

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

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Outline

Modelling Motivation

Related Simulation Models

Agent Design

Implementation

Initial Results

Discussion on Further Modelling Issues

- ▶ 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"

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

Agent-Agent Interactions

- ▶ co-authorship networks
- ▶ collaboration history
- ▶ transitivity mechanism

Collaboration Behaviors

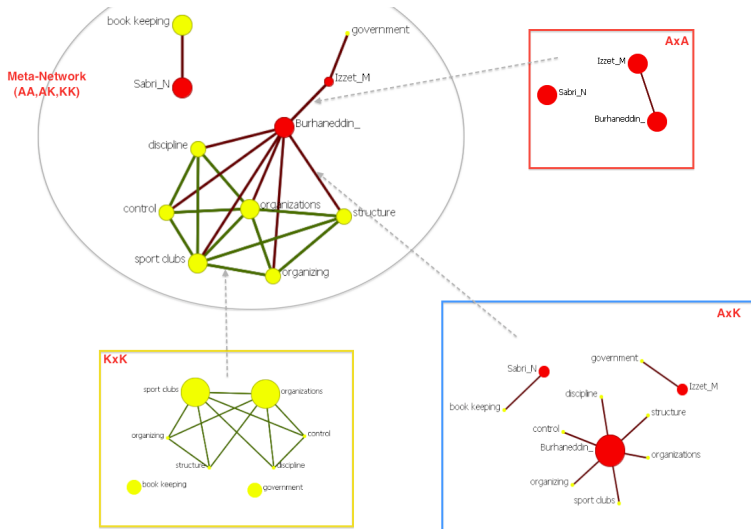
- ▶ stay idle
- ▶ publish solo
- ▶ seek for co-authors

$$P_{w}^n = \begin{cases} \frac{w_{ij}}{\sum_k w_{ik}} & \text{if } n \leq 2 \\ \left(\frac{w_{ij}}{\sum_k w_{ik}}\right)^{n-1} & \text{otherwise} \end{cases}$$

Cognitive Structure of Agents

- ▶ publication keywords
- ▶ keyword co-occurrence 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:

