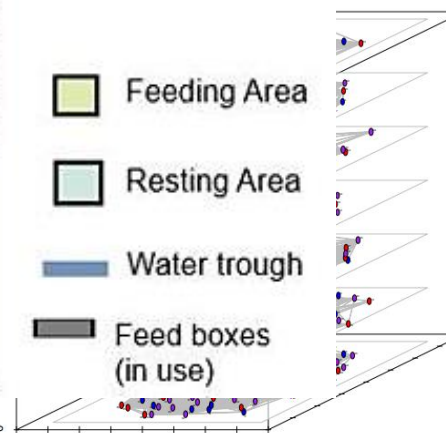
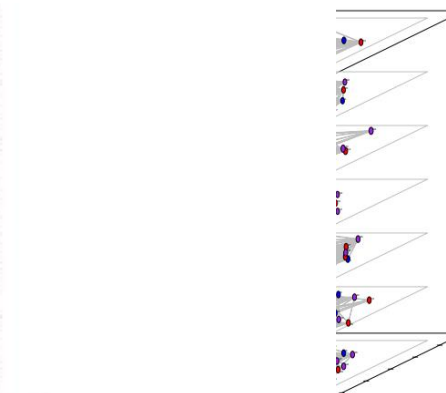
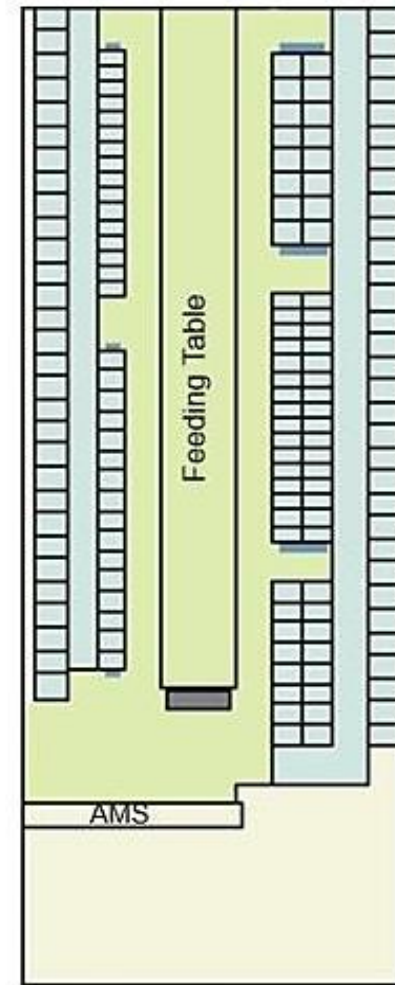
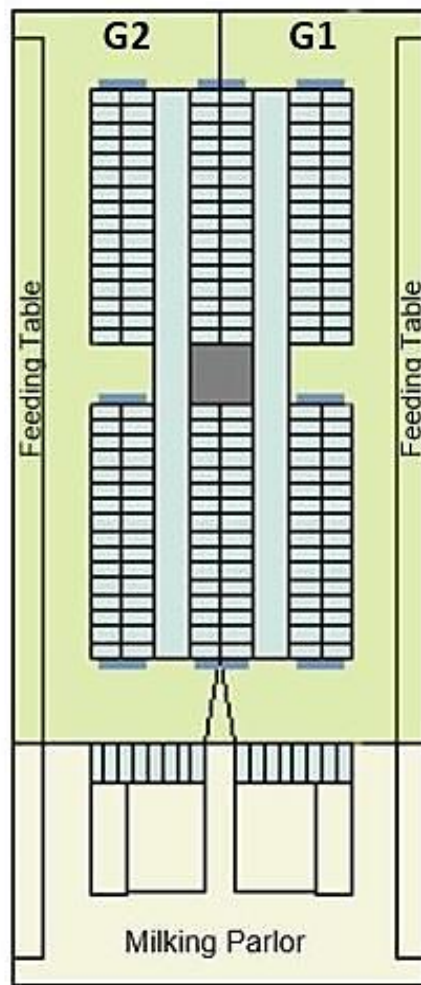
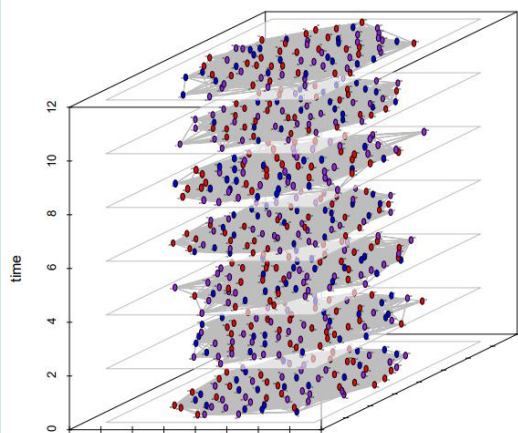
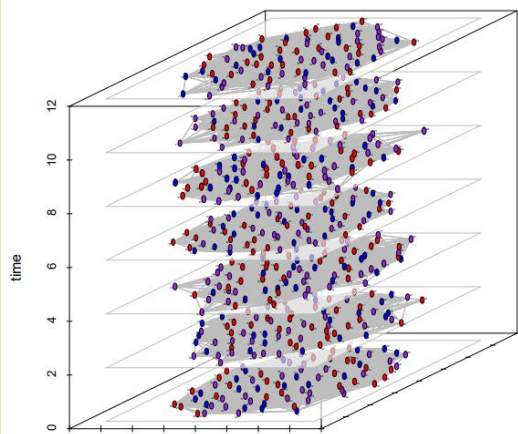
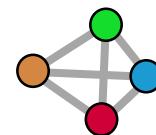
Longitudinal data



Time

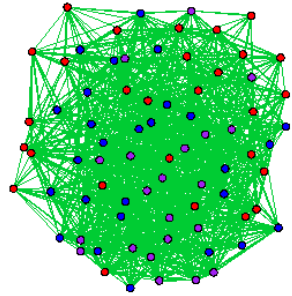
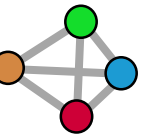


Spatial interactions

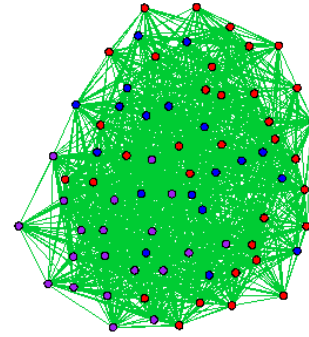


- Feeding Area
- Resting Area
- Water trough
- Feed boxes (in use)

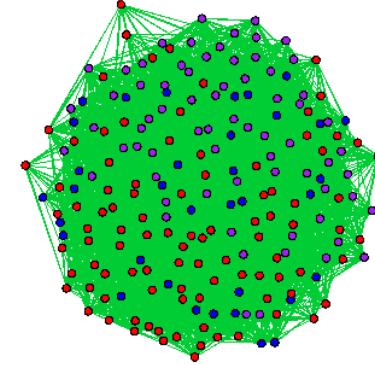
Spatial interactions



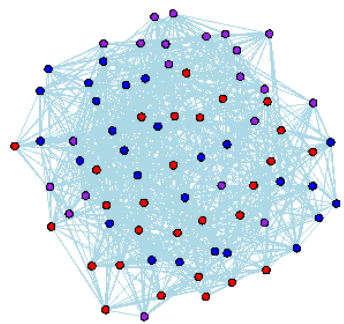
t=0-1



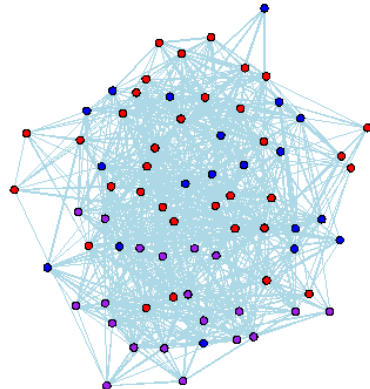
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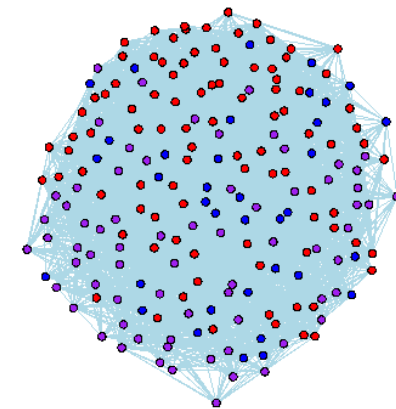
t=0-1



t=0-1

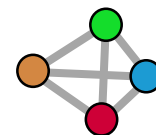


t=0-1



t=0-1

Dyad-level models



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

0	1	X	0	1	0	X	1
1	0	X	1	0	0	1	0
1	X	0	X	1	X	0	0
X	1	X	0	1	0	1	X
X	0	1	1	0	1	1	X
1	0	X	0	1	0	1	X
0	1	0	1	1	1	0	X
X	0	0	X	X	X	X	0
1	0	1	X	1	0	X	1

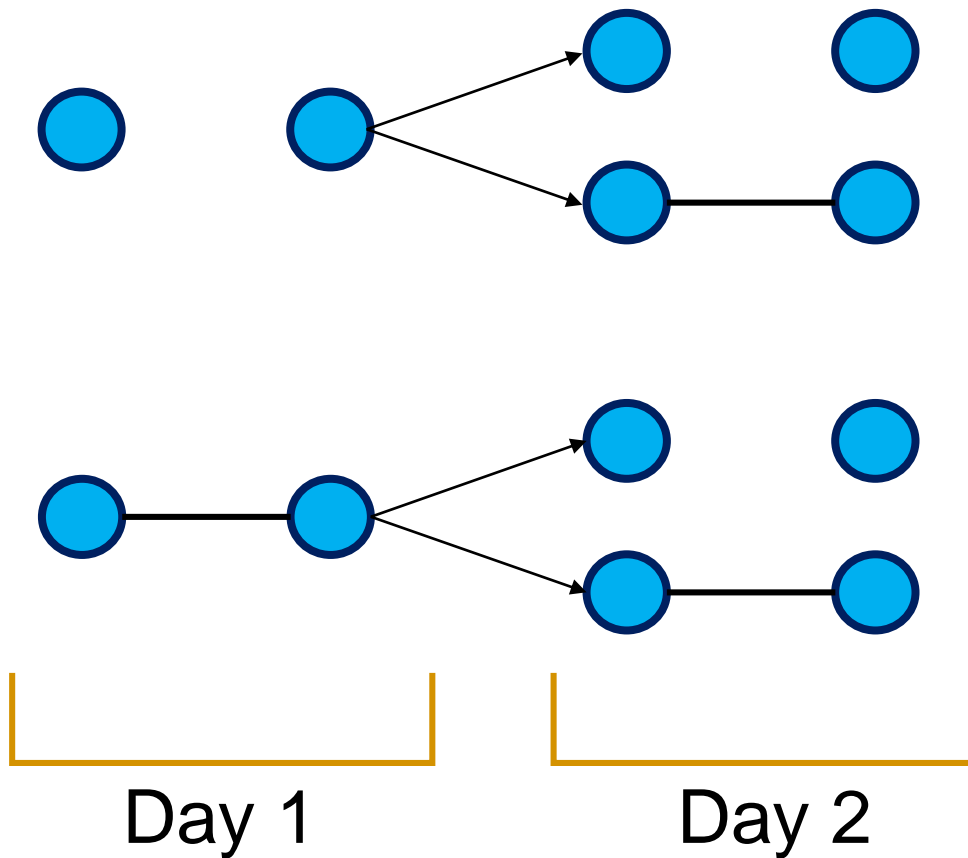
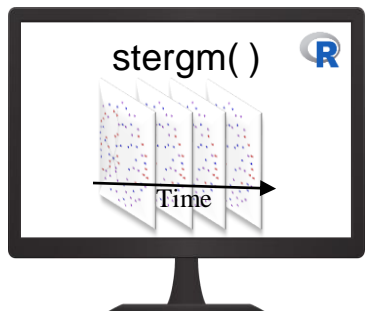
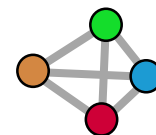
0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

