A Multi-agent Simulation Model on Individual Cognitive Structures and Collaboration in Sciences

Bülent ÖZEL

ozel@uji.es
Universidad Jaume I
Department of Economy
Castellon De La Plana, Spain

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Outline

Points of Departure

- Mutuality of knowledge and social structure theory borrowed from sociology of knowledge literature, where knowledge is perceived as an essentially social and societal category.
- Limitations of approaches caused by applying isolated techniques which detach social structure from knowledge.
- Possibility of decoding fundamental aspects of scientific practices, such as knowledge diffusion and collaboration structures which are encoded in bibliographic entries.

Motivation Simulation Modelling

- incorporating a dynamic social network perspective while modeling interactions in between agents
- examining and designing various knowledge creation and diffusion mechanism as the outcomes of agent-agent interactions
- examining impact of cognitive structure of scientists at incentives to pick a collaborator

Related Simulation Models

- Zhuang et. al. (2011)
  - knowledge diffusion and knowledge accumulation
  - random number of neighbors is formed
  - knowledge is quantified
  - knowledge absorption is proportional to agent's existing knowledge
- Gao and Madey (2007)
  - exemplifies a multi-agent simulation of collaboration
  - no knowledge structure
  - agents joins to tasks no explicit agent-agent interactions
- Sun et.al. (2012)
  - multi-agent collaboration to simulate split and merge of new fields.
  - random walks at picking collaborators
  - knowledge representation is attributional and is at disciplinary level
- Edmonds, B. (2014) "A Simulation of a Formal Science - inference of new theorems and publishing results"

Agents

- agent: author
- memory: individual cognitive structure
- memory: collaboration history

Agent-Agent Interactions

- co-authorship networks
- collaboration history
- transitivity mechanism

Collaboration Behaviors

- stay idle
- publish solo
- seek for co-authors

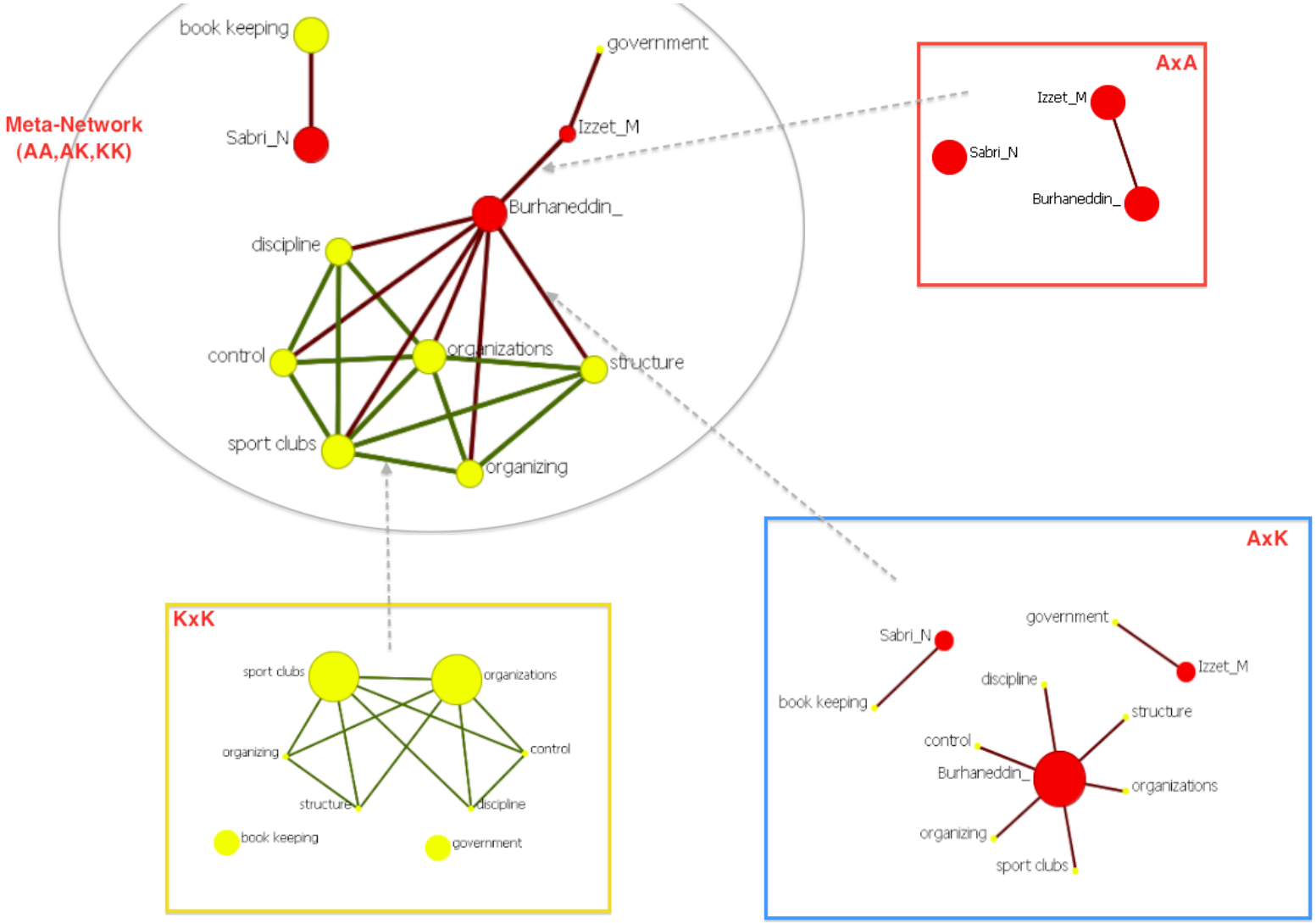
Co-authorship

$$P_w^n = \begin{cases} \dfrac{w_{ij}}{\sum_k w_{ik}} & \text{if } n <= 2 \\ \left(\dfrac{w_{ij}}{\sum_k w_{ik}}\right)^{n-1} & \text{otherwise} \end{cases}$$

Cognitive Structure of Agents

- publication keywords
- keyword co-occurance relations

Cognitive Structure of Agents



Knowledge Transfer

- common knowledge space of dyads
- random walk on semantic ties
- update of individual cognitive structures

