Learning to Reciprocate

An Agent-based Model of Conditioned Social Exchange

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The emergence of reciprocal exchange relations

research question: *How does the opportunity structure affect the formation and dynamics of reciprocal exchange relations?*

opportunity structure: distribution of actors & their resources

- an agent's resources
- an agent's neighbours (exchange opportunities)
- general availability of resources

The social exchange approach

George C. Homans [1958]: "interaction between persons is an exchange of goods, material and non-material"

Peter M. Blau [1964]: "Neighbors exchange favours; children, toys; colleagues, assistance; acquaintances, courtesies; politicians, concessions"

$\rightarrow$ flow of beneficial events through social interaction

an agent-based simulation of conditioned reciprocal exchange

- based on statements in Emerson [1972a,b]
- operant conditioning / behaviourism
- emergence of exchange relations
- expansion to large numbers of independent actors
- explaining macro-phenomena on behaviourism

The actors' model

- set of agents: $N = \{a, b, \dots\}$
- set of resources: $X = \{help, cake, thank, \dots\} \cup \{rest\}$
- neighbours: $N_a \subseteq N \setminus \{a\}, a \in N$
- abilities: $X_a \subseteq X \setminus \{rest\}, a \in N$
- actions: $Z_a = (N_a \times X_a) \cup \{\overline{x}\}, a \in N$
- probability distribution: $p_a : Z_a \to [0, 1], \sum_{z \in Z_a} p_a(z) = 1$

The actors' model

- actors are differently equipped with resources and opportunities to exchange
- initially, only random actions
- actors develop beliefs about the chances to obtain resources after emitting an action to a certain neighbour
- the received resources act as reinforcement for the preceding action
- relationships emerge if agents emit actions with a non-trivial probability
- the value of a resource is subject to its overall availability. Emerson [1972a]: *Assumption 4:* The value of a resource y varies directly with its degree of uncertainty $U(y) =$ "something like" $4 \cdot E(y) \cdot (1 - E(y))$.

The actors' model

- an agent a remembers $n_a \leq n_{max}$ transactions
- agent a's 'beliefs': $E_a(y|z) = \frac{n_a(y,z)}{n_a(z)}$, $n_a(z) = \sum_{y \in X} n_a(y,z)$
- $E_a(y) = \sum_{z \in Z_a} \frac{n_a(y,z)}{n_a(y)} \cdot E_a(y|z)$, $n_a(y) = \sum_{z \in Z} n_a(y,z)$
- value: $v_a(y_k) = 4 \cdot E_a(y) \cdot (1 - E_a(y))$

$$p_a(z) = \frac{\sum_{y \in X} v_a(y) \cdot E_a(y|z)}{\sum_{z_i \in Z_a} \sum_{y \in X} v_a(y) \cdot E_a(y|z_i)}$$

- random actions with probability $\hat{p} > 0$

Differential reinforcement

Assumption 1: Given a neighbour b and any response y: If $E_a(y|bx_1) \leq E_a(y|bx_2) \leq \cdots \leq E_a(y|bx_n)$, then the probability distribution over the actions of agent a will change until $p_a(bx_1) \leq p_a(bx_2) \leq \cdots \leq p_a(bx_n)$.

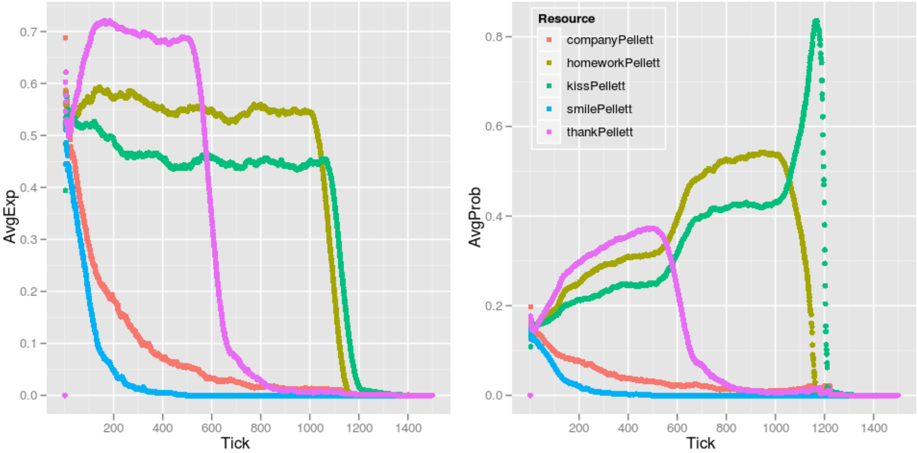
Assumption 1.1 ("Exploration"): Given a neighbour b, a decrease in $E(y|bx)$ produces an increase in behavioural variation across actions in $\{b\} \times (X_a \setminus \{x\})$.

