Hybrid Models for Achieving and Maintaining Collaborative Symbiotic Groups

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Outline

- Introduction
- Edmonds' Symbiotic Group Model
- Modeling Reciprocity
- Hybrid Models
- Evaluation
- Conclusion

Introduction

- In many real life settings, resources are distributed unevenly among individuals.
- Symbiotic groups are groups in which individuals complement each other in resources.
- However, not all individuals are equally collaborative!

Selfish behavior

- In a collaborative group, selfish behavior is useful for the individual itself.
- But this may obstruct others to collect necessary resources.
- Hence for members, it is best to be in a collaborative symbiotic group without selfish agents.

Desired Properties

- A collaboration model that will allow symbiotic groups to be formed effectively and efficiently.
  - Effective: Allow trading of resources
  - Efficient: Formed with few interactions
- After they are formed, the groups should live long.
- The agents that are threat to life-span of the group should be eliminated fast.

Multiagent-Based Modeling

- We model human societies as autonomous and heterogeneous agents.
  - Autonomous: They may or may not help each other.
  - Heterogeneous: They may have different resources.
- We study two leading techniques of collaboration:
  - Tag based: Each agent has a public tag; collaborate with others of similar tags.
  - Reciprocity based: Agents keep track of who is helping them and collaborate accordingly.

Edmonds' Symbiotic Group Model

- Environment consists of agents and different types of resources.
- Each agent represents an individual with:
  - a certain skill
  - a tolerance value
  - particular amount of each kind of resource
- Each agent must have each kind of resource to survive. That makes agents form groups.
- Agents with certain amount of each kind of resource give offspring.

Properties of Agents

- Tag: An observable property of an agent; says nothing about agent's capabilities.
  - i.e. people with red beards.
- *Skill* of an agent: Determines the type of food that agent can harvest.
- *Tolerance* of an agent: Determines how selfish an agent is.
- *Tag* of an agent is the only observable value.

Sharing the resources

- Consider that there are 3 types of food, so there are 3 different skills. An agent of skill 2 can harvest food of type 2.

- At every time step agents are randomly paired to see if they exchange food.

- Consider agents A (tag=0.5, tolerance=0.03) and B(tag=0.52) are paired. A donates to B, because:

A.tag-A.tol		B.tag		A.tag+A.tol
0.47	≤	0.52	≤	0.53

- Consider now agent C (tag=0.5 tolerance=0.01) and B (tag = 0.52) are paired. C doesn't donate to B, because:

C.tag-C.tol		C.tag+C.tol		B.tag
0.49	≤	0.51	≤	0.52

Offsprings and Death

- At each step, agents with enough resources give offspring, with or without some Gaussian noise.
- An agent can die for one of two reasons: either it has reached to maximum possible age, or it starves (i.e. doesn't have one kind of food)

The evolution of the agent society in Edmonds' model

- A small "seed" collection of cooperative agents with similar tags arises initially.
- The cooperative agents grow in number due to their interaction. The ones out of cooperation starve.
- Eventually selfish agents arise in the group. Since they do not share resources, but receive donations, selfish agents are more advantageous.
- Therefore they give many offsprings. They dominate the group.
- But the more selfish agents, less the sharing of resources. Hence the group dies.

Observations

- In Edmonds' model, agents form groups but the groups do not live long. They are defected by selfish members.
- Groups cannot live long enough to detect selfish individuals.
- If agents can cooperate to eliminate selfish members early on, they can form persistent groups that live long and not wiped out by the selfish members.
- To achieve long lived societies, add reciprocal behavior to agents!

Modeling Reciprocity

- The intuition behind reciprocity:
  - Agents should help those that help them in return. For that purpose we add memory to the agents.
- Can be modeled in several ways:
  - Strict Individual Reciprocity Model
  - Relaxed Individual Reciprocity Model
  - Group Reciprocity Model

Hybrid Models

- Combinations of Edmonds' tag-based model, and reciprocity models.
  - Strict Individual Model
  - Relaxed Individual Model
  - Group Model