Cognitive Resemblances

- $AK_i \cap AK_j = \emptyset$
- $AK_i \cap AK_j = K_{ij}$
- $AK_i \subset AK_j$

Modelling Output of Collaboration

- start a random walk from common knowledge space
- random walks on semantic links
- semantic links in a breadth first search manner:

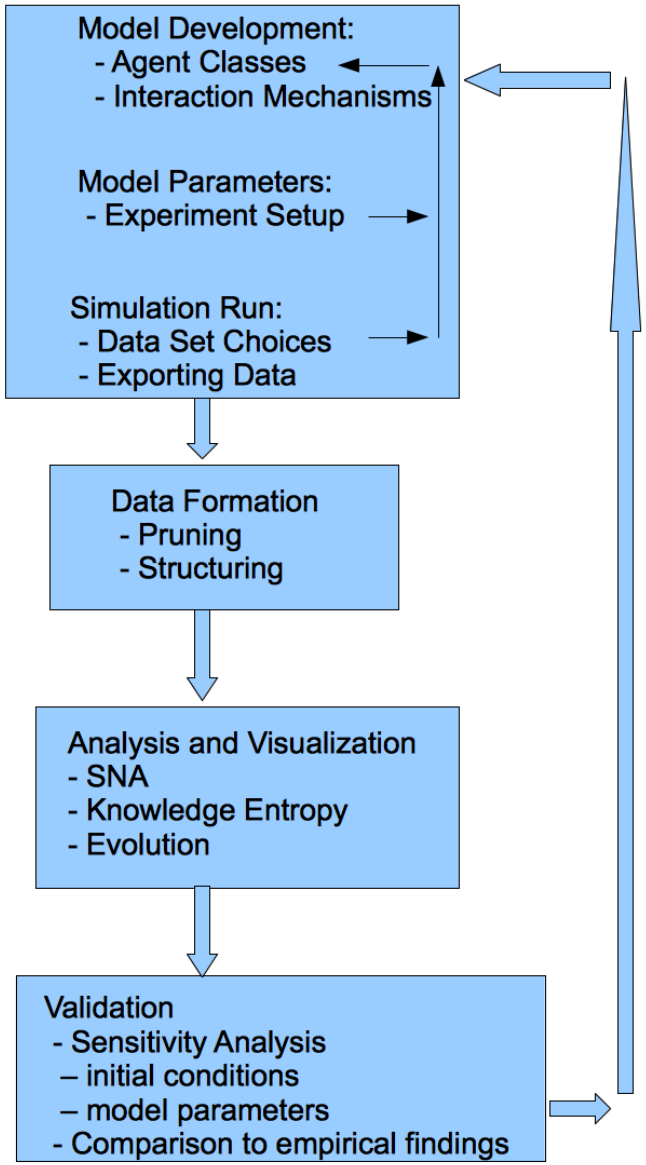
$$P_w = \frac{w_{ij}}{\sum_k w_{ik}}$$

- all keywords on a walk makes up the set of keywords of new publication

Injection of New Knowledge

- $P_{injection}$
- a uniformly random link to existing knowledge of co-authors
- link formation based on a preferential attachment mechanism