0	1	1	X	X	1	0	X	1
1	0	X	1	0	0	1	0	0
1	X	0	X	1	X	0	0	1
X	1	X	0	1	0	1	X	X
X	0	1	1	0	1	1	X	1
1	0	X	0	1	0	1	X	0
0	1	0	1	1	1	0	X	X
X	0	0	X	X	X	X	0	1
1	0	1	X	1	0	X	1	0

Day 1

Day 2

Dyad-level models



Absence









Formation

Dissolution




Persistence

Dyad-level models

- Exponential random graph models (ERGMs):

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

Parity

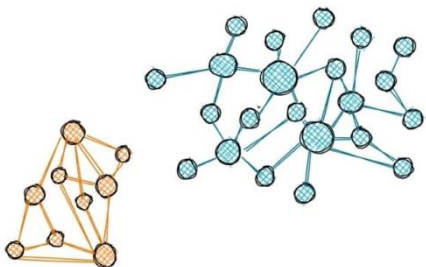
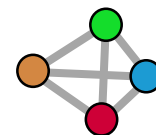
-  1
-  2
-  3+



Dyad-level models

- Separable temporal exponential random graph models (stERGMs):

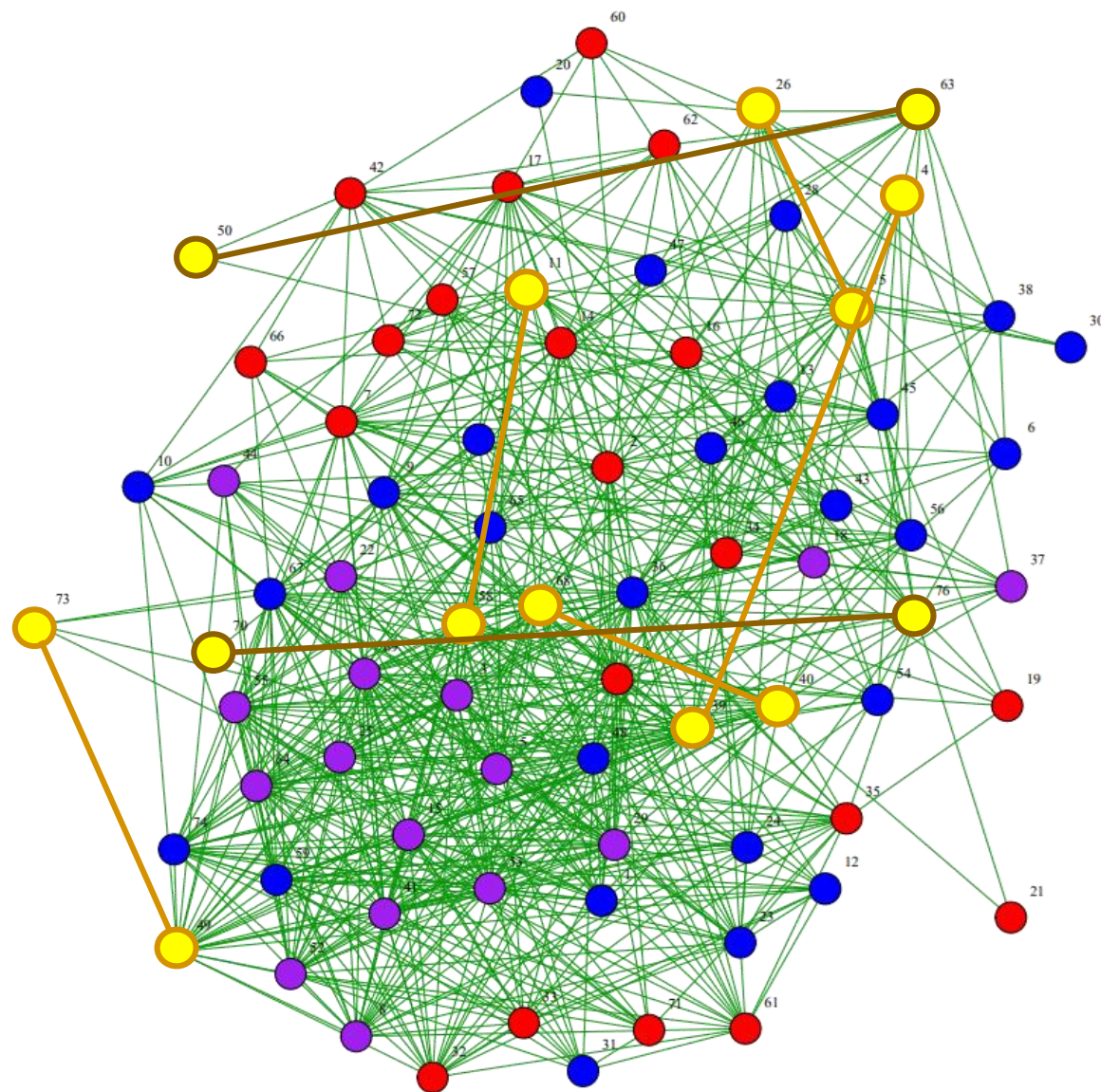
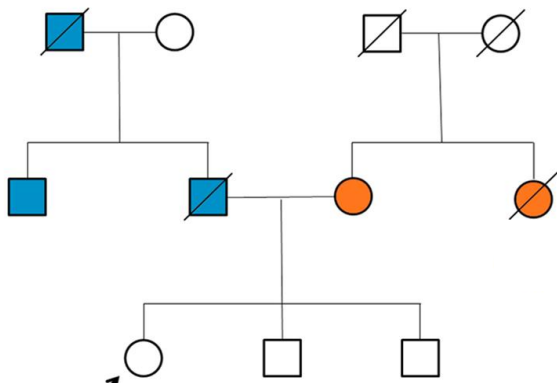
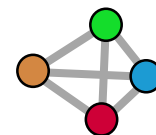
$(Y_{ij,t+1} = 1 Y_{ij,t} = y_{ij,t})$					Parity		TimeInArea	AGEnet		
					Match	Factor		Cov	Cov	
	0				1	0	0	0.22+0.43	1	Formation
	1				0	0	1	0.22+0.33	0	
	0				0	1	1	0.56+0.33	0	Persistence
	1				1	0	0	0.22+0.13	0	

Dyad-level models



Homophily				
	Formation	Persistence	Formation	Persistence
Parity	(+) ***	(+) ***	(+) ***	(+) ***
Early life	(+) **	(+) *	-	-
Pedigree	(+) **	(+)	-	-

Network dimensions

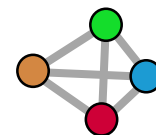





Parity

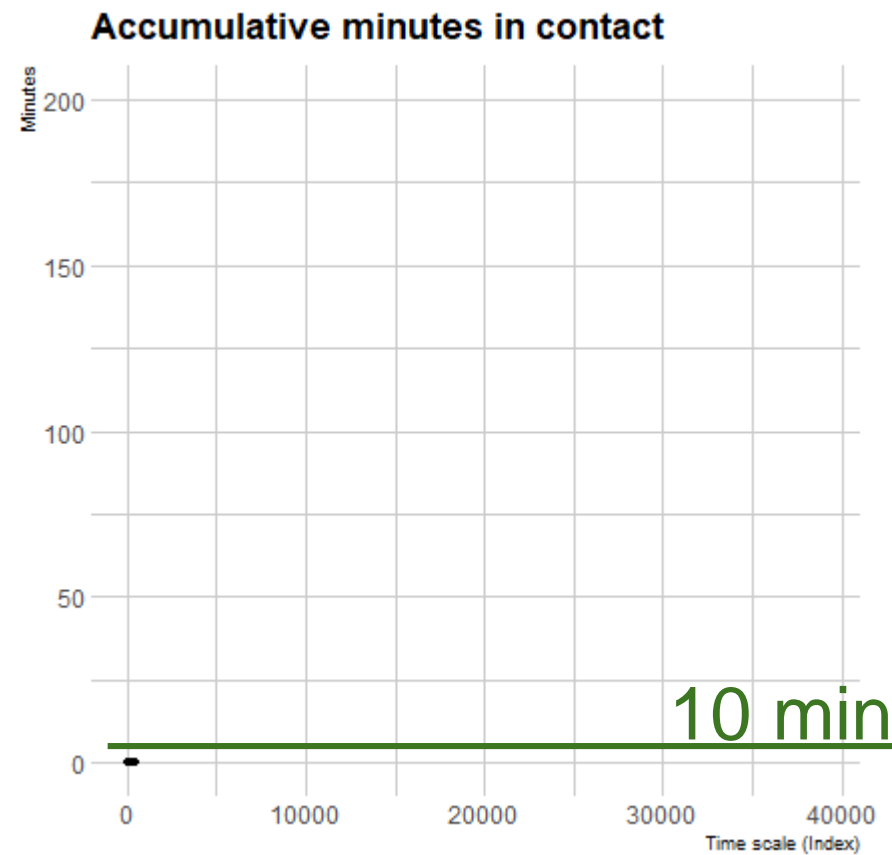
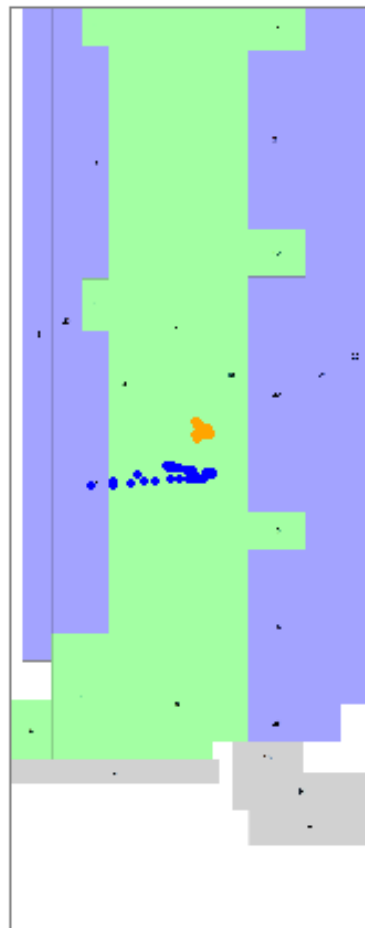
- 1
- 2
- 3+



