Multiagent Collaborative Search with Self-Interested Agents

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Background & Motivation

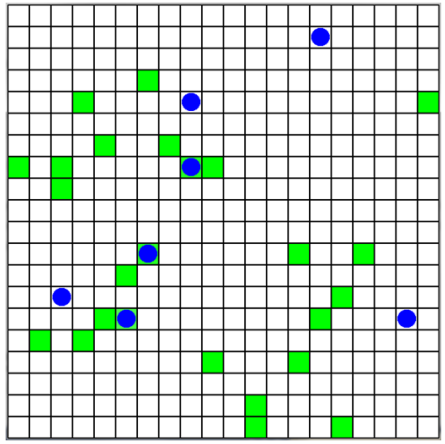
- In cooperative problem solving, agents exchange information and act cooperatively to achieve a goal.
- In human society, there exist self-interested individuals who may act non-cooperatively or even deceptively to increase one's profit.
- What happens if such **self-interested agents** exist in cooperative problem solving in MAS?

Purpose

- Observe the effect of self-interested agents in **multiagent collaborative search**.
- Observe whether self-interested agents increase/ decrease in **repeated games**.
- Explore conditions under which self-interested agents flourish/perish.

Multiagent Collaborative Search

- Agents move in a 2-dimensional cellular space and collect target objects randomly put on the field.
- An agent can view its surroundings and inform other agents of its view information.
- An agent can memorize the explored area by itself and record information brought by others.
- Whether an agent transmits information or not depends on a **strategy**.



Rules of Behavior

1. An agent either stays at the present cell or move to horizontally/vertically adjacent cells at each time step.
2. If targets are in its view, move to the closest targets.
3. Else if no target is in its view, move to the closest targets which are either in its own memory or in the external information. If two information conflict (existence and non-existence), prefer the latest info.
4. Otherwise, when no information of target is available, search areas unexplored by any agent.

Strategies

strategy	transmit info.	use external info.
cooperative	yes	yes
skeptical	yes	no
free rider	no	yes
liar	transmit disinfo.	yes
skeptical liar	transmit disinfo.	no
solitary	no	no

transmit info: transmit information whether each cell contains targets or not

transmit disinfo: transmit disinformation that targets exist at some vacant cell

use external info: trust external information brought by other agents

Experiments

- Implemented using C++ and DirectX libraries.
- Field size = 50×50
- When a **game** starts, agents explore and collect targets randomly put on a field until no target is left.
- Compute **Collect Rate** = (collected targets by agents with a particular strategy) / (all targets)
- Games are performed 100 times and the average collect rate is calculated.

Experiments

- How collect rates change by **population of agent**s with different strategies?
- How collect rates change by **the number of target objects** in a field?
- What happens if different strategies have **different populations**?
- What happens if **view** of each agent is changed?
- How **time steps** for a game change by combining different strategies?

Population

- 10 cells are randomly selected out of 2500, each of which contains 100 target objects.
- Collect rates are expressed as relative values, with the rate of cooperative agents being 100%.

population	cooperative	skeptical	free rider
9 (3×3)	100%	77%	109%
30 (10×3)	100%	72%	112%
60 (20×3)	100%	68%	109%

low high

skeptical	liar
78%	109%
74%	104%
70%	103%

decrease

- Skeptical agents are relatively low than coop. as they use no external info.
- Free Riders and Liars are relatively high; when population increases, disinfo. will be revised by correct one in shorter time, which weaken the effect of lying.