Implementation Chart



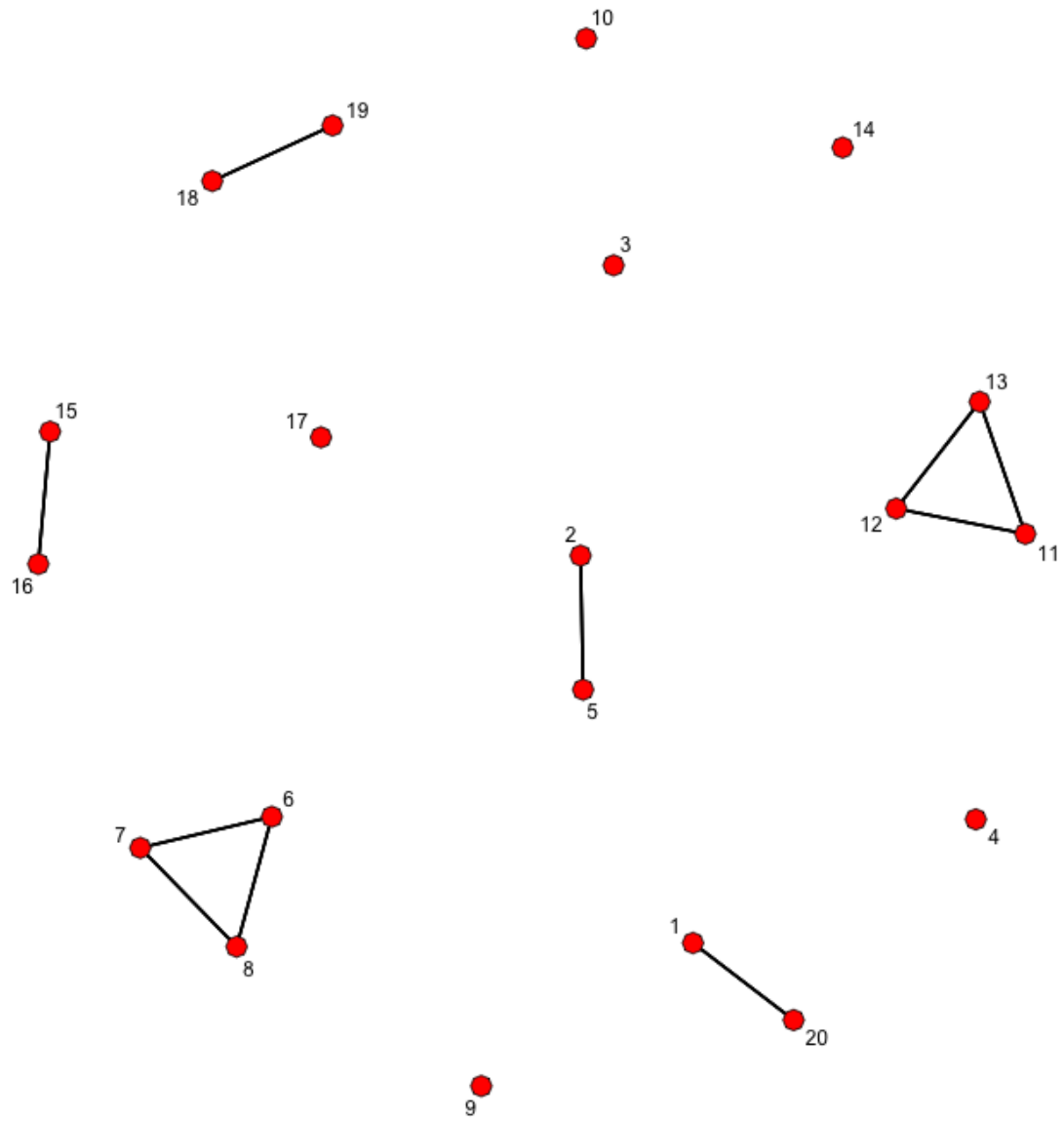
Software Tools

- RePast(Java) Platform
  - model development
  - initialization
  - experiment setup
  - simulation
- Python
  - simulation output data formation
- R Programming
  - Packages: Base, SNA, Network, RSiena
  - analysis
  - visualization
  - validation