Network dimensions

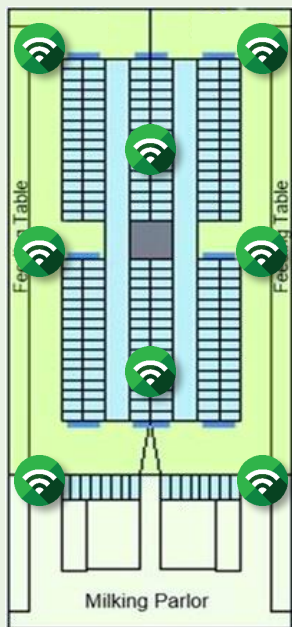
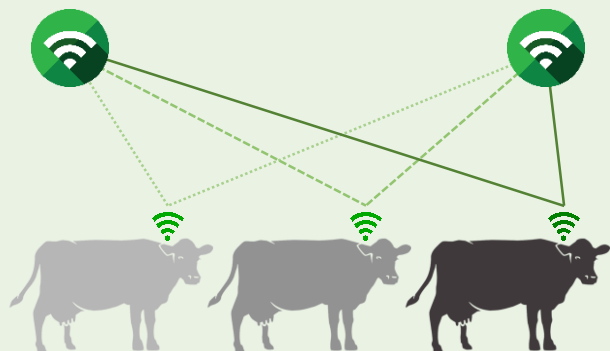






-  Mother
-  Daughter
-  Spatial contact



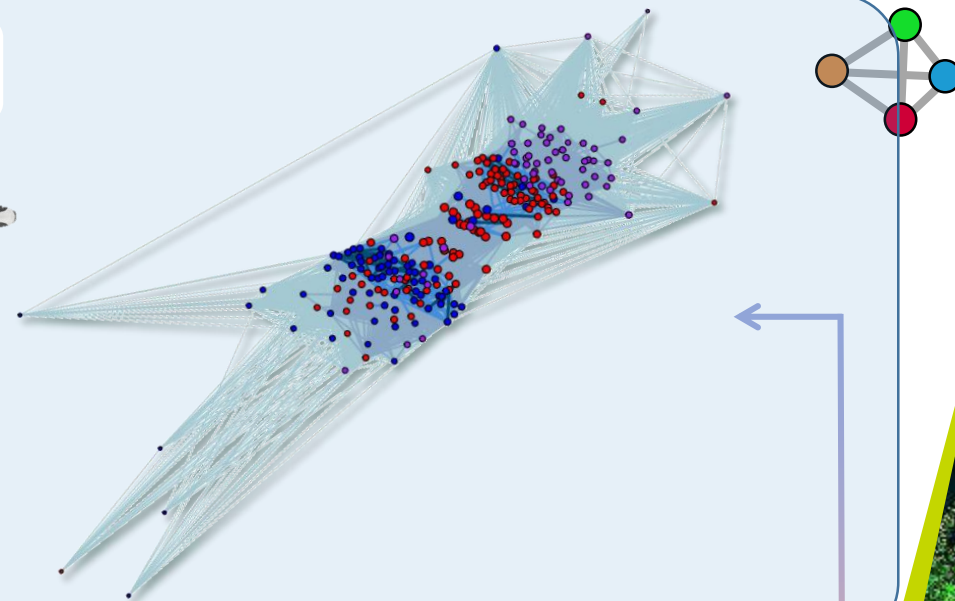
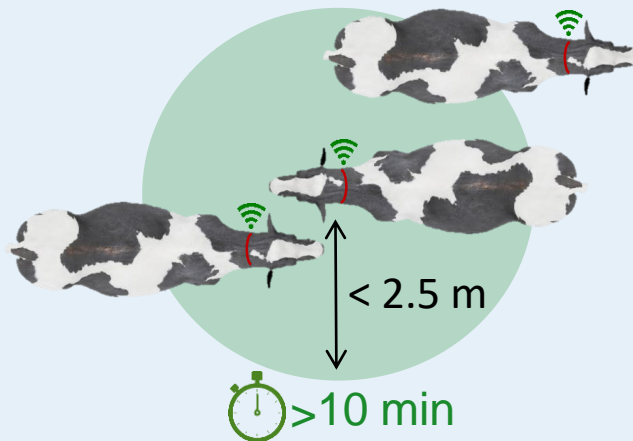
HR similarity

Real time location system

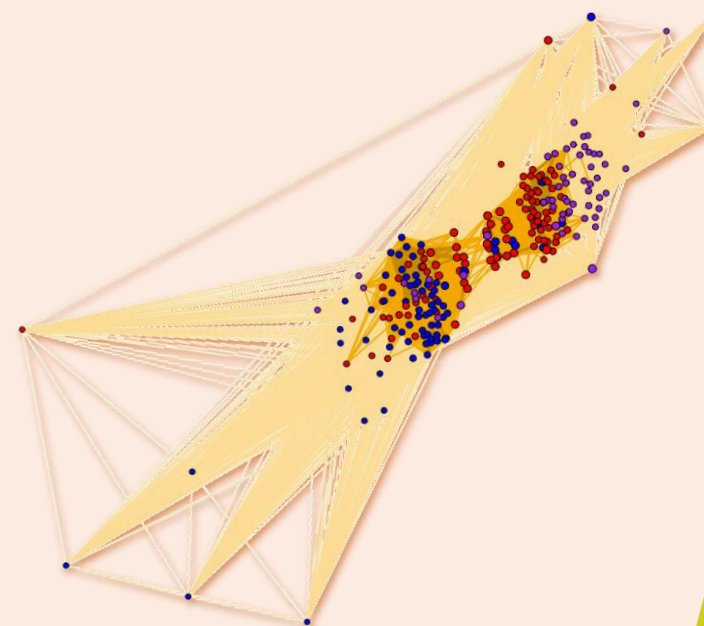
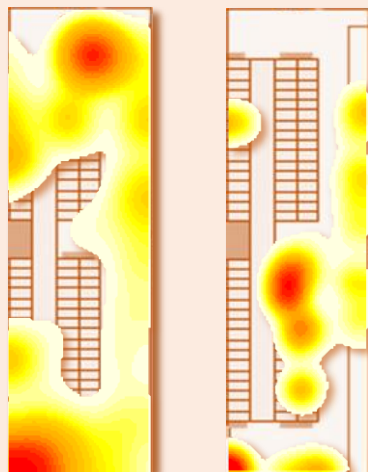


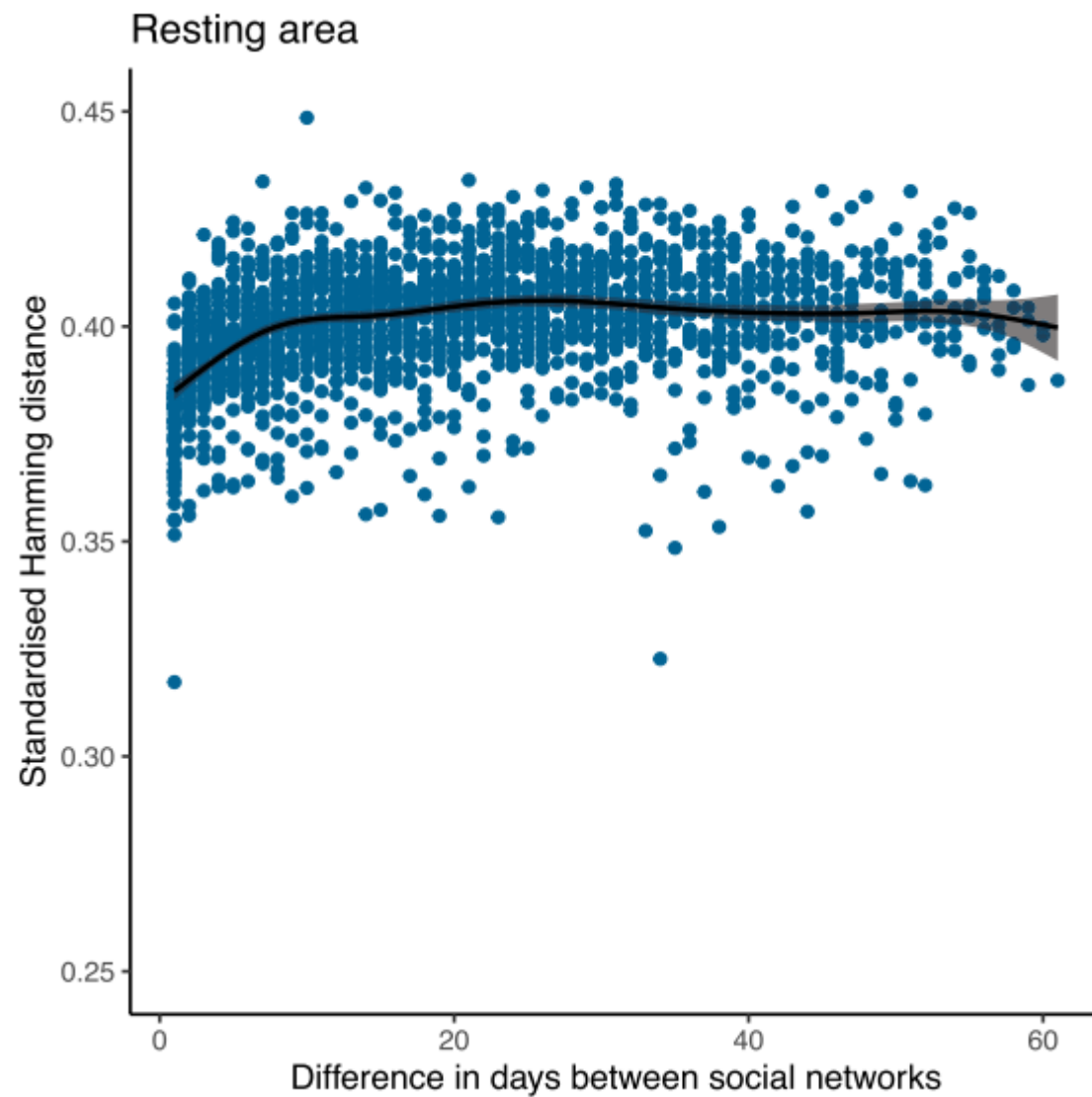
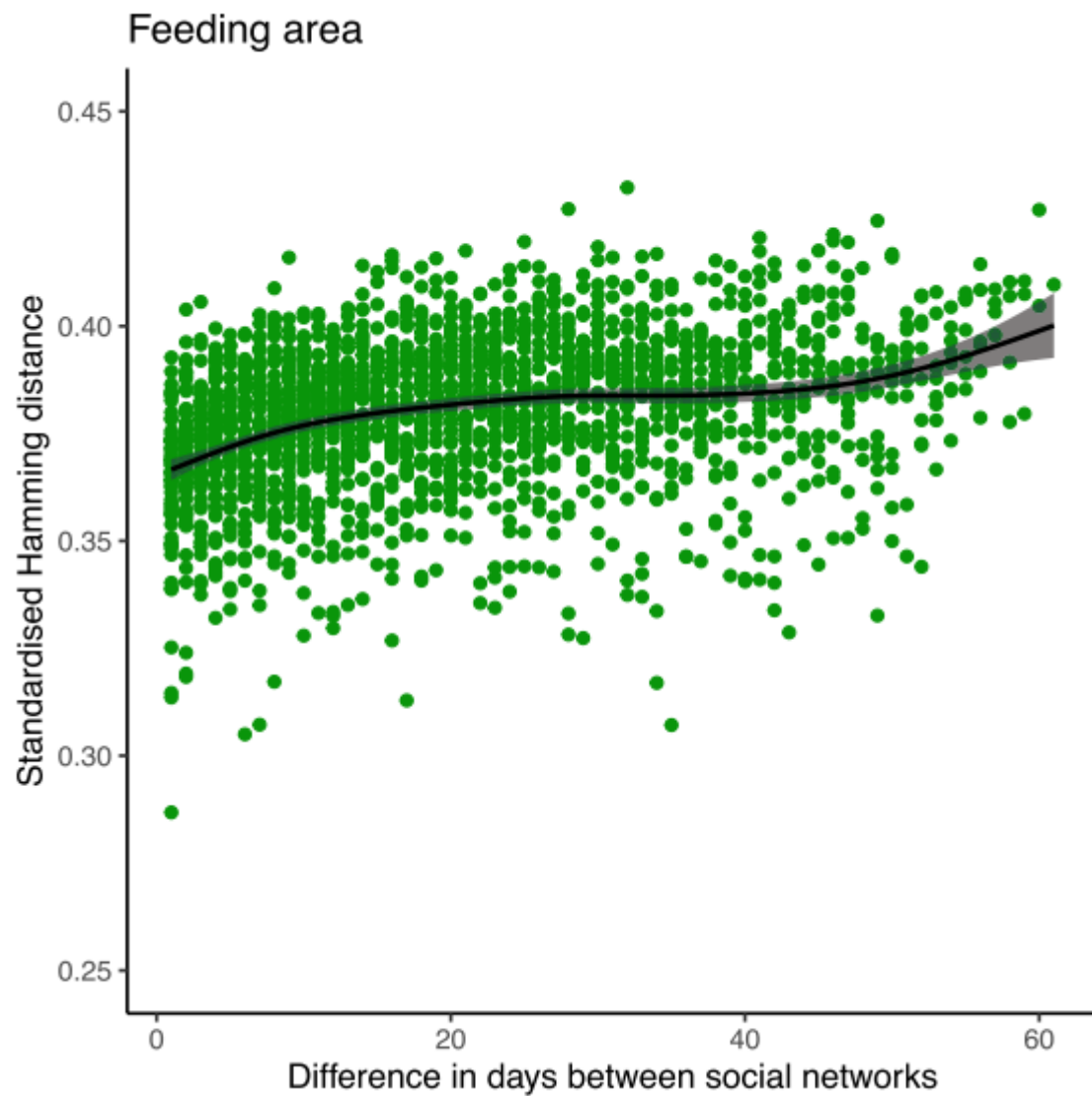
-  Anchor
-  Feeding area
-  Resting area
-  Water trough