Number of Targets

- #targets × #cells: 10×10, 100×10, 500×10, 2×50, 20×50, 100×50; field:2500 cells
- 9 agents with 2 different combinations of strategies

targets	3coop.	3skeptical	3free rider
100 (10×10)	100%	109%	110%
1000 (100×10)	100%	77%	109%
5000 (500×10)	100%	84%	104%
100 (2×50)	100%	116%	102%
1000 (20×50)	100%	100%	107%
5000 (100×50)	100%	89%	102%

high

low

decrease

3coop.	3skeptical	3liar
100%	103%	117%
100%	78%	109%
100%	82%	103%
100%	115%	99%
100%	94%	112%
100%	90%	104%

decrease

- Skeptical agents are effective when the number of targets in each cell is smaller (cooperation is less effective to share small number of targets)
- Free Riders or Liars are less effective when the number of targets in each cell is too big (cannot monopolize them) or too small

Liars

- Can liars get more targets if more cooperative agents exist?
- 6 coop + 3 liars (liars rate 33%), 8 coop + 1 liar (11%)
- #targets × #cells: 10×10, 100×10, 500×10

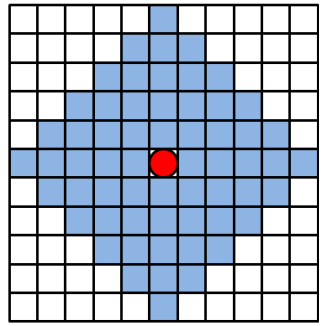
targets	6 coop.	3 liars
100 (10×10)	100%	108%
1000 (100×10)	100%	118%
5000 (500×10)	100%	106%

>

8 coop.	1 liar
100%	105%
100%	112%
100%	105%

- By increasing cooperative agents, disinformation is more likely to be revised by correct one. → Lying is less effective.
- The disposition is more important for liars to collect targets effectively.

View



- Neumann neighborhood of radius 3, 5, 10;
- 3 coop + 3 skep + 3 fr; 3 coop + 3 skep + 3 liar
- 2500 cells; 100×10 targets

view	3coop.	3skeptical	3free rider
3	100%	71%	117%
5	100%	79%	113%
10	100%	87%	99%

increase decrease

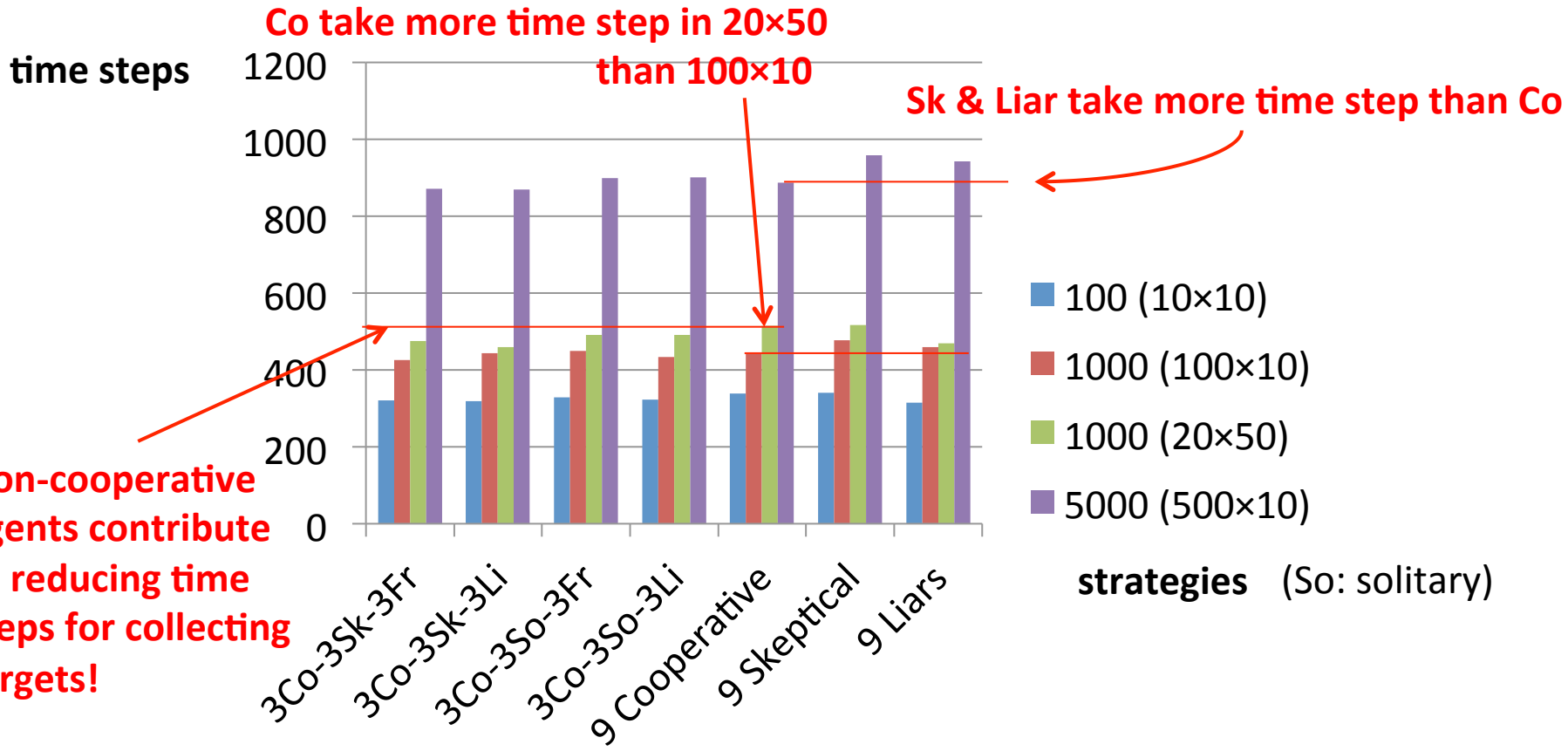
3coop.	3skeptical	3liar
100%	70%	113%
100%	78%	109%
100%	89%	105%