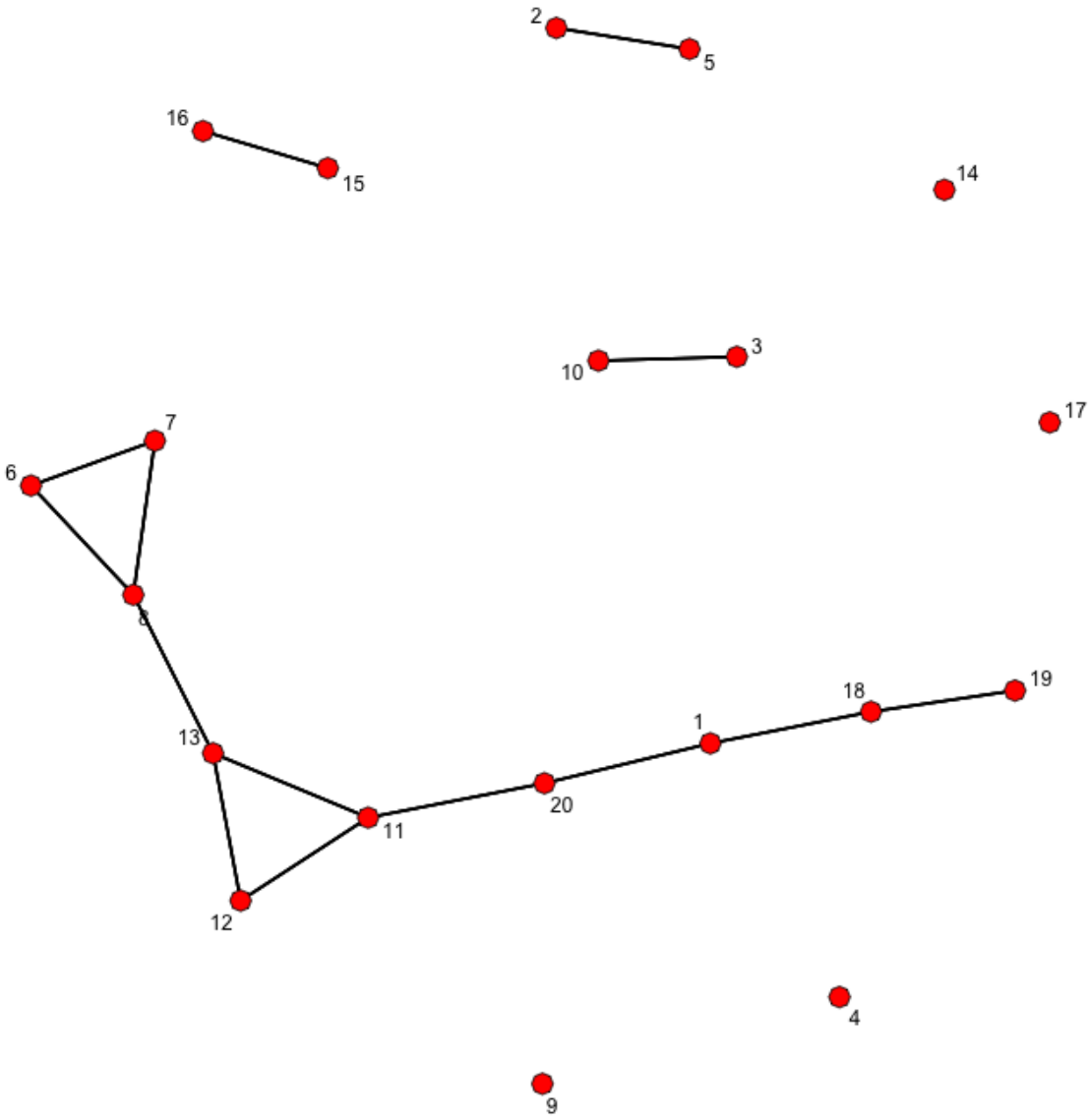
Data

- 20 Authors
- 200 Papers
- 10 years
- initialization
- validation

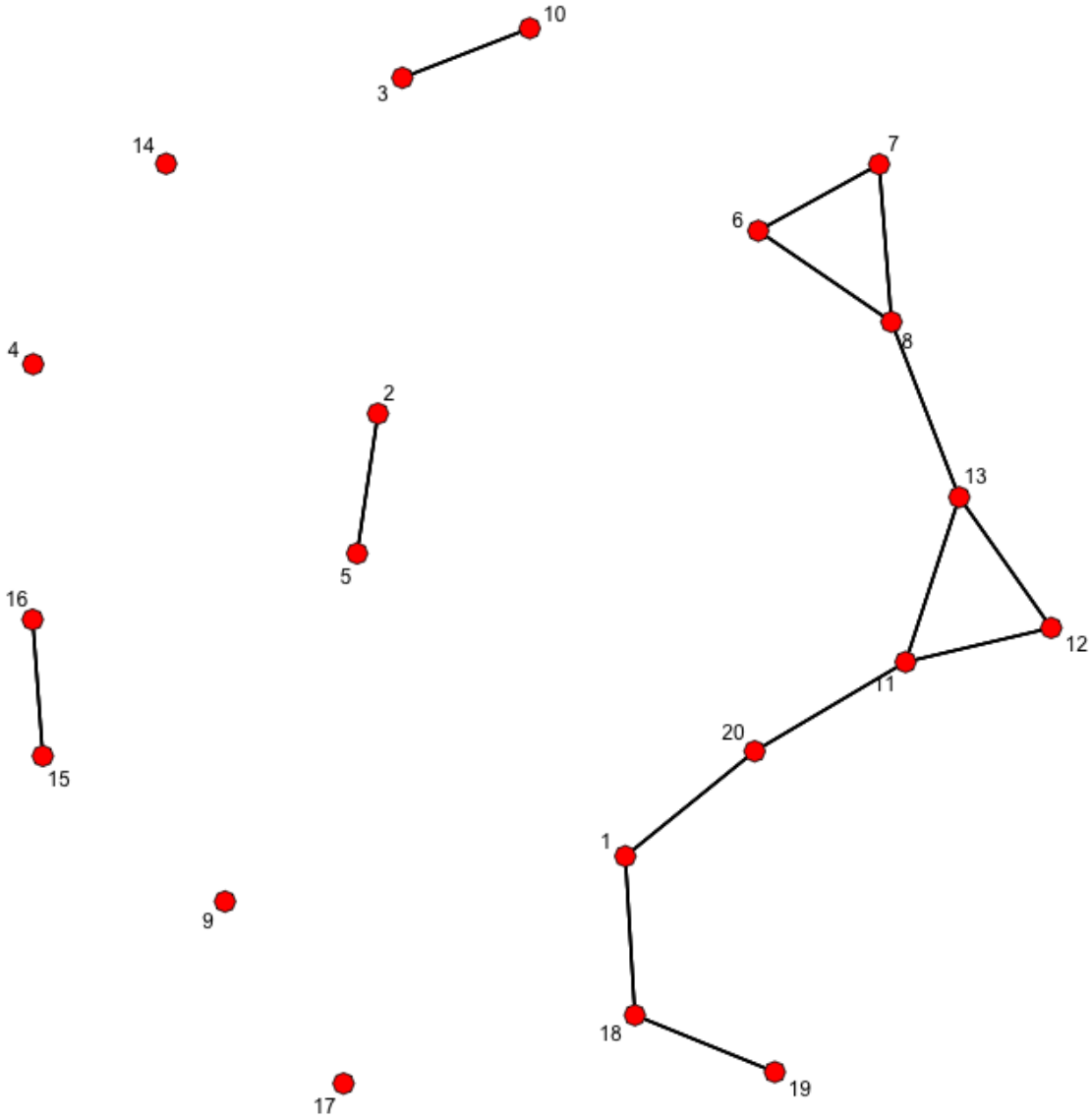
A Sample Run - Year1



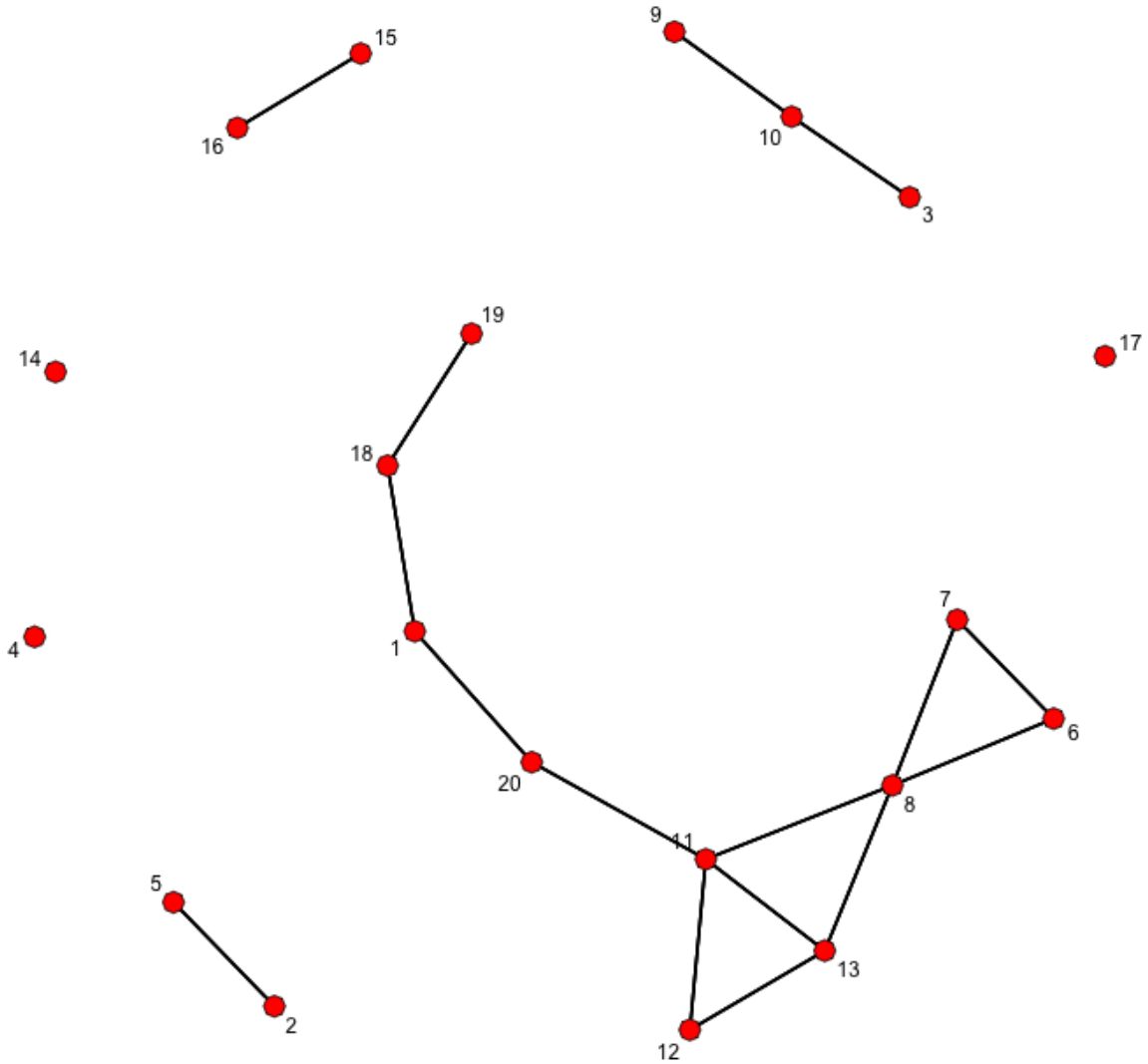
A Sample Run - Year2