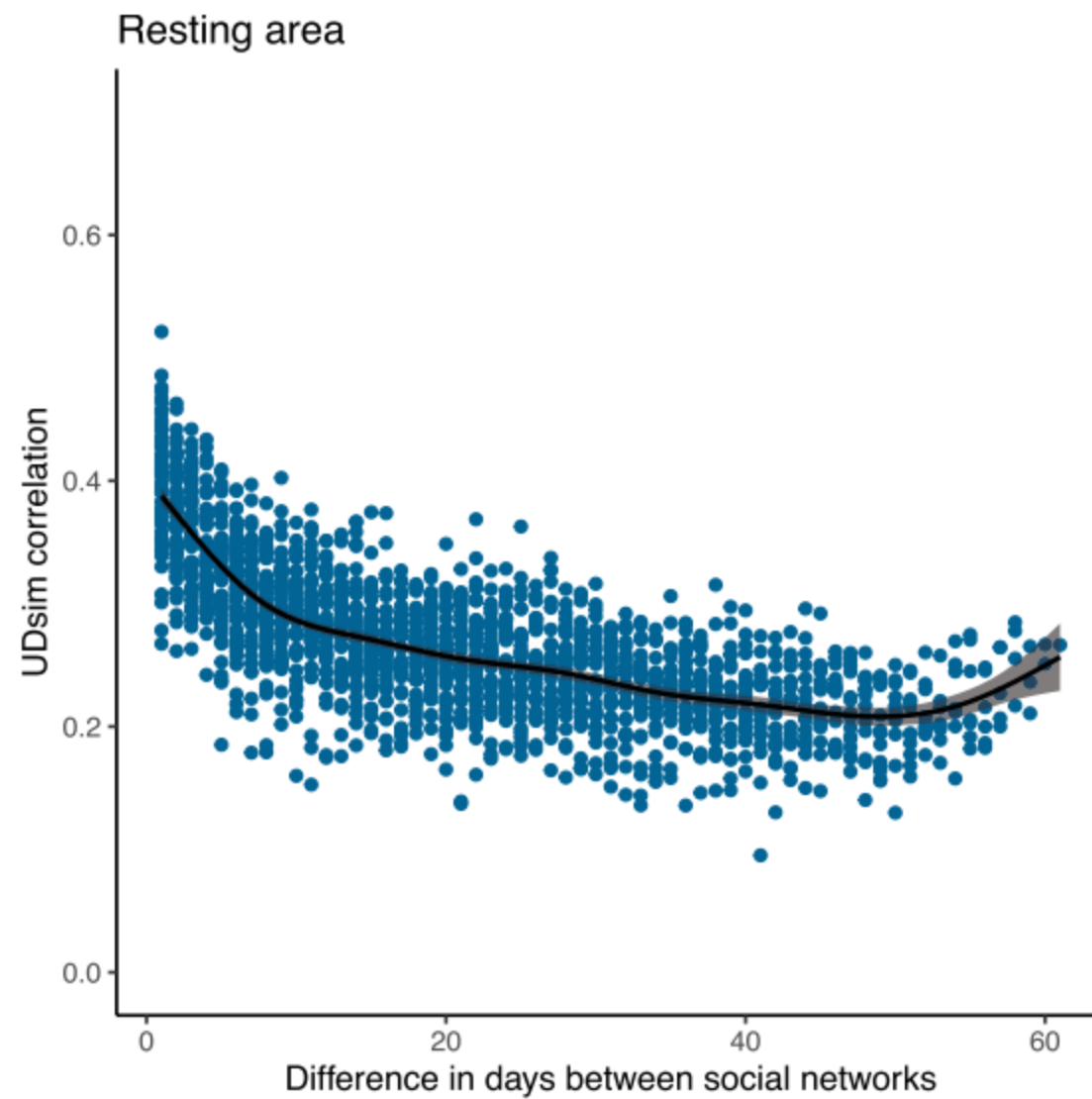
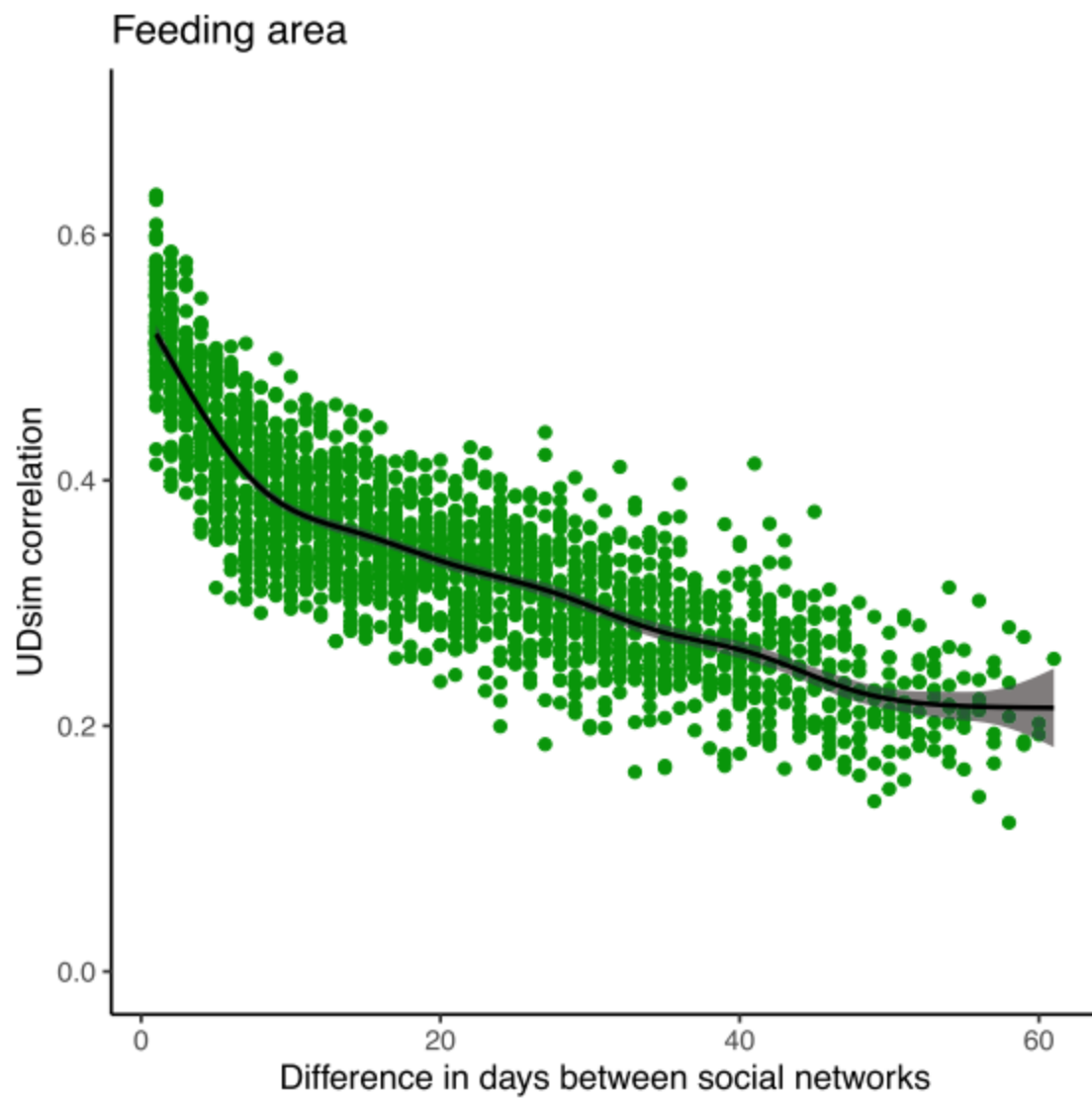
Social contacts