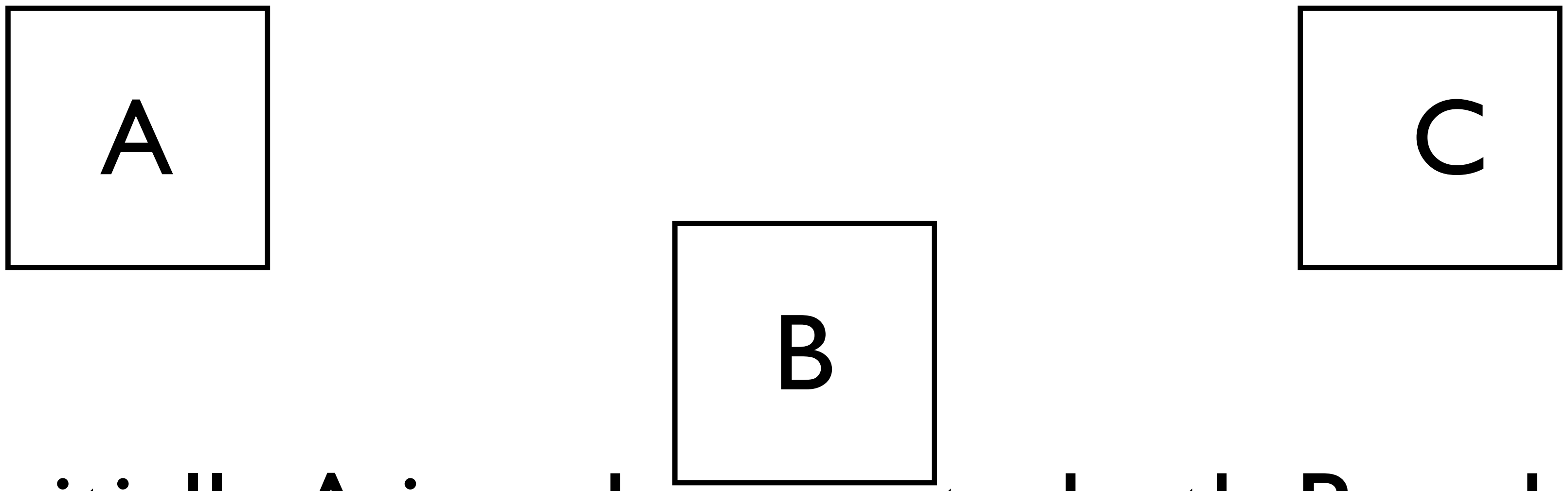
Strict Individual Model

- An agent will only help other agents if they have necessarily been helpful before.
- Consider two agents A and B.
  - A has donated to B 2 times,
  - B has donated to A 10 times until now.
  - When B is paired with A, B rejects to donate A even if they are similar in terms of tag values.

Relaxed Individual Model

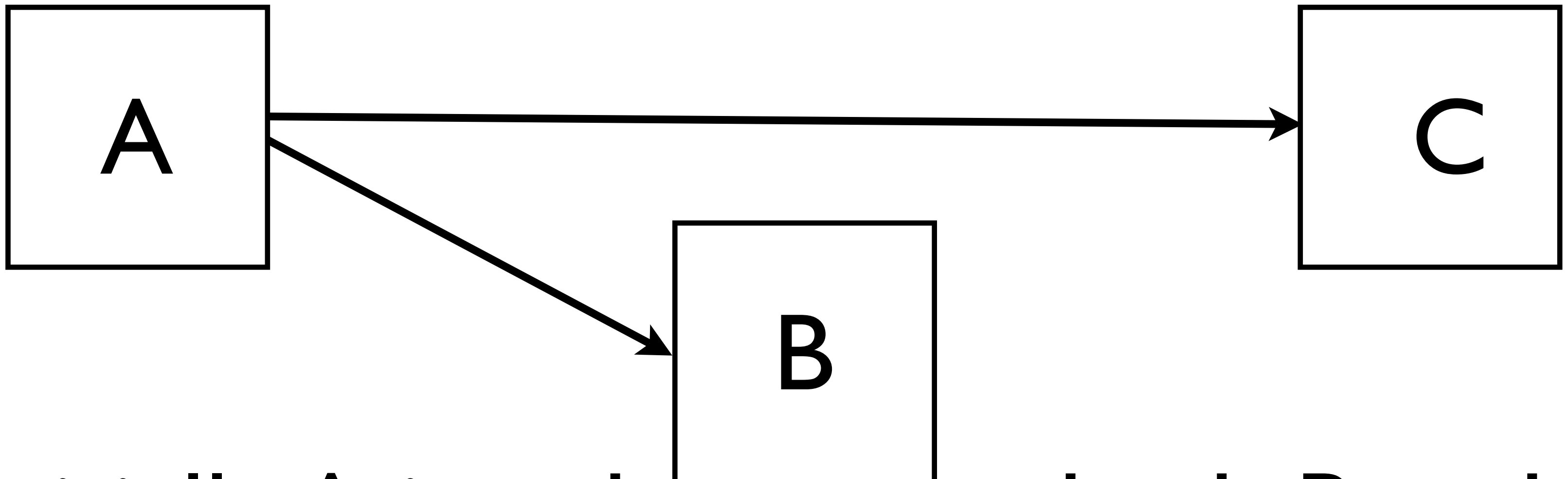
- Each agent maintains a general opinion about every other agent, but does not model them precisely as it was in Strict Individual Model.
- Agent A can model agent B as *donating, selfish or unknown.*
  - B is a donating agent, if it donated to A last time.
  - B is a selfish agent, if it refused to donate to A last time.
  - B is unknown, if A and B have never interacted before.
  - A donates to B, if B is either *donating* or *unknown* and has similar enough tag value.
- In the beginning each agent is unknown to all others.