Assumption 1.2 ("Extinction"): Given a neighbour b, if $E(y|bx)$ reduces to 0.0 for all actions $(b, x) \in \{b\} \times X_a$, then the corresponding $p_a(bx)$ will decrease to the "operant level".

Differential reinforcement

100 agents in 100 “Skinner boxes”

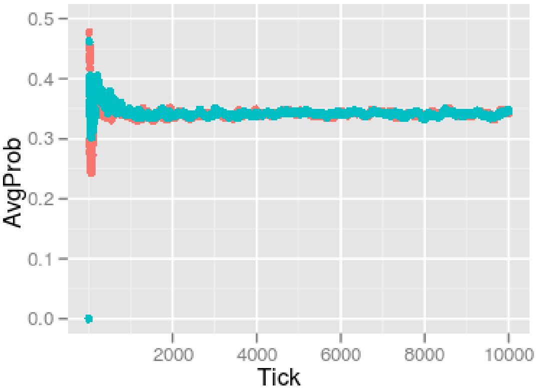
$\hat{p} = 0.001,\ t_{max} = 3,\ n_{max} = 100$

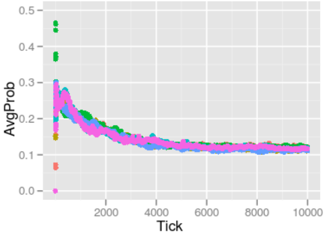


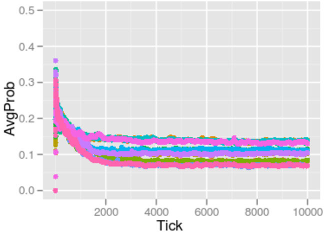
Learning to reciprocate

$\hat{p} = 0.001,\ t_{max} = 3,\ n_{max} = 100$

2-4 agents, 1 resource per agent

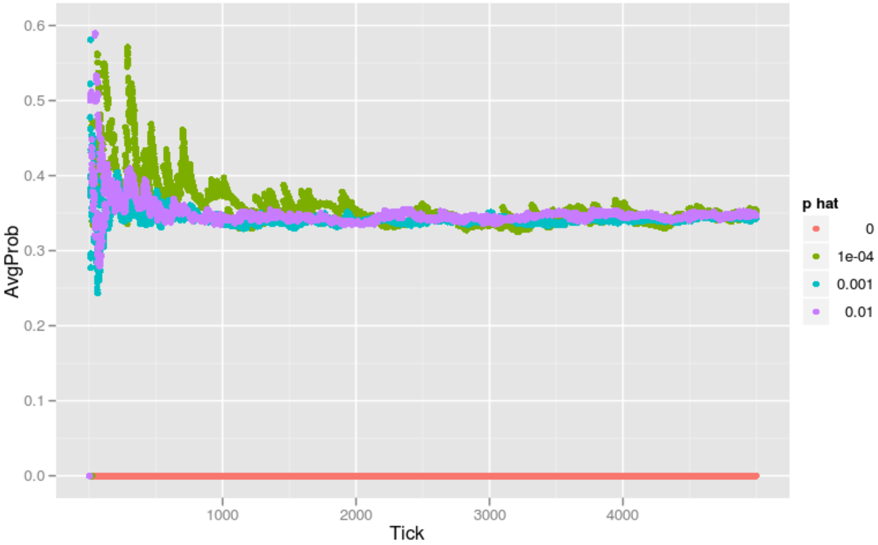






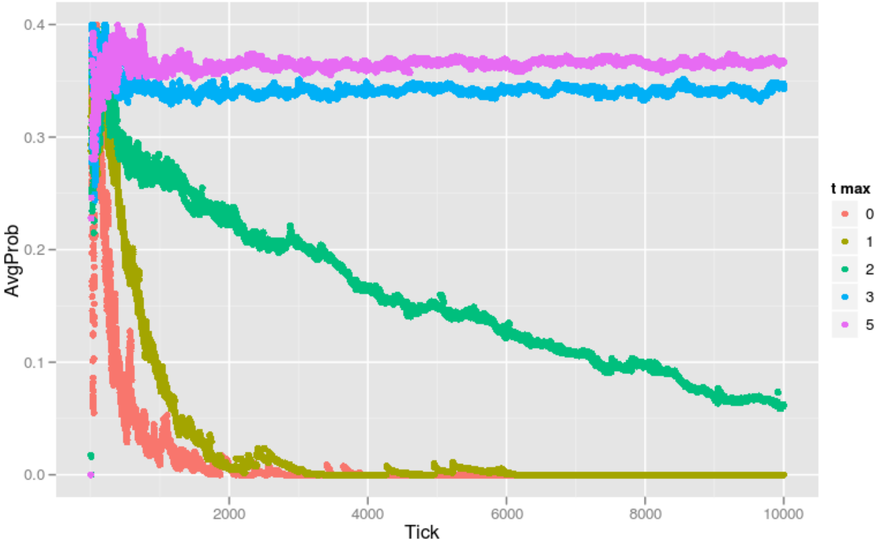
Learning to reciprocate - "operant level"

$t_{max} = 3, \ n_{max} = 100$



Learning to reciprocate - maximal waiting time

$\hat{p} = 0.001, \ n_{max} = 100$



Dependence

Definition