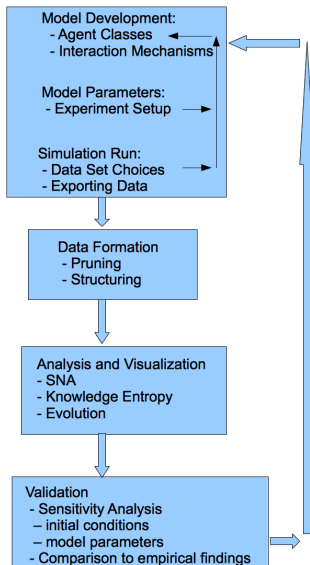
$$P_w = \frac{w_{ij}}{\sum_k w_{ik}}$$

- ▶ 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

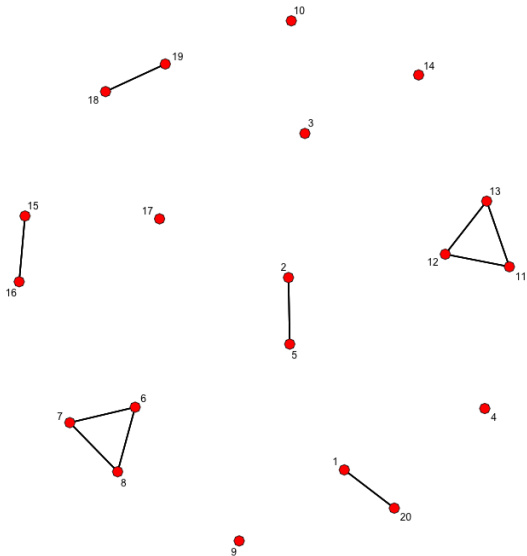
Implementation Chart



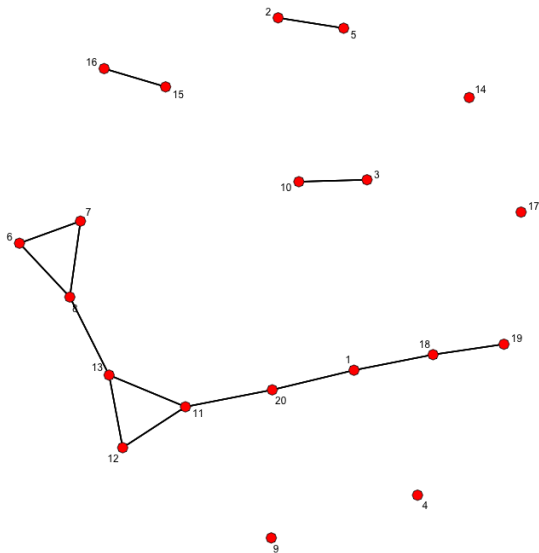
- ▶ RePast(Java) Platform
 - ▶ model development
 - ▶ initialization
 - ▶ experiment setup
 - ▶ simulation
- ▶ Python
 - ▶ simulation output data formation
- ▶ R Programming
 - ▶ Packages: Base, SNA, Network, RSiena
 - ▶ analysis
 - ▶ visualization
 - ▶ validation