Relaxed Individual Model



- Initially A is unknown to both B and C.
- Then A is paired with B and C. And A donates B, but rejects to donate C.
- After all, B labels A as donating, whereas C labels A as selfish.

Relaxed Individual Model



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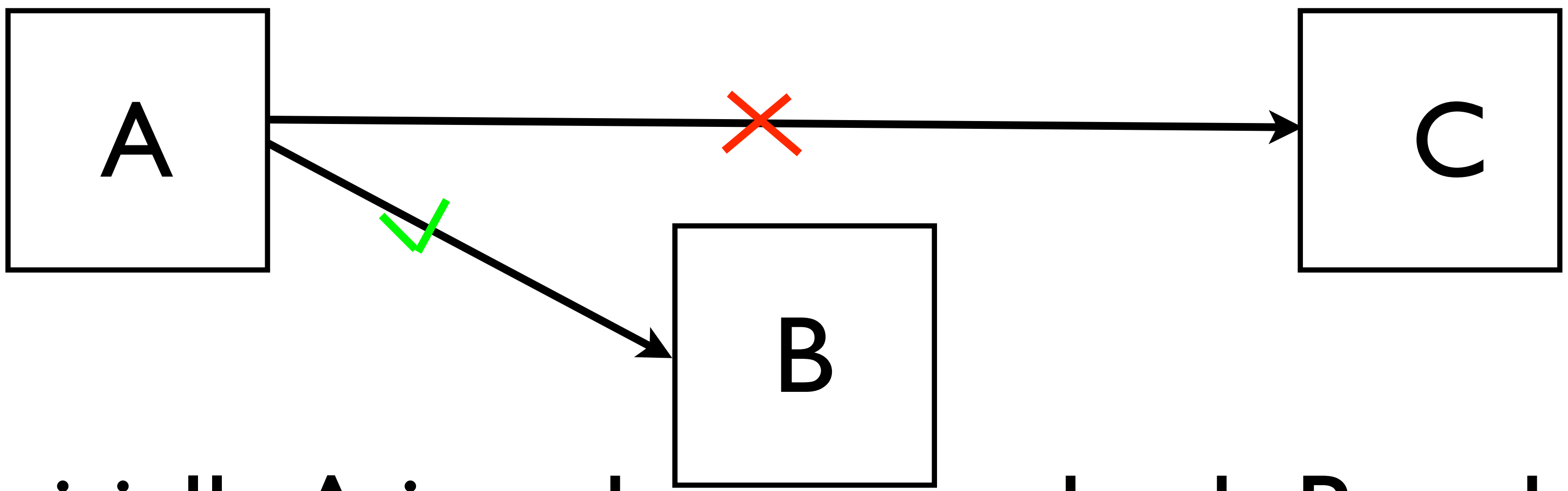