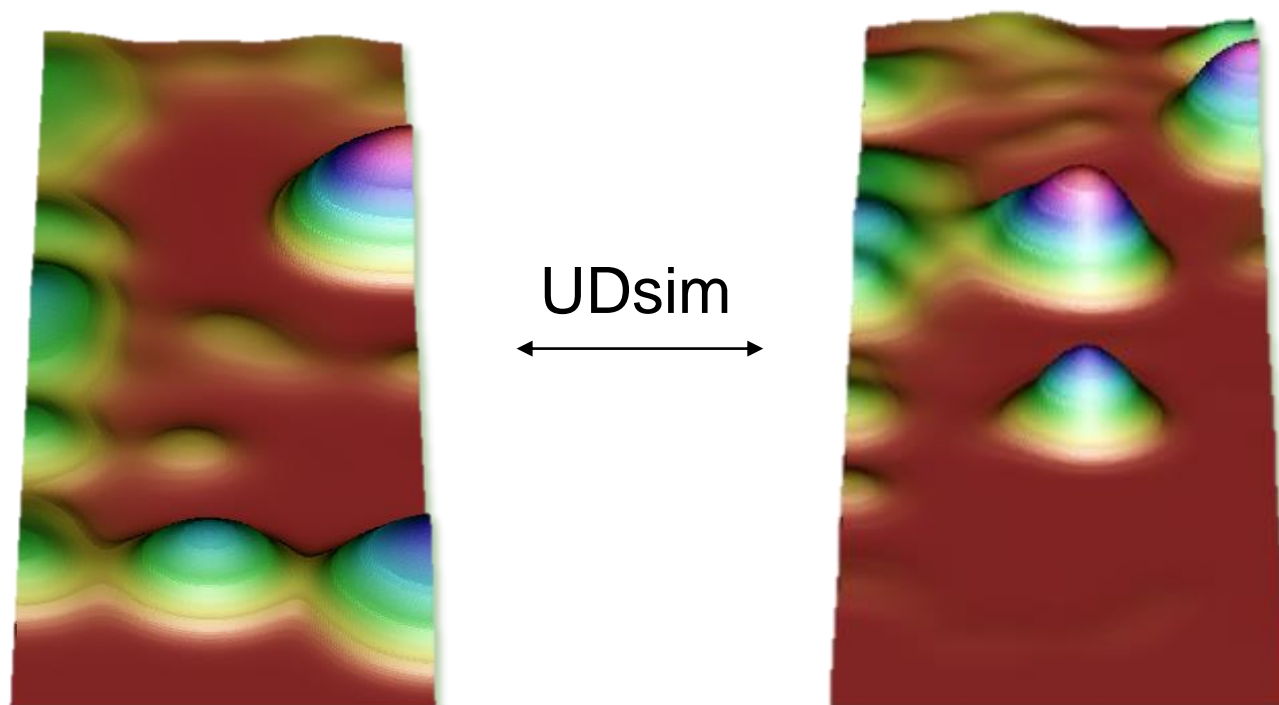


Utilisation Distribution

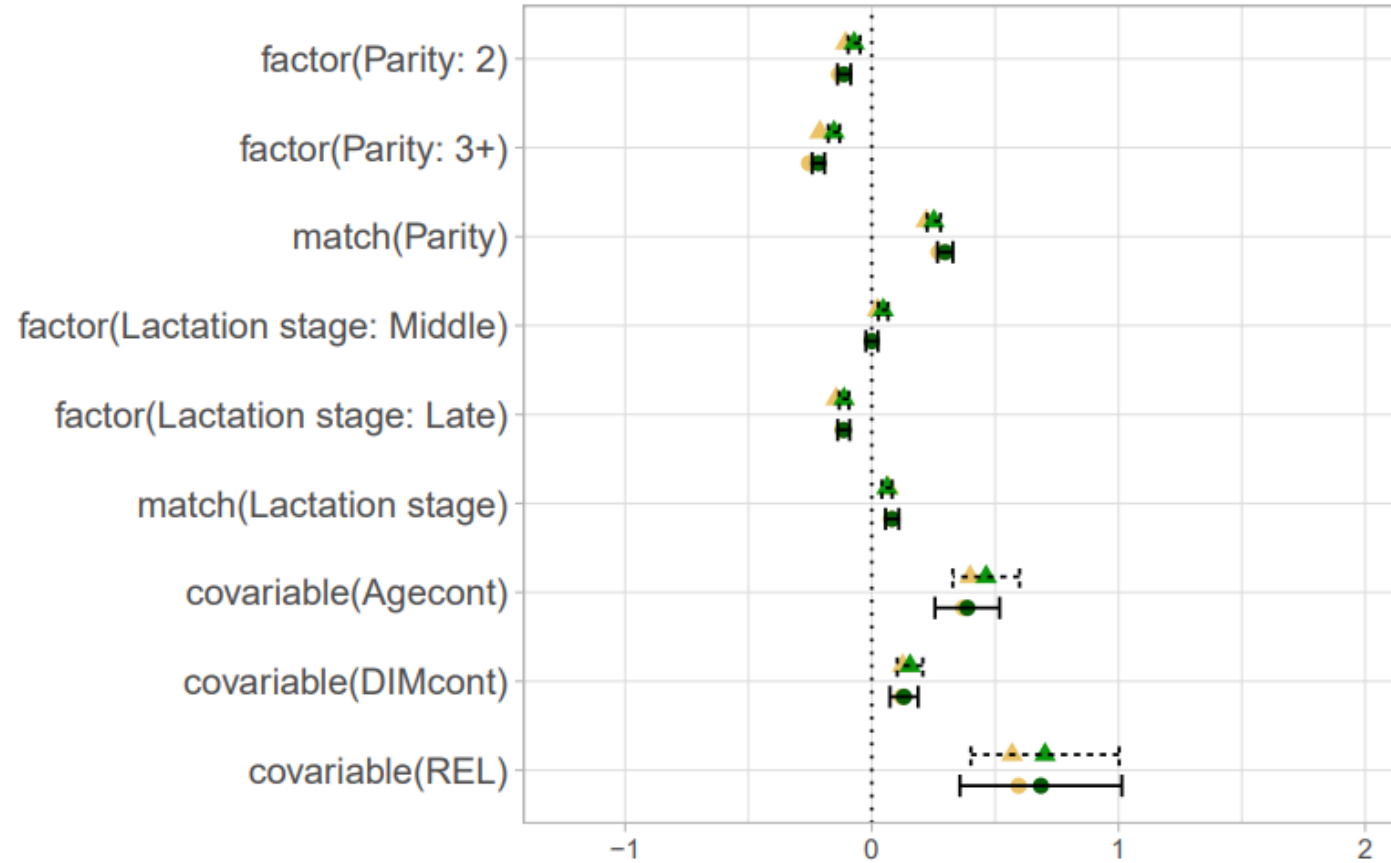




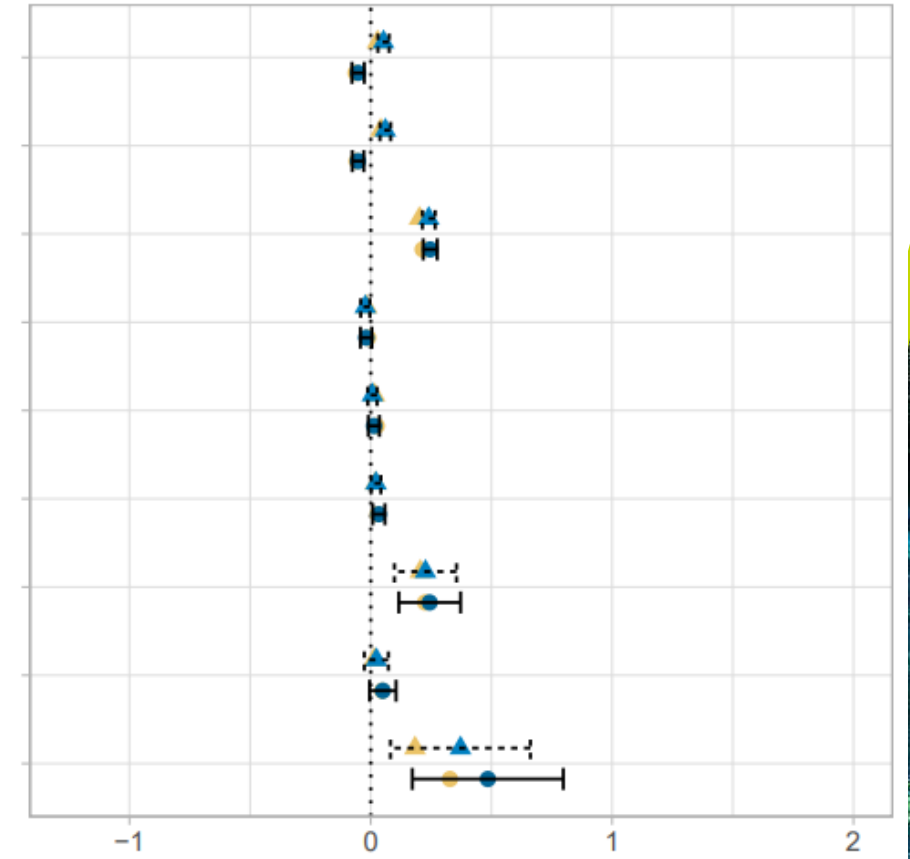




Feeding area

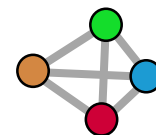


Resting area



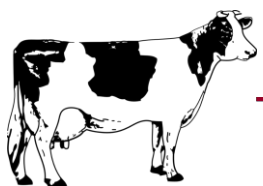
Endogenous parameters

Endogenous parameters



14 consecutive days:

- 2020-10-16
- 2020-10-29

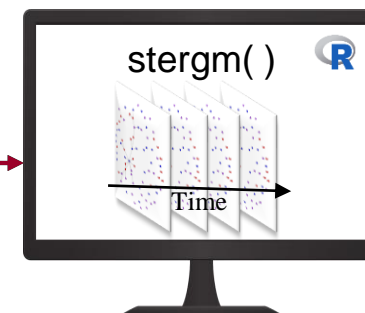


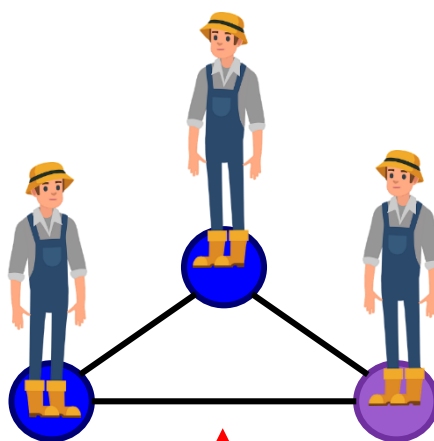
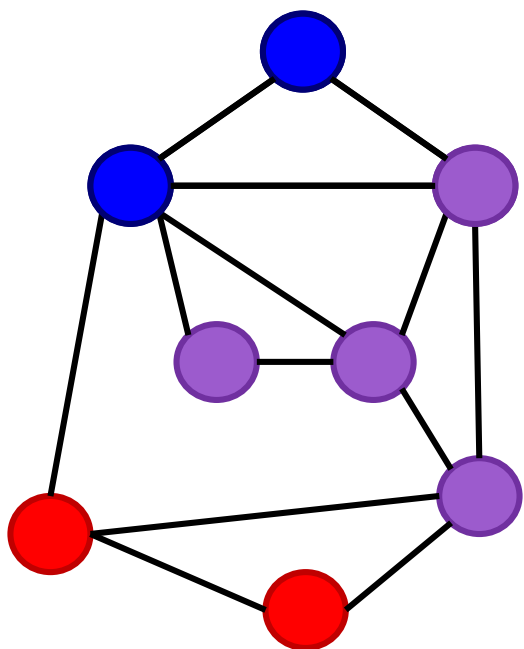
Information available:

- Parity
- Lactation stage
- Claw health
- Breed
- Early-life experience
- Calving experience
- Pedigree