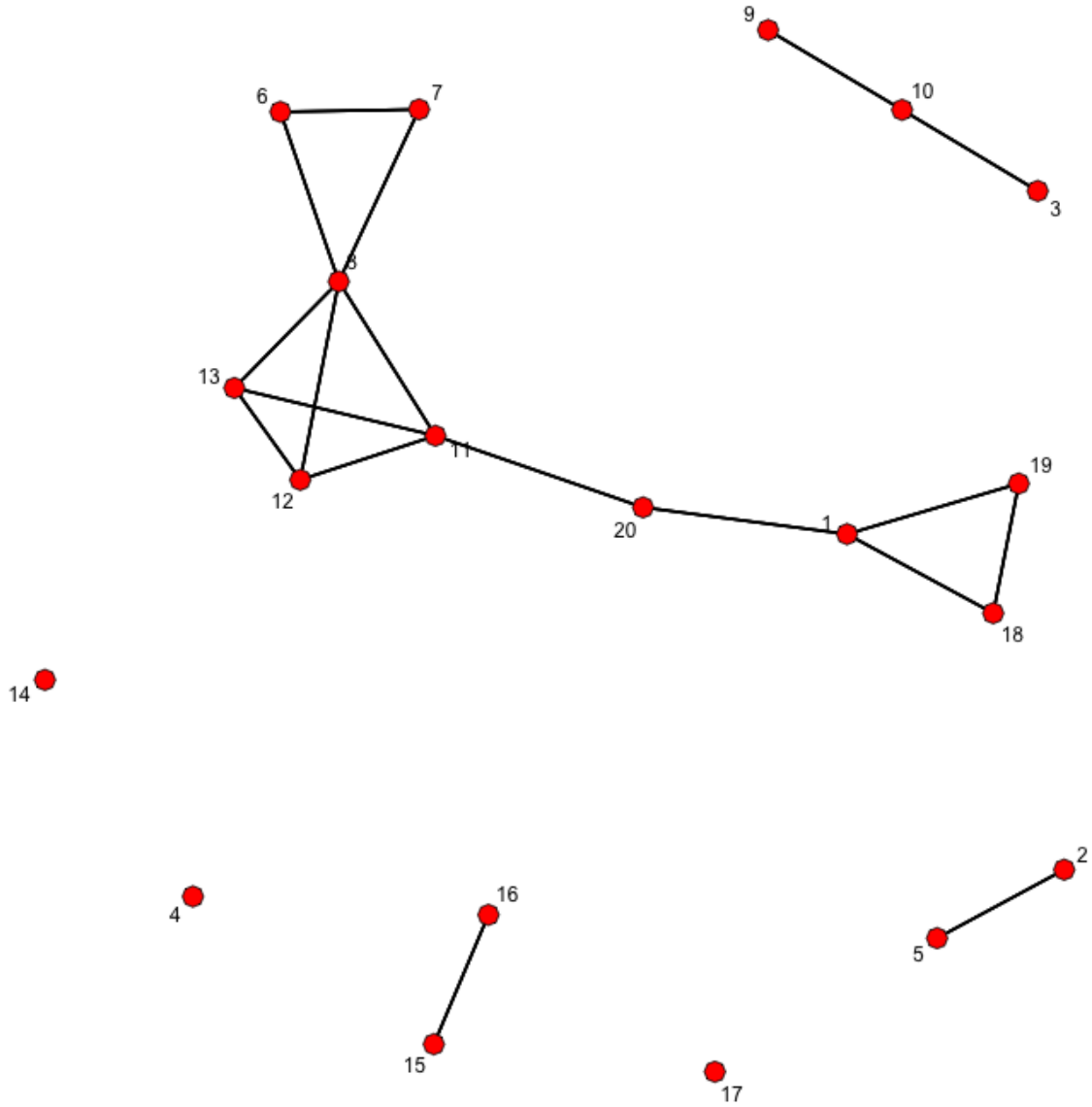
A Sample Run - Year3



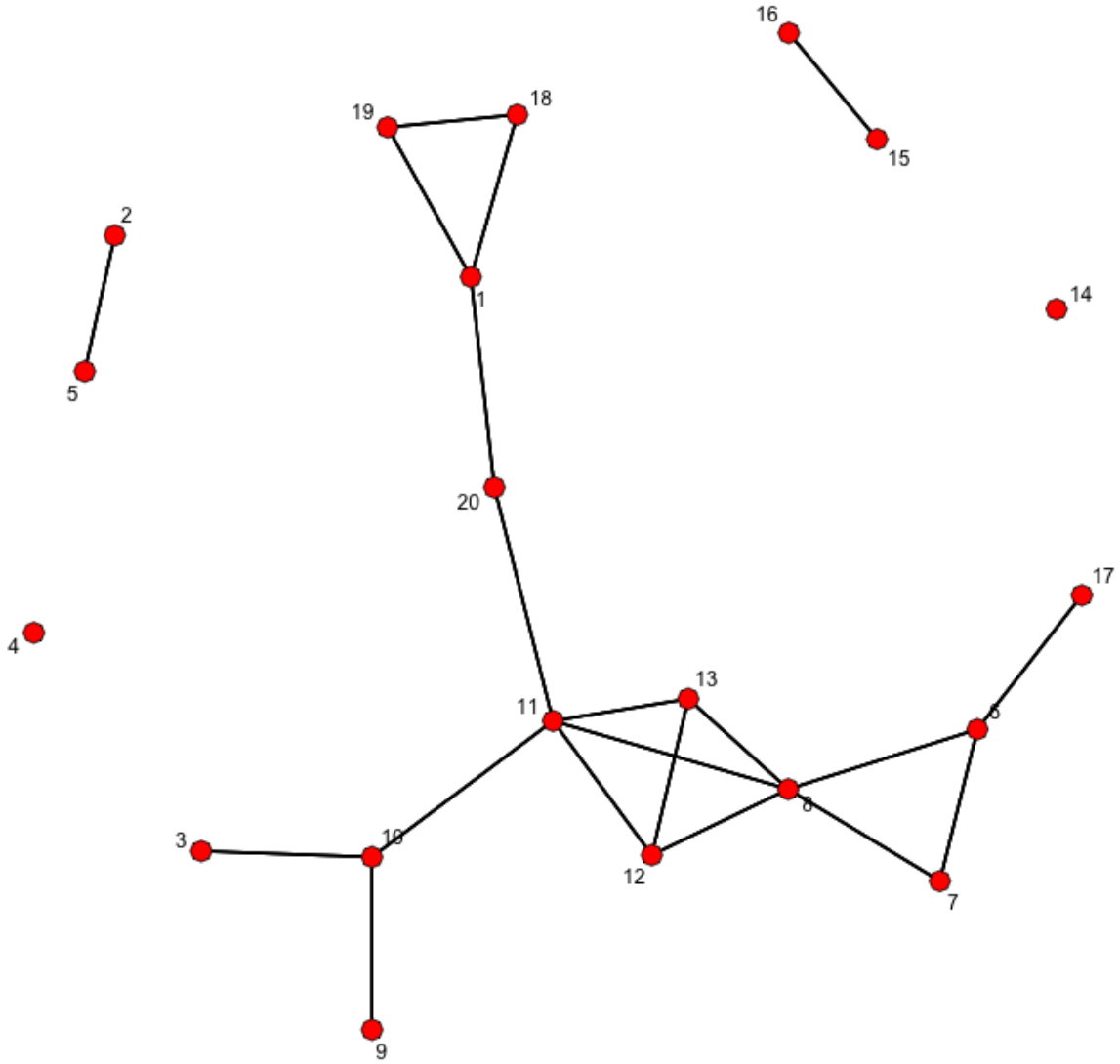
A Sample Run - Year4



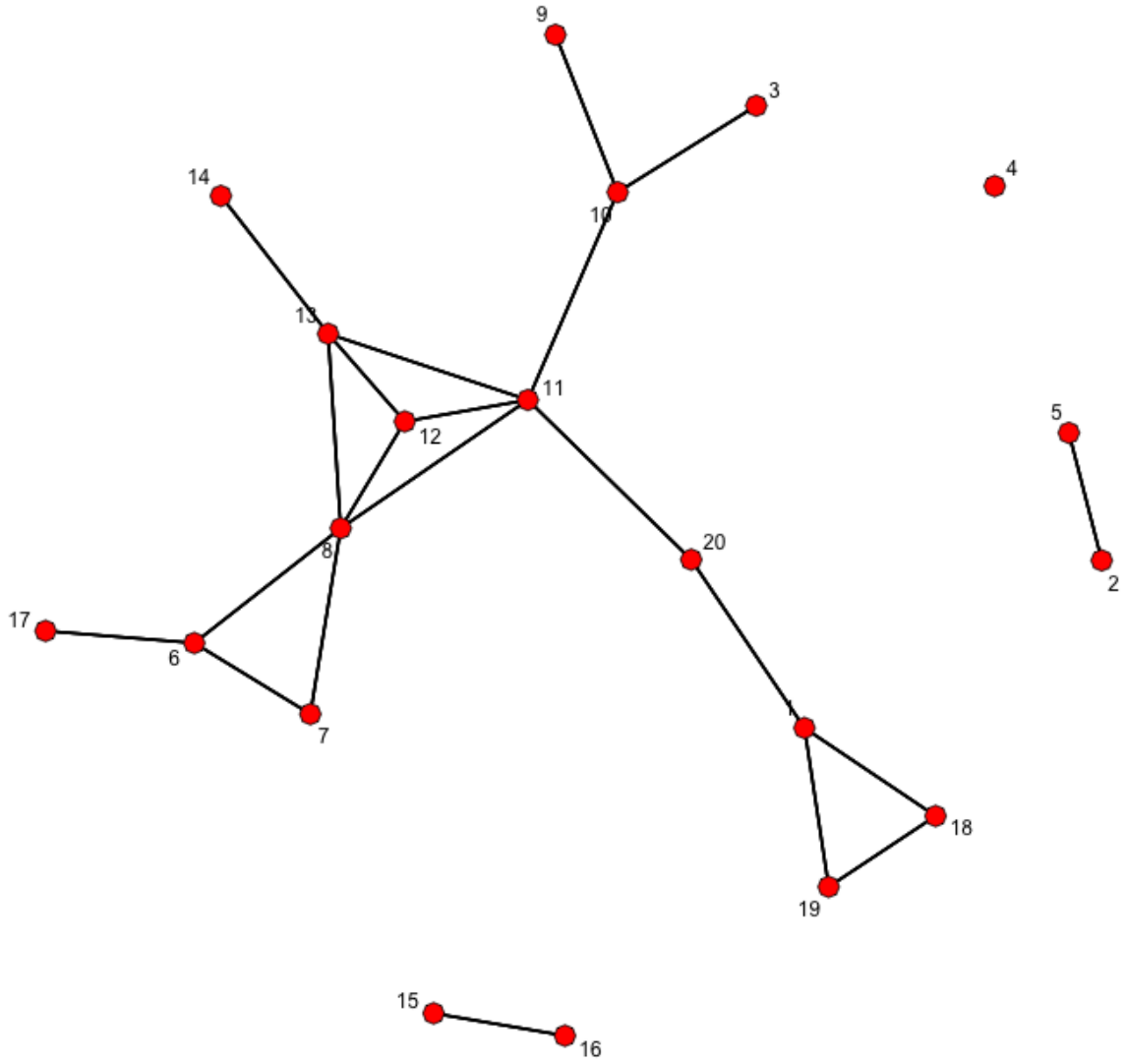
A Sample Run - Year5



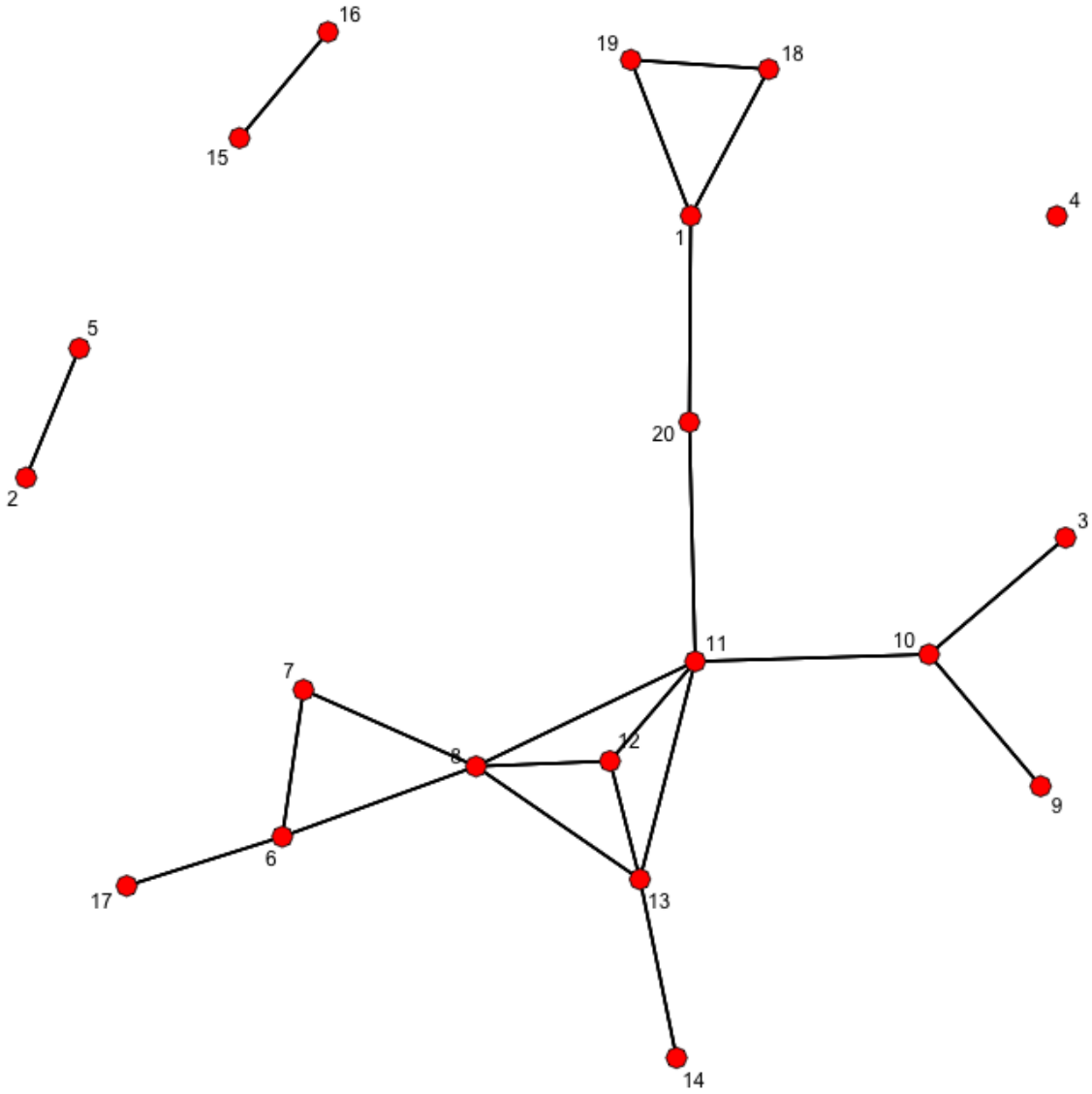