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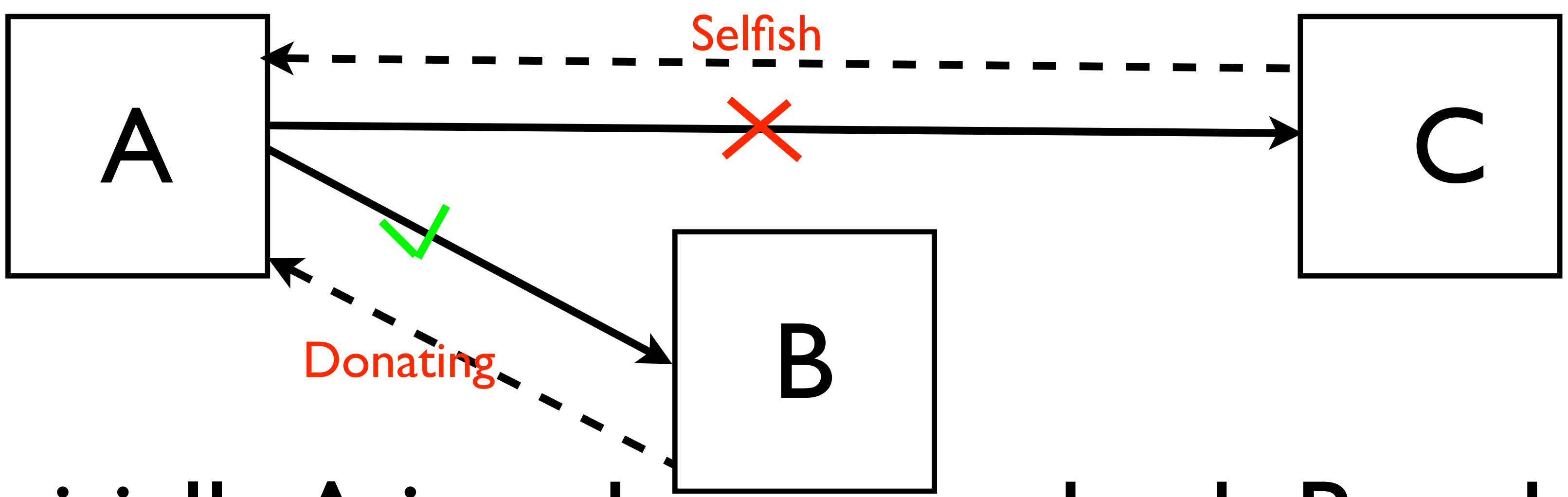

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- Then A is paired with B and C. And A donates B, but rejects to donate C.
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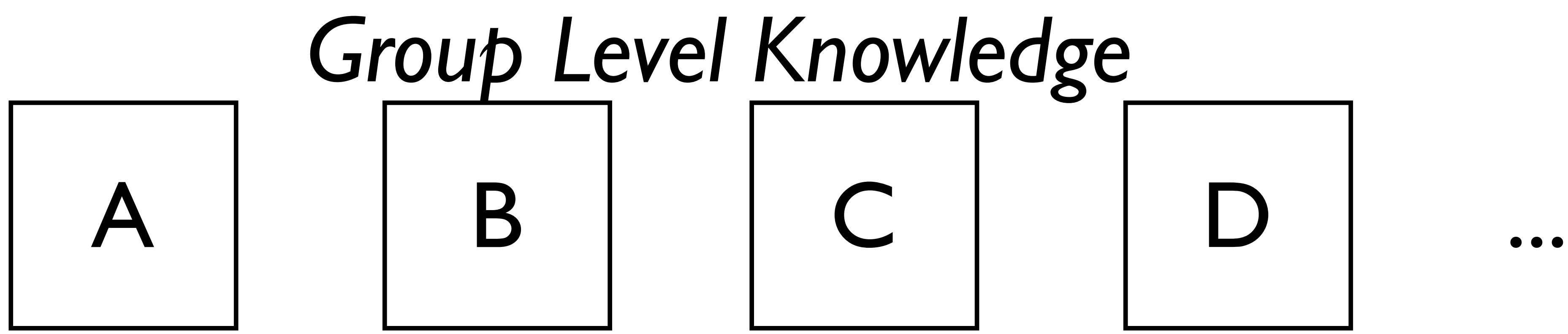
Group Model

- Contrary to the previous two models, we assume that agents in the same group share information among the group.
- If an agent is known to be generous group wise, then agents will donate to that agent and vice versa.