increase decrease

- Skeptical agents do not use external info. so wider view increases collect rate.
- The increase of view makes external info. less valuable. This results in the loss of Free Riders who rely on external info. and the loss of Liars who use disinformation.

Time Steps

- Compare time steps for collecting targets in one game by agents with different strategies. (7 combinations)
- 2500 cells; 10×10, 100×10, 500×10, 20×50 targets

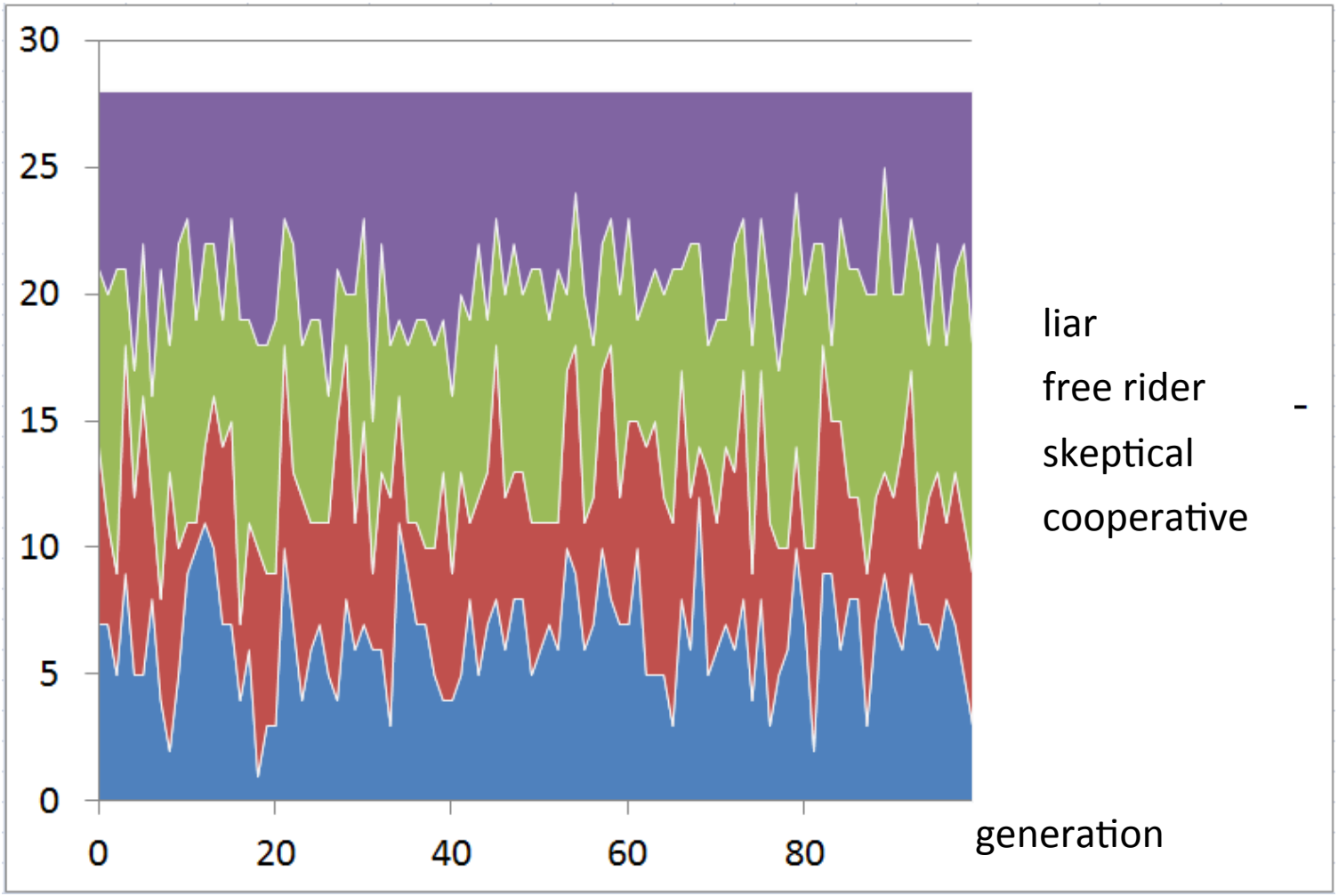


Repeated Games

- Observe the evolution of different strategies by performing repeated games.
- After playing 10 games, the average number of collected targets is computed for each strategy.
- Let N be the number of all objects and n_s the average number of collected targets by agents with a strategy s.
- Strategies of agents in the next generation are decided by the proportionate selection in which a strategy s is selected based on the probability n_s / N

number of agents

28 agents in 87×87 cells with 100×30 target objects



Initially, co=7, sk=7, fr=7, and liar=7.

In 100 generations, co=6.5, sk=6.1, fr=7.6, and liar=7.8.