A Sample Run - Year6



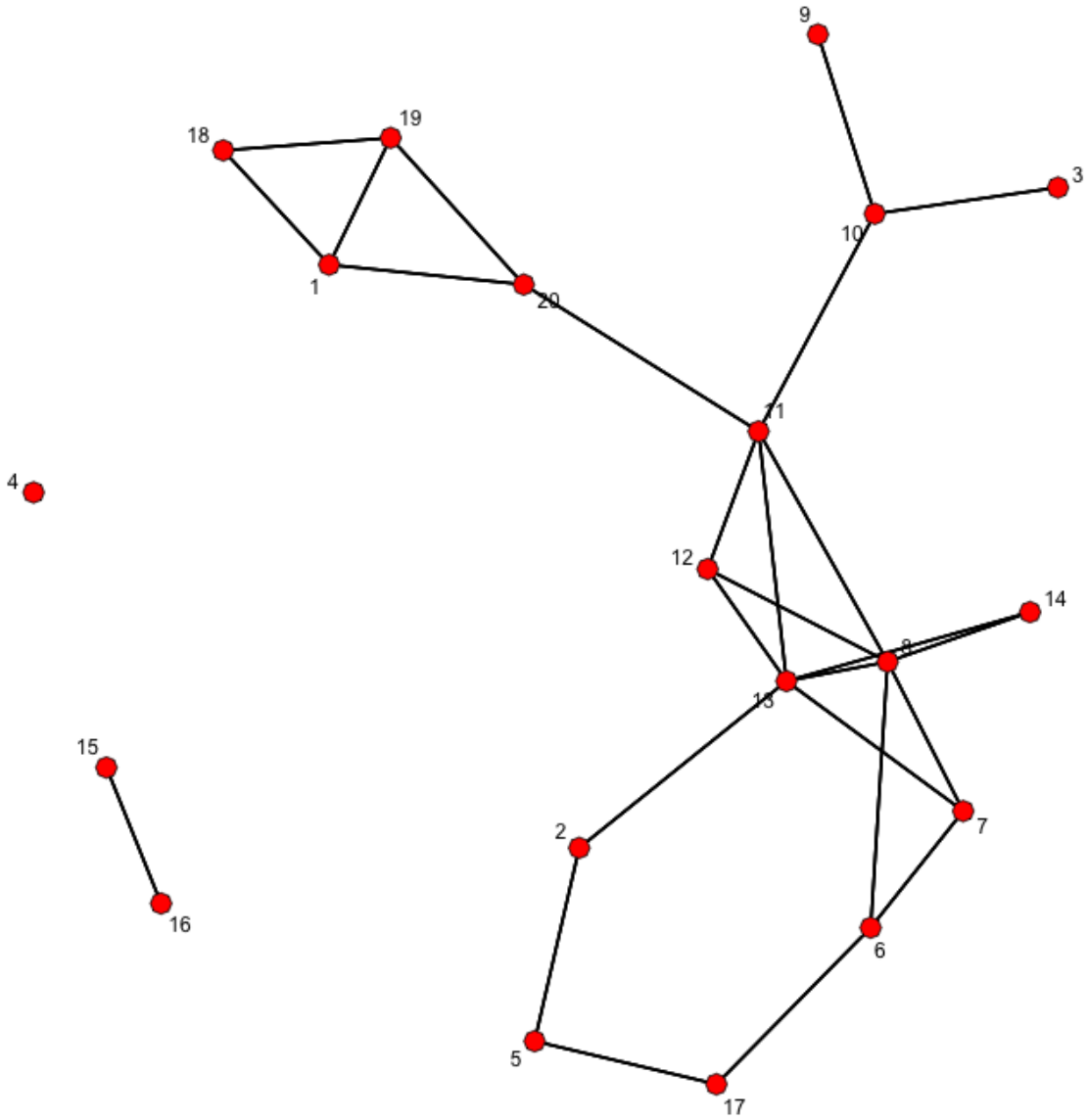
A Sample Run - Year7



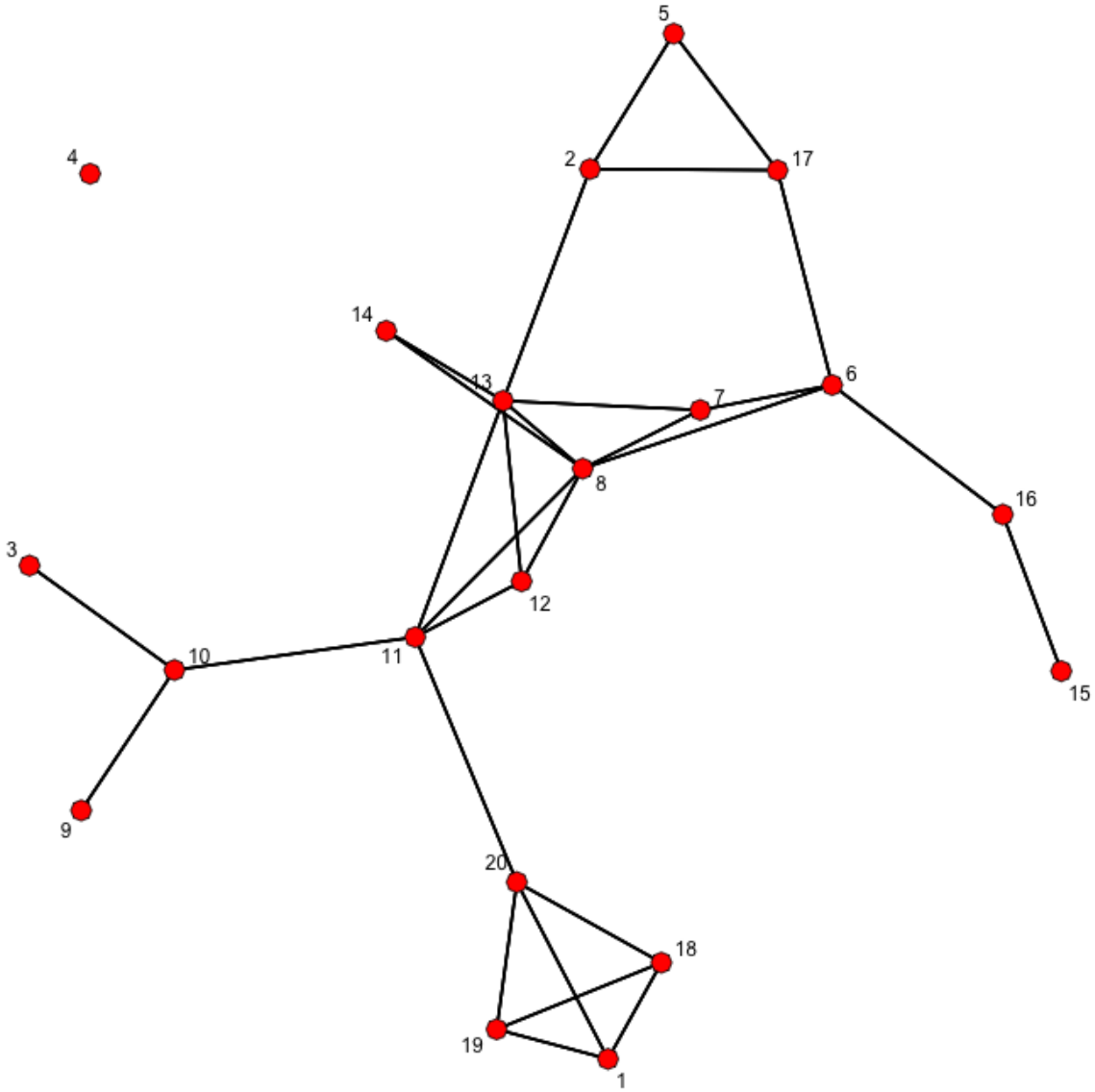
A Sample Run - Year8



A Sample Run - Year9



A Sample Run - Year10



Initial Results

WaveIDs	Components	Density	Triangles	Transitivity
1	12	0.11	2	1.00
2	8	0.15	2	0.40
3	8	0.15	2	0.40
4	7	0.17	3	0.41
5	7	0.19	6	0.58
6	5	0.21	6	0.46
7	4	0.22	6	0.43
8	4	0.22	6	0.43
9	3	0.27	9	0.41
10	2	0.31	12	0.46

Discussion on Further Modelling Issues

- arrival and leave of new agents
- impact of current cognitive structure at incentives to pick a collaborator
- relation in between emergent collaboration structures and cognitive structures
- how new knowledge is semantically related
- validation
- using large data sets