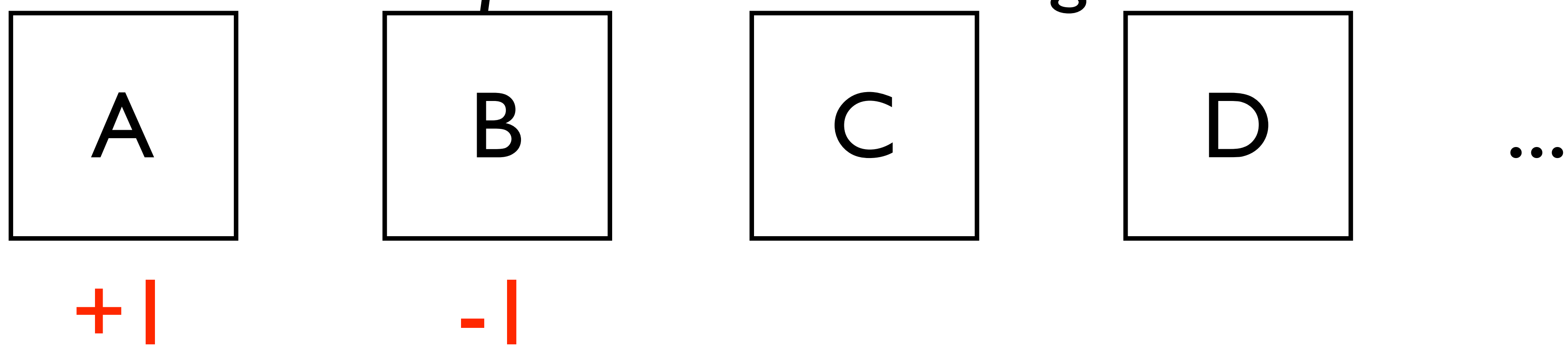
Group Model



- A donates to B.
- All other agents now know that A is donated.
- And all other agents now know that B received a donation.

Group Model

Group Level Knowledge



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Evaluation of the Hybrid Models

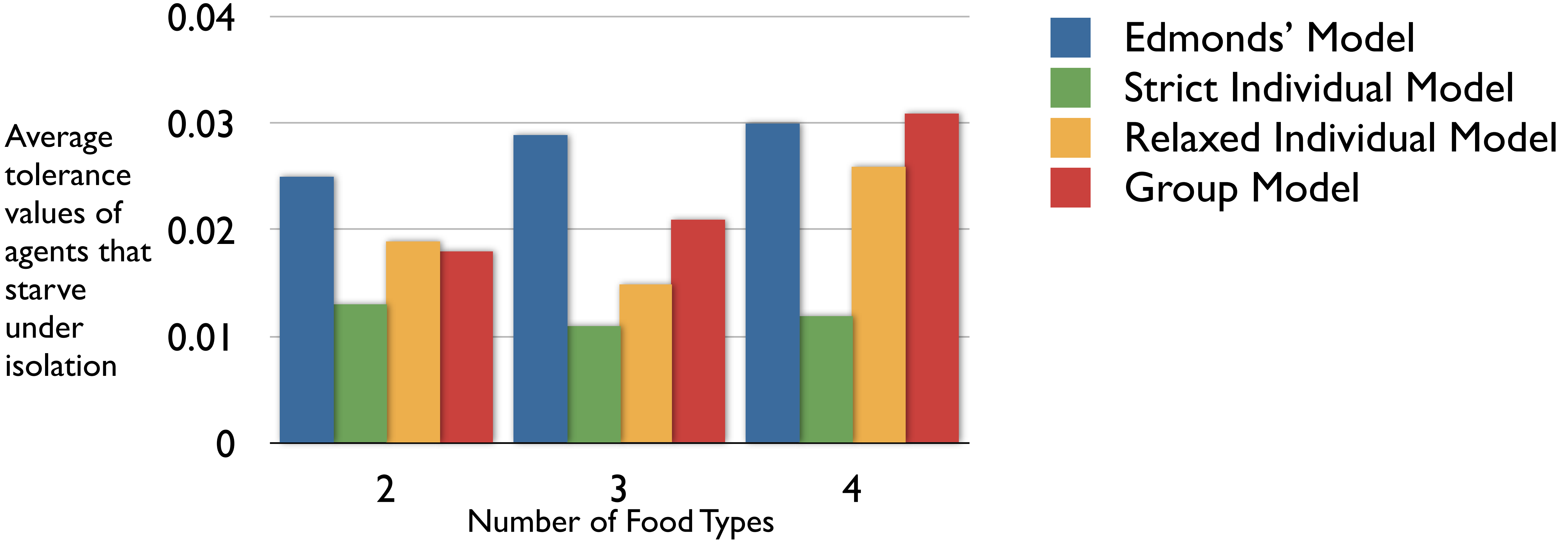
- Eliminating Selfish Agents
  - Success in Eliminating Selfish Agents
  - Time-line of Eliminating Selfish Agents
- Effectiveness of Symbiotic Groups
- Efficiency of Symbiotic Groups

Simulation Environment

- Repast simulation environment.
- We replicated each configuration for 20 runs over 5000 steps.
- We *isolated* the population to observe models better.
    - After population reaches a size, ϕ
    - Difference between sizes of any two subpopulation is smaller than Δ.