In any exchange relation, a is said to be *dependent* upon b if some resources y are contingent upon b, and the magnitude of dependence is a joint function of this contingency and the value and number of resources in the relation:

$$D_a(b) = \sum_{y \in X} v_a(y) \cdot \frac{n_a(y, b)}{n_a(y)}$$

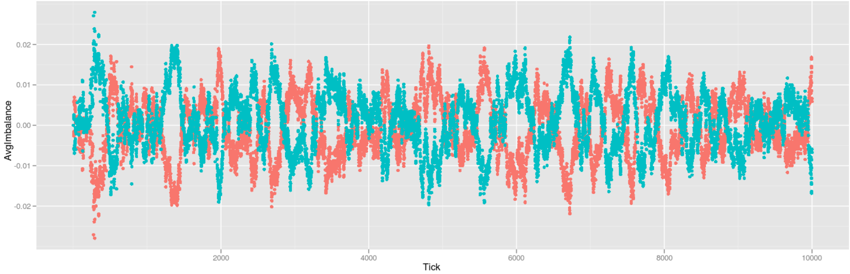
- $D_a(b)$ varies inversely with the number and degree of alternatives to b.

Balancing

Definition

A (bilateral) exchange relation between a and b is said to be *balanced* if $D_a(b) = D_b(a)$. Imbalance $= |D_a(b) - D_b(a)|$.

Theorem 5: In any exchange relation, if $D_a(b) > D_b(a)$ at time t_1, then $D_a(b)$ decreases or $D_b(a)$ increases across continuing transactions until $D_a(b) = D_b(a)$ at time t_n.



2 agents, 1 resource each

Balancing operations

If $D_a(b) > D_b(a)$

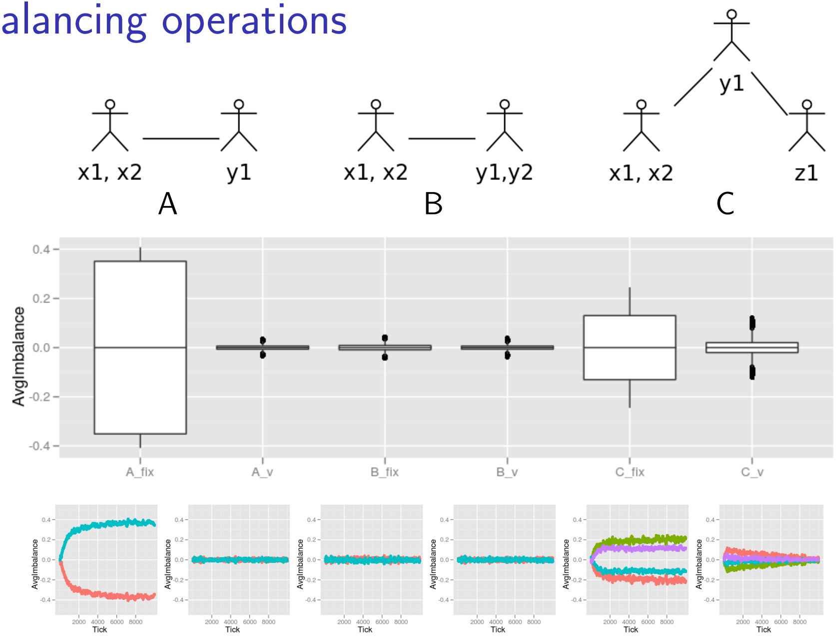
Op1 ("Withdrawal"): A decrease in the value of y for a.