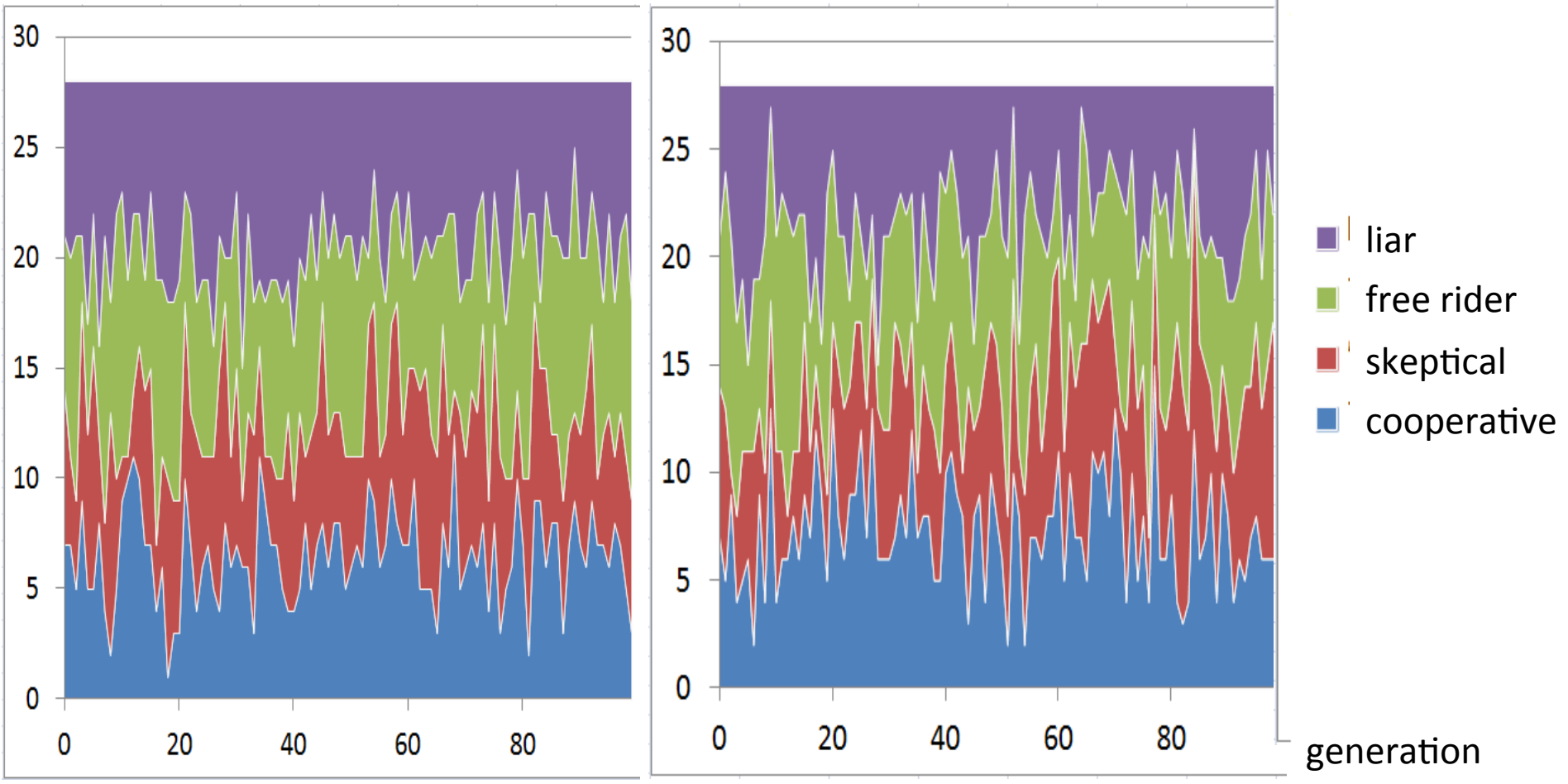
Non-cooperative agents evolve in the presence of cooperative ones.

Penalty

- Liars are charged penalties if detected.
- If an agent knows that no object is at some cell, while external info says there is some on the cell, the agent knows the sender is a liar.
- The agent does not rely on the info. by the liar, and it sends no information to the liar thereafter (in the current game).
- Info. who is a liar is not shared among agents.