Internal network structure

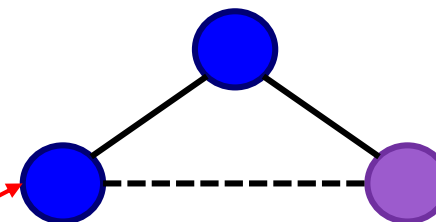
- Triangles



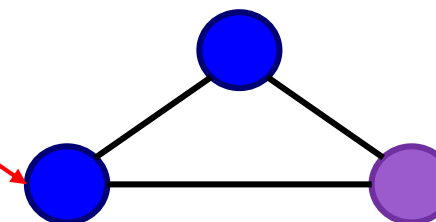


Likelihood

Formation

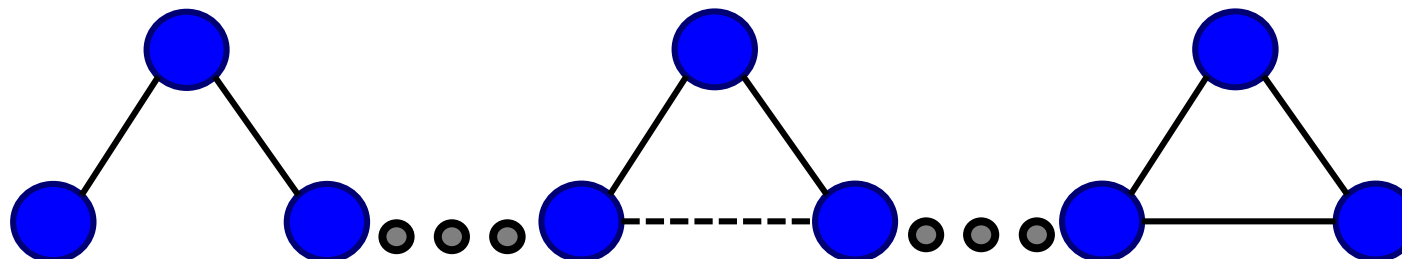


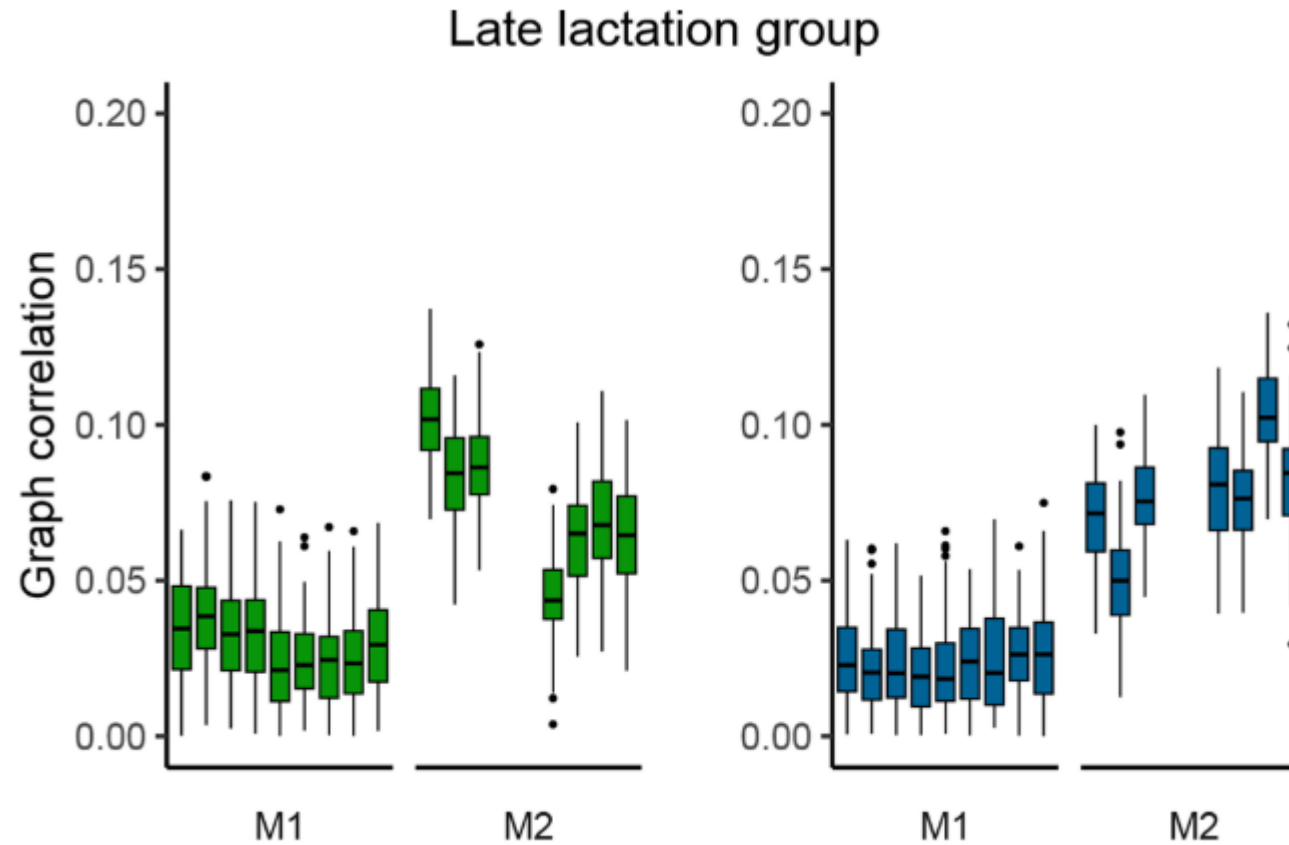
Persistence



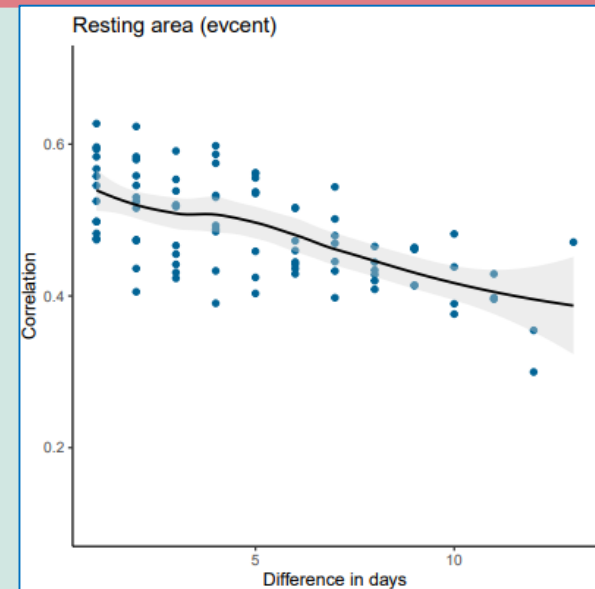
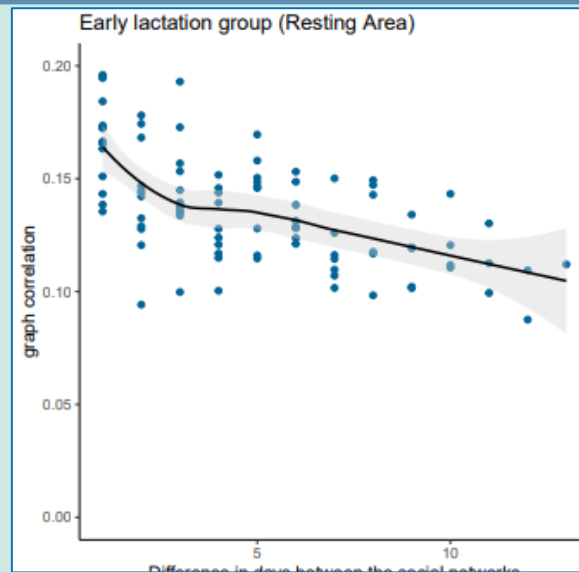
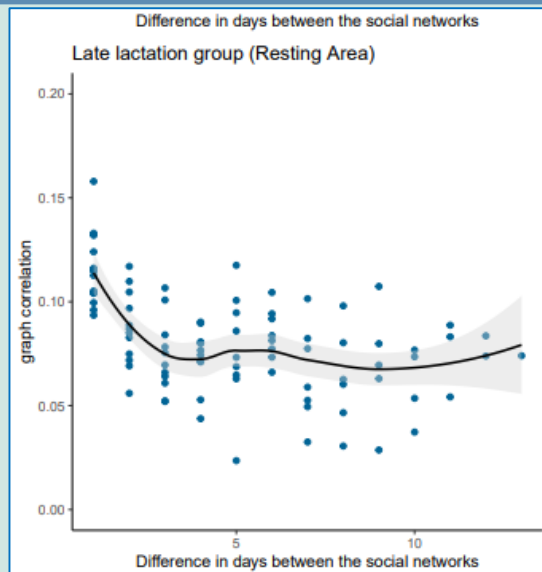
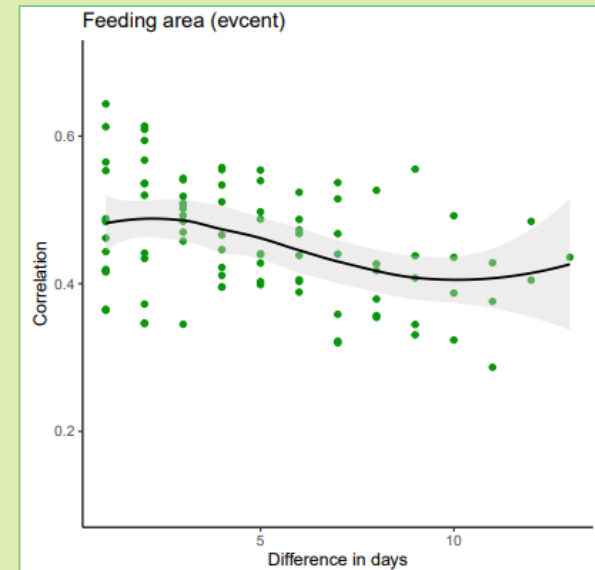
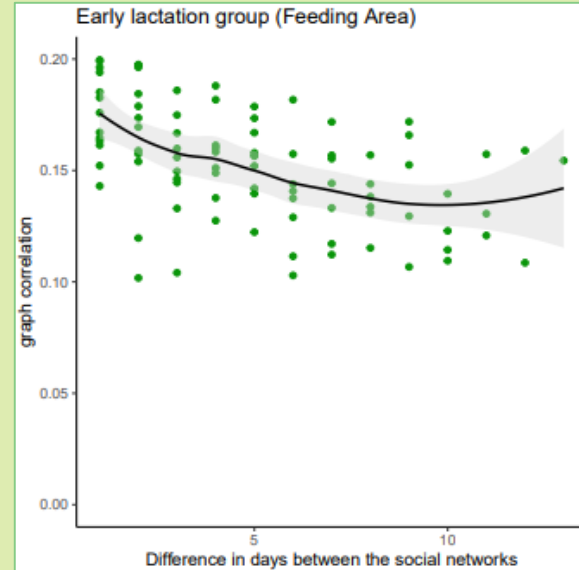
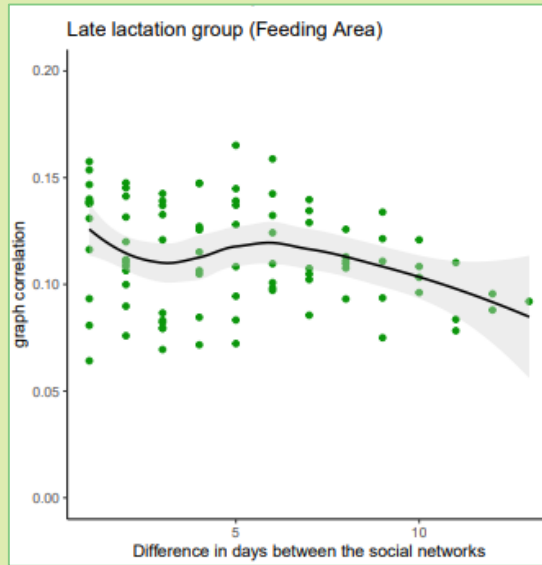


	Formation	Persistence
Triangles	(+) ***	(+) ***
Parity	(+) ***	(+) ***
Early life	(+) ***	(+) *
Pedigree	(+) ***	n.s.