Op2 ("Network Extension"): An increase in the number of alternatives open to a.

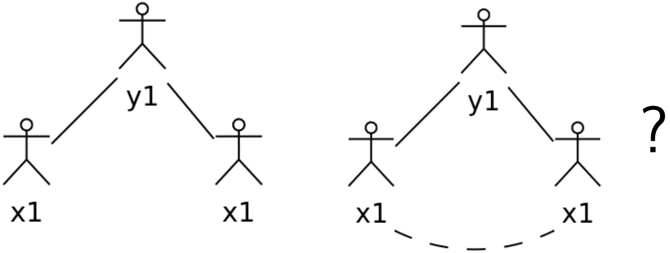
Op3 ("Status Giving"): An increase in the value of x for b.

Op4 ("Coalition Formation"): A reduction in the number of alternatives open to b.

Balancing operations



Balancing operations



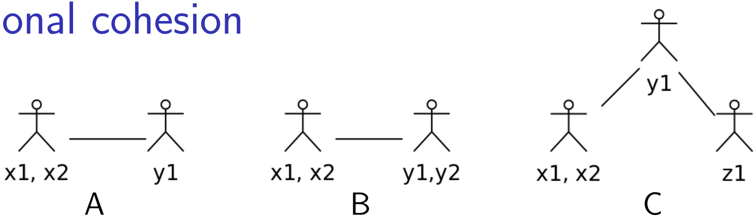
Relational cohesion

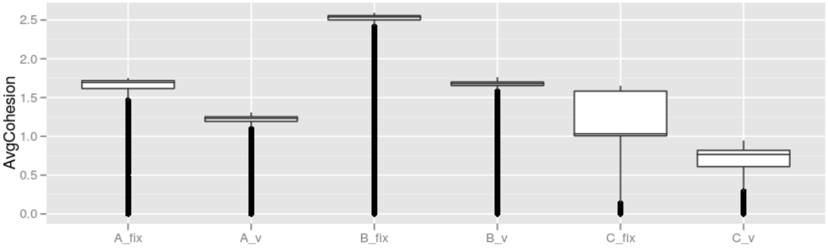
Definition

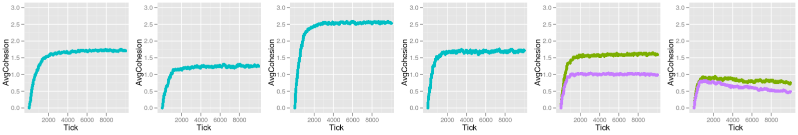
For a relation between a and b, cohesion $= (D_a(b) + D_b(a))/2$.

Corollary 3.5: Operation 1 and 2 decrease relational cohesion, and Operation 3 and 4 increase cohesion.

Relational cohesion







Outlook

1. defending the model - does it imply all corollaries and theorems by Emerson [1972a,b]?
2. sensitivity analysis: varying the independent variables
3. expand to large groups and indirect reciprocal exchange
4. build (macro-)hypotheses: relationship between resources distribution and network structure
5. empirically test the hypotheses by using the World Wide Web, e.g. Twitter, Google Groups

References

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Richard M. Emerson. Exchange Theory, Part I: A Psychological Basis for Social Exchange. In Joseph Berger, Morris Zelditch, and Bo Anderson, editors, *Sociological Theories in Progress*, volume 2, chapter 3, pages 38–57. Houghton Mifflin Company, 1972a.

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George C. Homans. Social Behavior as Exchange. *American Journal of Sociology*, 63(6):597–606, 1958.