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

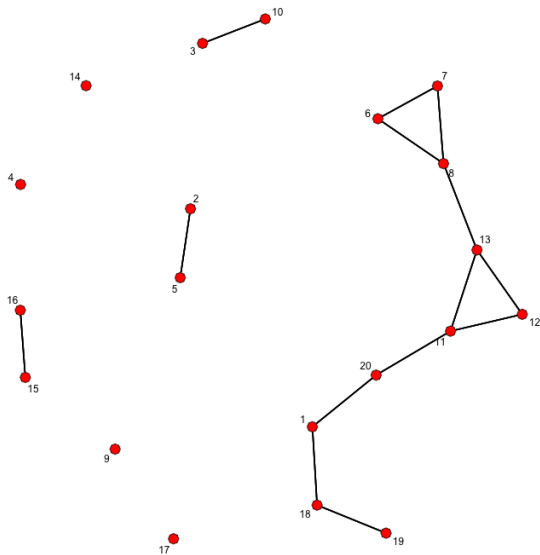
A Sample Run - Year1



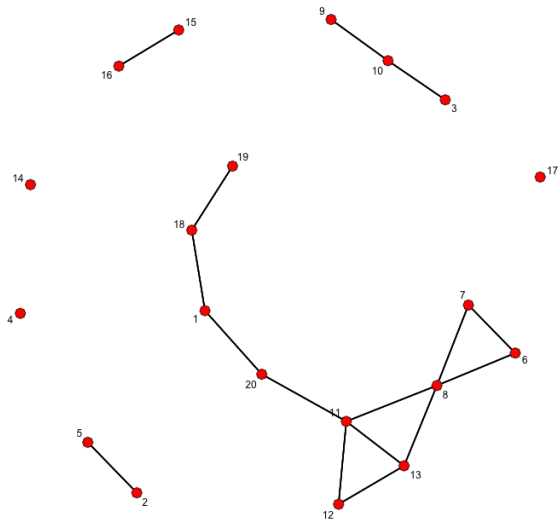
A Sample Run - Year2



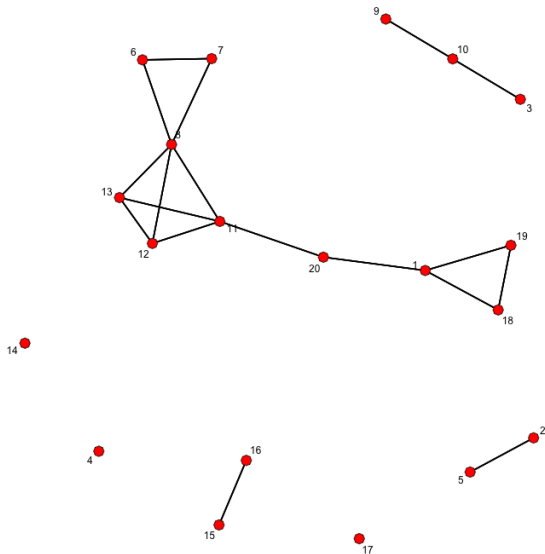
A Sample Run - Year3



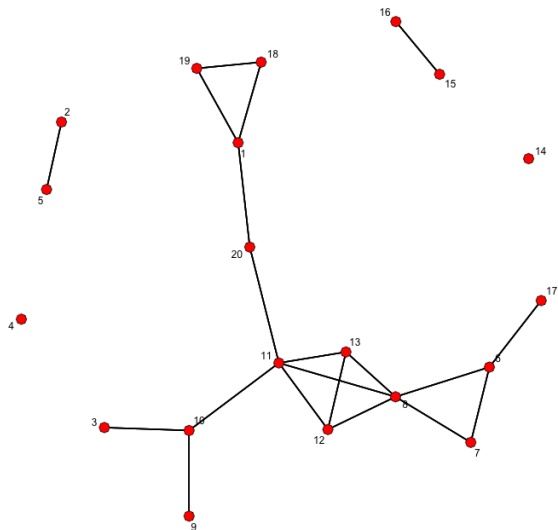
A Sample Run - Year4



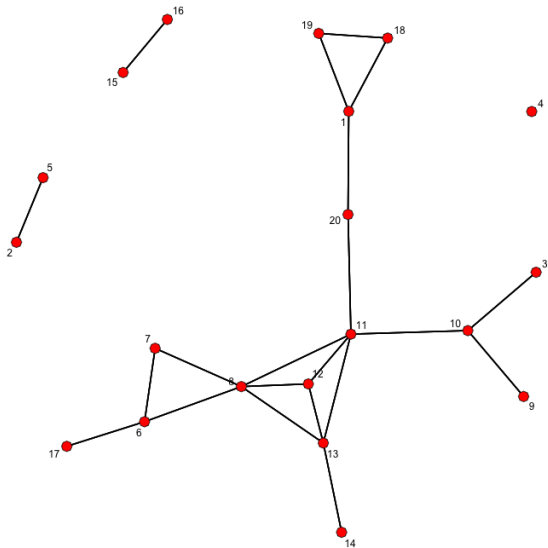
A Sample Run - Year5



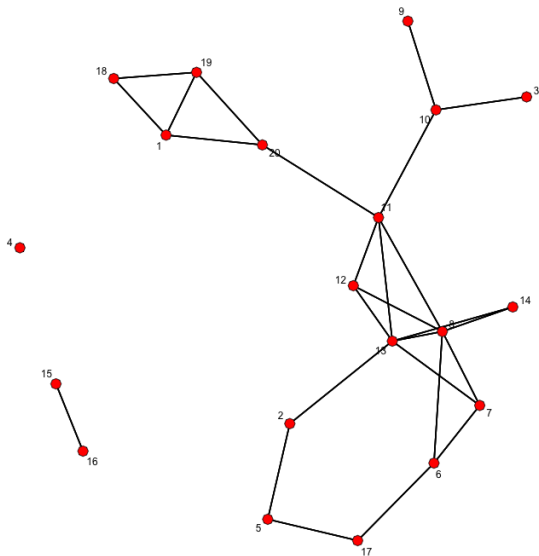
A Sample Run - Year6



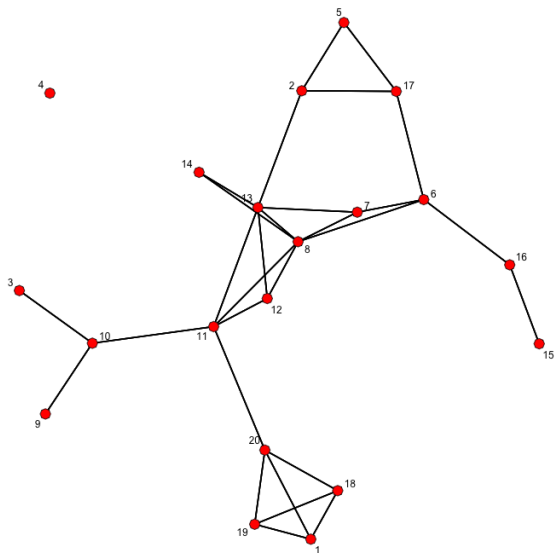
A Sample Run - Year8



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