Success in Eliminating Selfish Agents

- Observe the tolerance values of the agents that die from starvation in cooperative group.
- In all three models the average tolerance value of the agents that die from starvation is less than that of Edmonds'.



Time-line of Eliminating Selfish Agents

- We need to show that these eliminations of selfish agents take place quickly and that the groups stabilize in a short time.
- We observe the percentage of selfish agents in the population at the beginning of the simulation, and after 1%, 2%, 3%, 10%, 50% and 90% of the time passed.

MaxTol = 0.05, Φ = 150, Δ = 60 # of foodtypes =2	%0	%1	%2	%3	%10	%50	%90
Edmonds' Model	0.16	0.16	0.16	0.16	0.16	0.16	0.15
Strict Individual Model	0.15	0.14	0.14	0.14	0.07	0.07	0.07
Relaxed Individual Model	0.10	0.09	0.06	0.06	0.06	0.06	0.06
Group Model	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Table 2. Percentage of remaining selfish agents after isolation started of 20 runs with 5000 steps

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Effectiveness of Symbiotic Groups

- Effectiveness of the population denotes how well the agents in the population cooperate.
- In our setup this is equal to average donation rate of the population.
- We compare our hybrid models with both tag models and non-tag reciprocity models.
- A non-tag model is expected to achieve the highest effectiveness, since any two agents can cooperate in the population.

Effectiveness of Symbiotic Groups

- Relaxed individual model is by itself effective (both tag and non-tag versions).
- Since strict individual model is too strict about who will help to whom, its effectiveness is low.
- Agents in group model are more tolerant each other in terms of cooperation.

$\Phi = 150$ $\Delta = 60$	2	3	4
Edmonds' Model	0.881 (0)	0.877 (0)	0.942 (6)
Non-Tag Strict Individual Model	0.863 (0)	0.863 (0)	0.863 (0)
Non-Tag Relaxed Individual Model	0.999 (0)	0.999 (0)	0.999 (0)
Non-Tag Group Model	0.877 (0)	0.876 (0)	0.877 (0)
Strict Individual Model	0.740 (0)	0.866 (0)	0.900 (11)
Relaxed Individual Model	0.890 (0)	0.980 (0)	0.993 (7)
Group Model	0.723 (0)	0.802 (0)	0.867 (6)

Table 3. Average donations over 20 run with 5000 steps

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Efficiency of Symbiotic Groups

- Efficiency of a model denotes how easily it allows generation of groups.
- To measure efficiency we observe the average count of agents contacted at each step (donation candidates) to form a cooperative group.

Efficiency of Symbiotic Group

- Non-tag models are very inefficient.
- All hybrid models achieves better efficiency rates than any other model.
- Group model achieves the highest, intuitively the reason is the existence of information sharing among the population.

$\Phi = 150$ $\Delta = 60$	2	3	4
Edmonds' Model	2.020 (0)	1.595 (0)	0.453 (5)
Non-Tag Strict Individual Model	5.063 (0)	5.407 (0)	5.565 (0)
Non-Tag Relaxed Individual Model	5.065 (0)	5.414 (0)	5.623 (0)
Non-Tag Group Model	4.829 (0)	4.989 (0)	5.110 (0)
Strict Individual Model	1.179 (0)	1.303 (0)	0.565 (5)
Relaxed Individual Model	1.789 (0)	1.325 (0)	0.464 (0)
Group Model	1.651 (0)	1.290 (0)	0.434 (7)

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Conclusion

- We proposed a hybrid collaboration model by combining Edmonds' model on symbiotic groups with reciprocity.
- Edmonds' model shows how such groups can emerge, but these groups emerge, flourish and then collapse because of selfish agents.
- We show that adding reciprocity eliminates selfish agents and can eliminate fast. Strict Individual Model performed the best for this activity.
- Hybrid models of tag and reciprocity generate more effective groups in the most efficient way.
- Simulation results show that Relaxed Individual Model is the most effective and Group Model is the most efficient model among three hybrid models.

Thanks!