number of agents

28 agents in 87×87 cells with 100×30 target objects



without penalty

with penalty

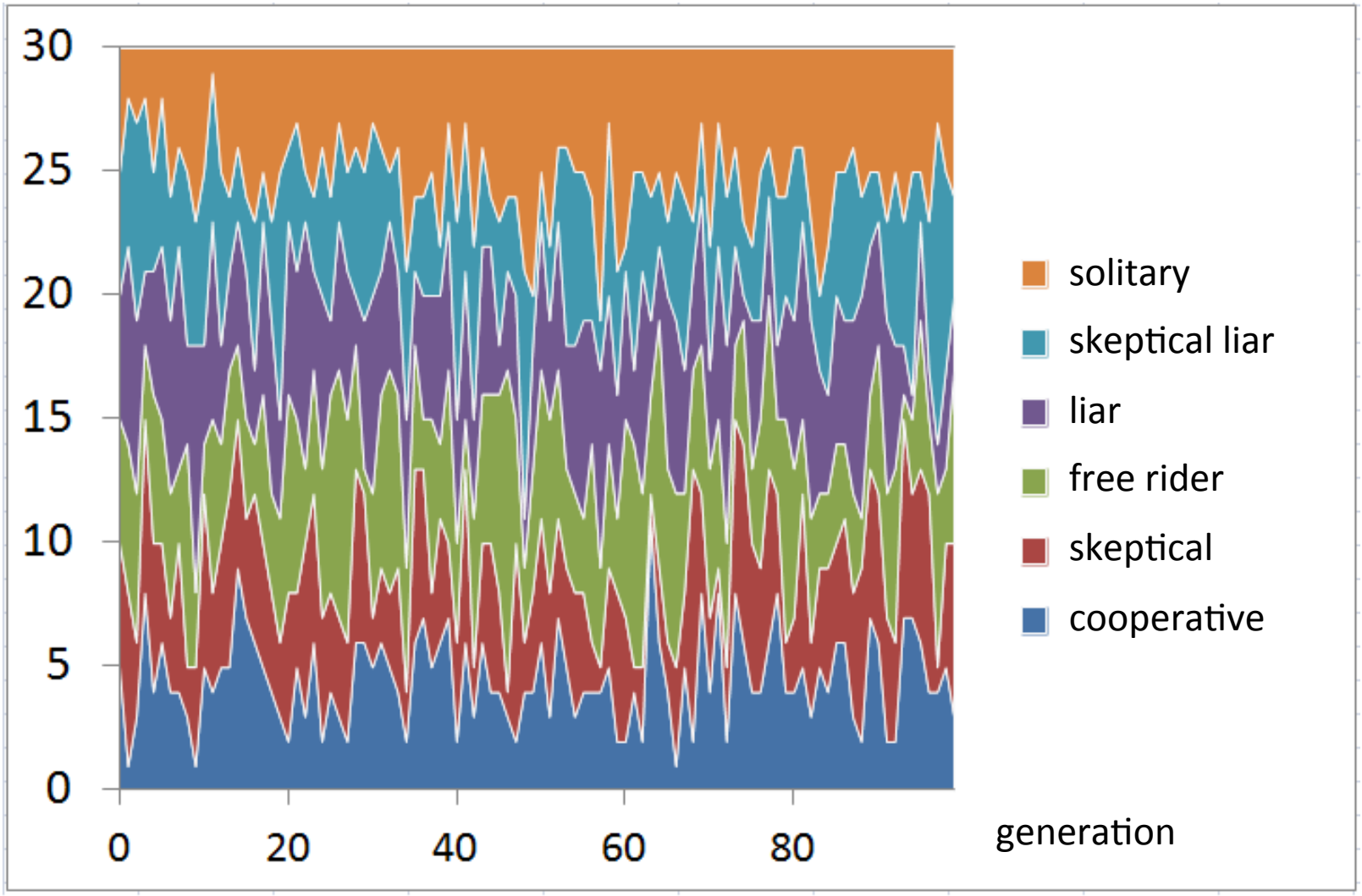
Without penalty, co=6.5, sk=6.1, fr=7.6, and liar=7.8 in 100 G.

With penalty, co=7.4, sk=6.6, fr=7.4, and liar=6.6 in 100 G.

Penalty works effectively to reduce liars.

number of agents

30 agents in 87×87 cells with 100×30 target objects



Initially, so=5, sl=5, co=5, sk=5, fr=5, and liar=5.

In 100 generations, so=5.3, sl=5.0, co=4.7, sk=4.6, fr=5.2, and liar=5.3

Summary

- Effects of parameters on self-interested agents are summarized as follows (+:positive, ー:negative)

	skeptical	free rider	liar
high population	-		-
wide distribution	+	-	-
wide view	+	-	-

- The effect of self-interested agents could be minimized if an environment is arranged in an appropriate manner.
- The existence of self-interested agents is not always harmful. They have the effect of preventing over-concentration of cooperative agents.
- In repeated games, cooperative and non-cooperative agents can coexist in a delicate balance in a society.