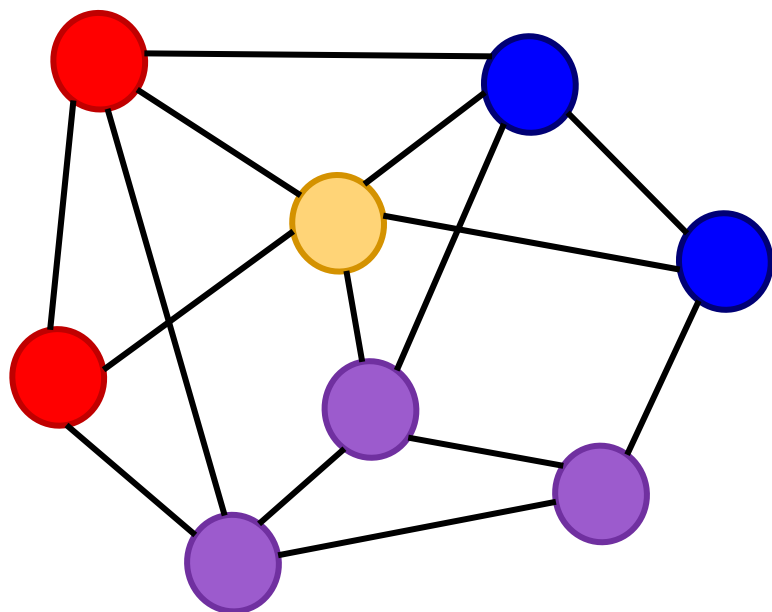
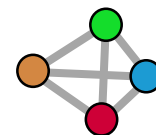


Marina, H., Fikse, W.F. & Rönnegård, L. (2024). Social network analysis to predict social behavior in dairy cattle. *JDS Communications*. Elsevier.



Topological parameters

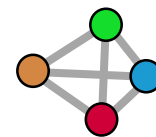
Topological parameters





- TP describe the structural properties and characteristics of the networks
- Quantify the influence of the nodes in the networks
- TP's repeatability indicate how constant is the social role of the animals over time

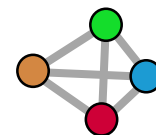




Topological parameters



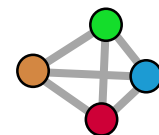
r^2				
	Feeding area	Resting area	Feeding area	Resting area
Degree	0.26-0.31	0.25-0.33	0.14	0.33
Betweenness	0.21-0.24	0.37-0.39	0.20	0.23
Closeness	0.23-0.24	0.38-0.40	0.12	0.32
Eigenvector	0.33-0.34	0.41-0.42	0.12	0.38

Topological parameters



h ²				
	Feeding area	Resting area		
Degree	0.07-0.11	0.08-0.16		
Betweenness	0.09-0.09	0.09-0.15		
Closeness	0.08-0.11	0.09-0.17		
Eigenvector	0.10-0.14	0.07-0.20		

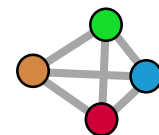




Understanding the dynamics of social networks could contribute to:

- Identifying social abnormal behaviour
- The stability of the social structure of dairy cattle
- The design of prevention protocols for transmissible diseases



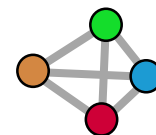


Understanding the dynamics of social networks could contribute to:

- **Identifying social abnormal behaviour**
- The stability of the social structure of dairy cattle
- The design of prevention protocols for transmissible diseases



Predict social behaviour

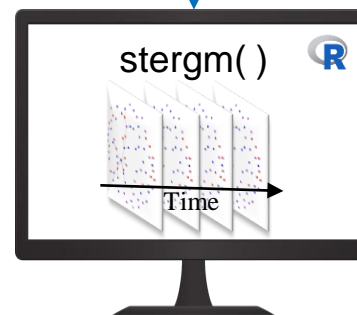


Prev. Adj. Mat.

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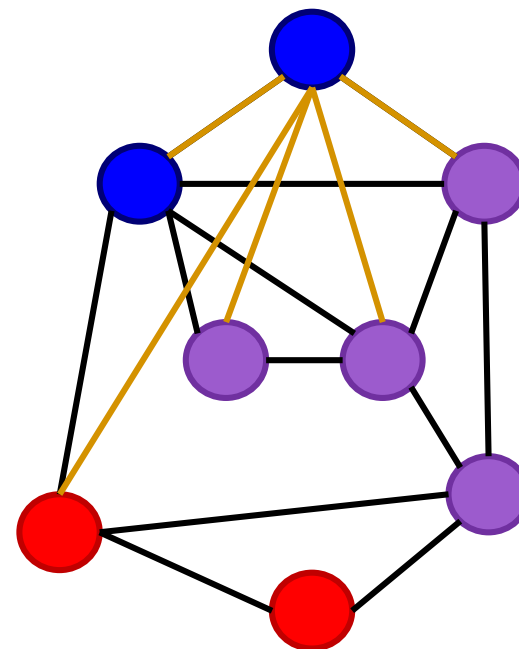
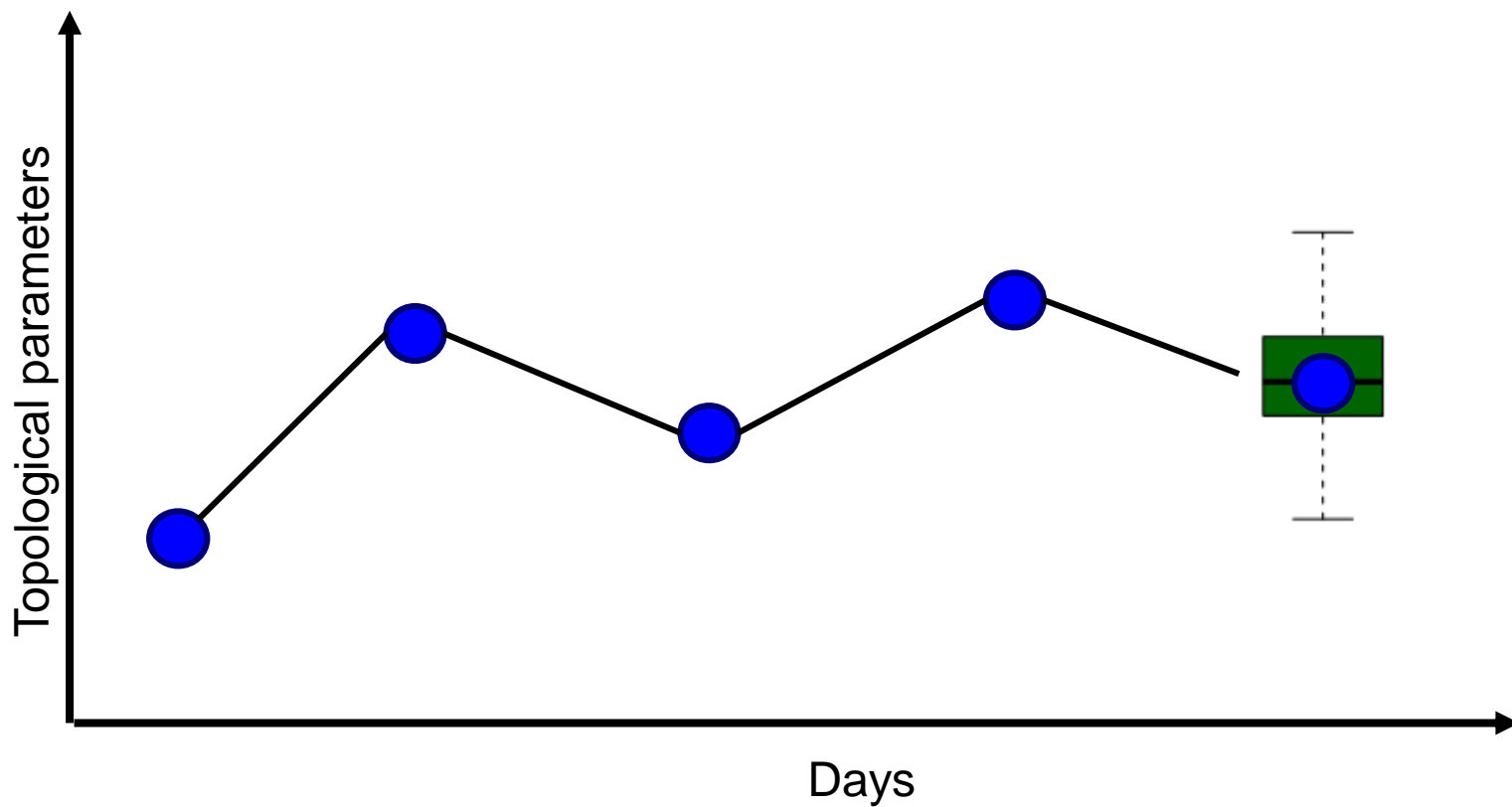
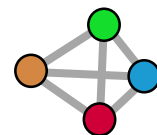
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1	0	0	0	1	0	1	0	0
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1	0	1	1	1	0	1	1	0

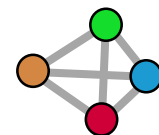
0	1	1	0	1	1	0	0	1
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0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0



0	0.1	0.7	0.3	0	0.8	0.7	0.3	0.3
0.1	0	0.5	0.9	0.6	0.1	0.9	0	0.9
0.7	0.5	0	0.2	0	0.8	0.5	0.7	0.2
0.3	0.9	0.2	0	0.6	0.5	0.1	0.3	0.3
0	0.6	0	0.6	0	0.3	0.8	0.9	0.6
0.8	0.1	0.8	0.5	0.3	0	0.2	0	0.4
0.7	0.9	0.5	0.1	0.8	0.2	0	0.5	0.4
0.3	0	0.7	0.3	0.9	0	0.5	0	0.6
0.3	0.9	0.2	0.3	0.6	0.4	0.4	0.6	0

Predict social behaviour





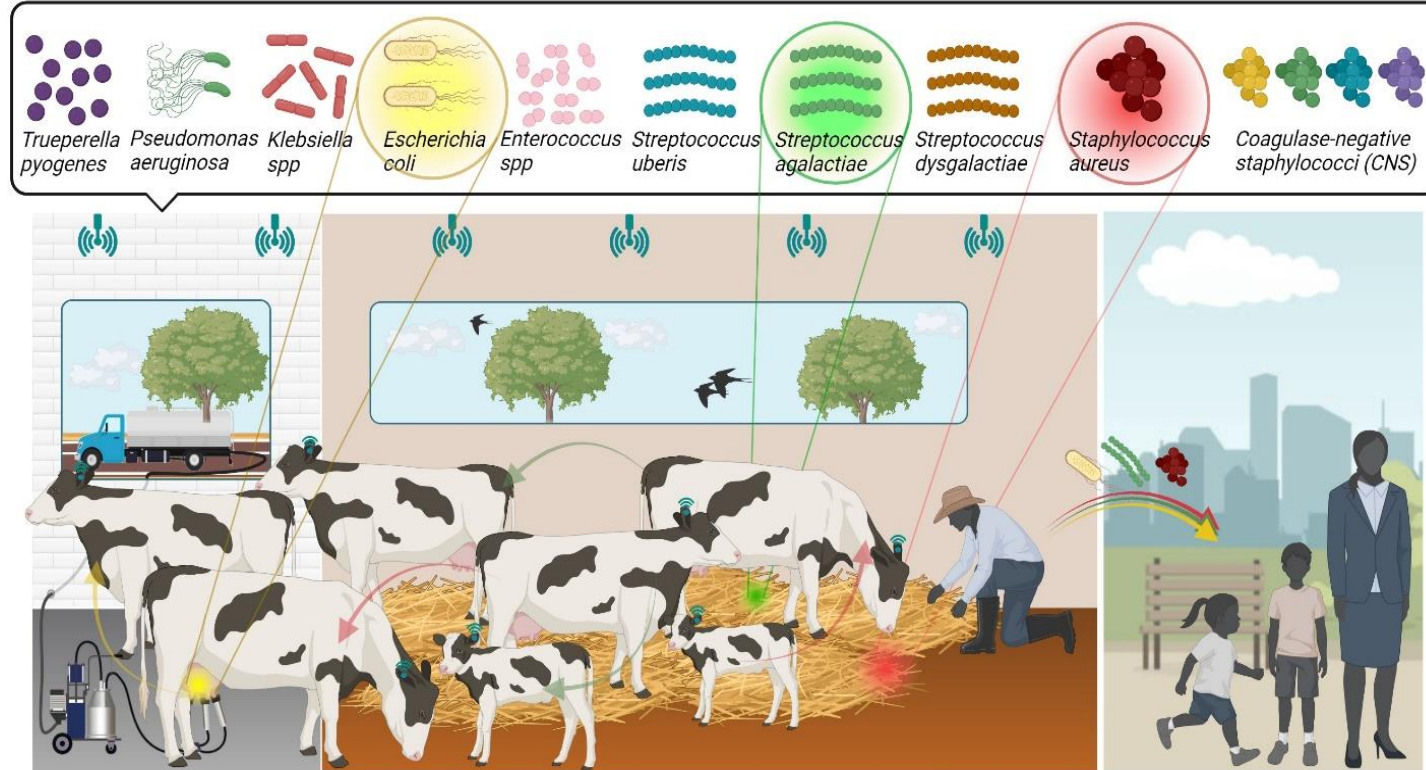
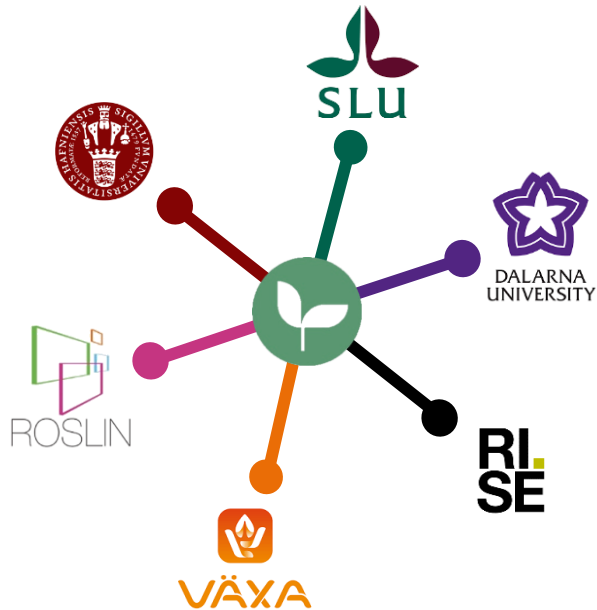
Understanding the dynamics of social networks could contribute to:

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Research ongoing

DigiGuard: Digitization for Mastitis Prevention and Resilience Enhancement in dairy cows



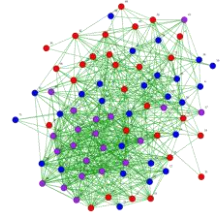
Hector Marina



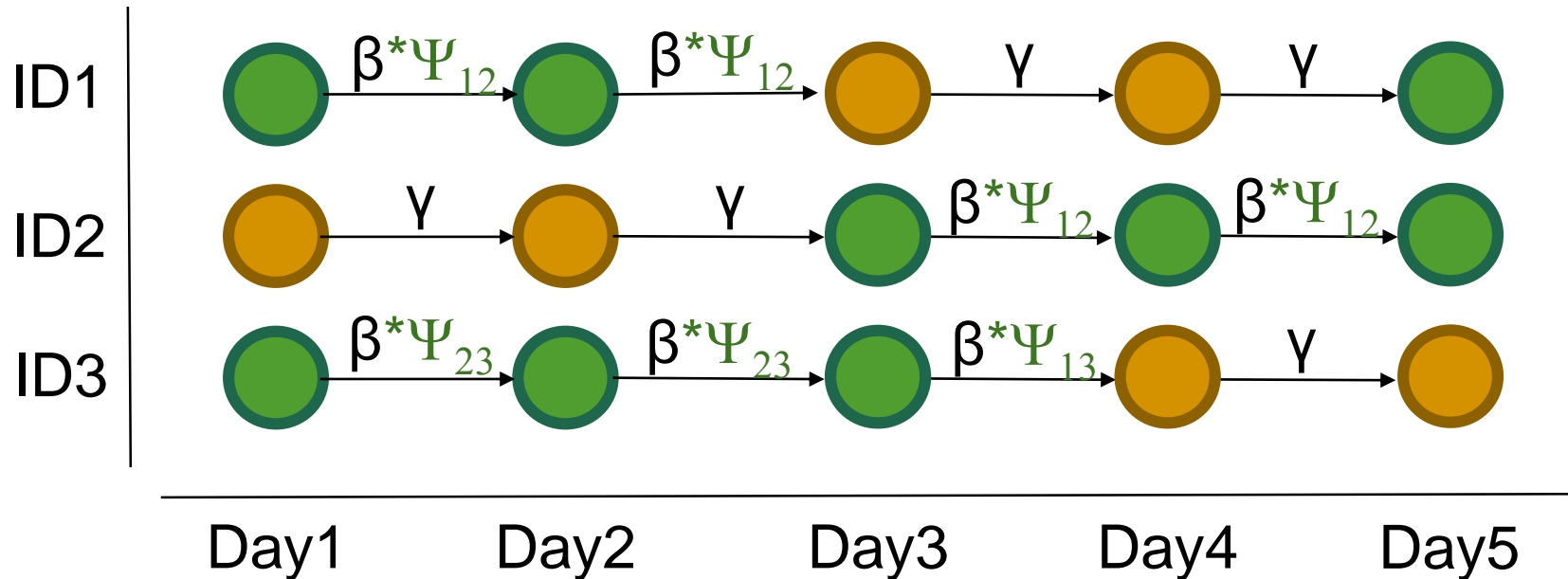
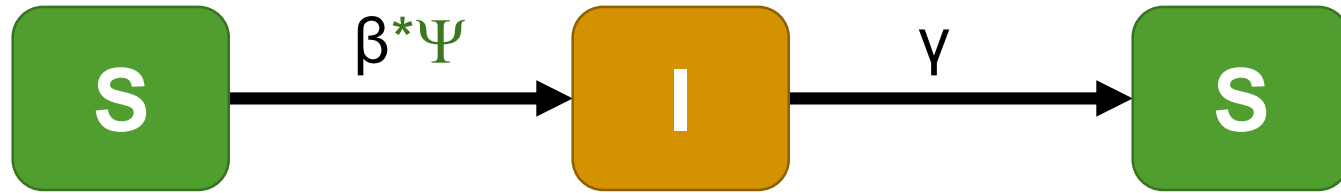
Lars Rönnegård

DigiGuard: Digitization for Mastitis Prevention and Resilience Enhancement in dairy cows

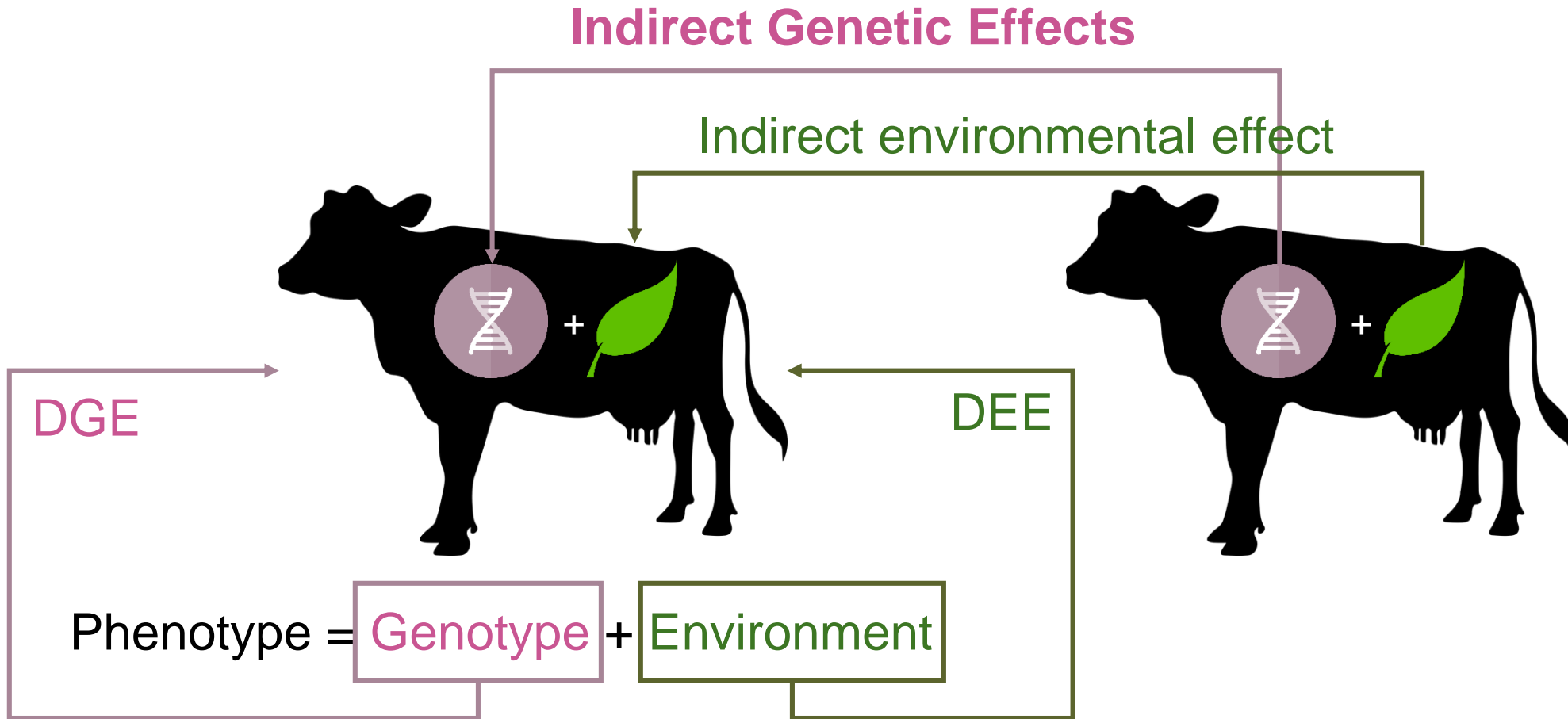
Simplified: β : Risk of becoming infected
 γ : Ability to recover.



Ψ Social contact



Underlying indirect genetic effect of sociability in dairy cattle



Hector Marina



Lars Rönnegård



GitHub



6th PLF
workshop
seminar

SCIENCE AND
EDUCATION
**FOR
SUSTAINABLE
LIFE**

hector.marina@slu.se