Multi-agent Simulation Showing Adaptive Property of Misperception

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Abstract: Misperception is defined as wrong beliefs, which are generated when an individual receives or processes information. Misperception has been assumed to be harmful in general. However, misperception can be adaptive, for example, in the case that concentrated searching toward specific resources reduces diversity in collective behavior. First, we focus on adaptive property of misperception, and propose our hypothesis regarding it. Then, we construct a computational model for a resource-searching problem by using multi-agent modeling. By conducting evolutionary simulation, we investigate both "direct misperception", that are caused when obtaining information directly from environment, and "indirect misperception", that are caused when obtaining information indirectly through communication. The experimental results have shown that misperception could increase diversity in behavior of agents, thus could be adaptive, while accurate communication could decrease a diversity of agent behavior, which might decrease fitness. This paper also discusses a correlative relationship between direct misperception and indirect misperception.

Keywords: Misperception, multi-agent modeling, collective behavior, behavioral diversity.

1. Introduction

It is natural to suppose that collective misperception must be detrimental. However, misperception might have a beneficial effect from a collective viewpoint when individuals misidentify or mispercept incoming information which promotes a specific kind of behavior. Suppose that there is traffic information that traffic on a certain road is very light during rush hours and car drivers get the information in a moment. It is easy to imagine that cars would rush to the road and be forced to slow down after all. In this case, if some drivers would misperceive the information then the traffic jam might ease off.

Very few computational studies have been conducted on adaptive property of misperception [1][2], and no study has discussed direct and indirect misperception based on the quantitative experiments focusing on diversity in behavior and information as far as we know. Arita and Koyama studied the evolution of linguistic diversity based on communication by using synthetic modeling and artificial life techniques [3][4]. The evolutionary dynamics of vocabulary sharing was analyzed based on these experiments. The results showed that mutation rates, population size, and resource restrictions define the classes of vocabulary evolution. They focused not on diversification caused by misperception but on diversification caused by evolution of a linguistic system.

The paper is arranged as follows: Section 2 describes our hypothesis regarding the adaptive property of misperception [5]. Section 3 describes a computational model so as to test the hypothesis, and Section 4 reports on the results of simulation experiments. Section 5 summarizes the paper.

2. Hypothesis

Adaptive property of misperception is supposed to show itself typically as follows. First, individuals in a population share information that has a nature promoting a specific behavior. This means that informational diversity decreases from a collective viewpoint. Then behavior of the population is homogenized and information sharing would be unadaptive as a result. On the other hand, if misperception occurs when obtaining information, the collective belief will be diversified and then collective behavior will be also diversified. In this context, misperception can be adaptive owing to diversification after all. Communication is a method of sharing information in general. In other words, communication tends to reduce the informational diversity and homogenize collective perception. Therefore, there is a possibility that misperception in communication is also considered to become adaptive.

Misperception can be classified into two categories depending on information sources (Fig. 1). Misperception which occurs when each individual obtains firsthand information from passive and certified sources (e.g. environment) is termed *direct misperception*. On the other hand, misperception which occurs

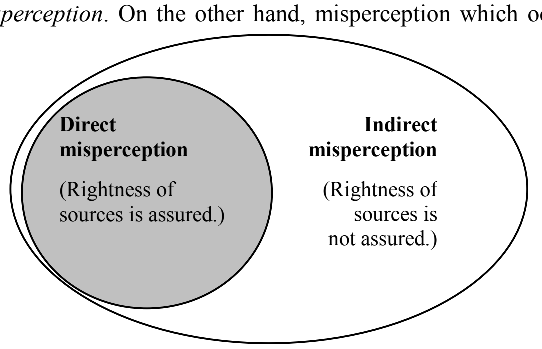

Fig. 1. Classification of misperception.

when each individual obtains indirect information from active and not-certified sources (e.g. other agents) is termed *indirect misperception*. Fig. 2 shows the flow of information and occurrence of misperception. The rectangles express agents and the arrows indicate information flow.

Here, we summarize the hypothesis regarding adaptive property of misperception as follows.

1) Direct misperception of information promoting a rate of occurrence of a specific behavior increases diversity in behavior of a population, which can result in increase in collective fitness.
2) Information sharing by communication promotes a rate of occurrence of a specific individual behavior and would reduce diversity in collective behavior, which could decrease collective fitness as a result.
3) Indirect misperception during communication can increase the collective fitness as is the case with 1).
4) The effects of adaptive property of misperception depend partly on specificity of the behavior accelerated by the information. If the information promotes all behaviors but one specific behavior (which means that the information prohibits a specific behavior), the effect will be minimized.

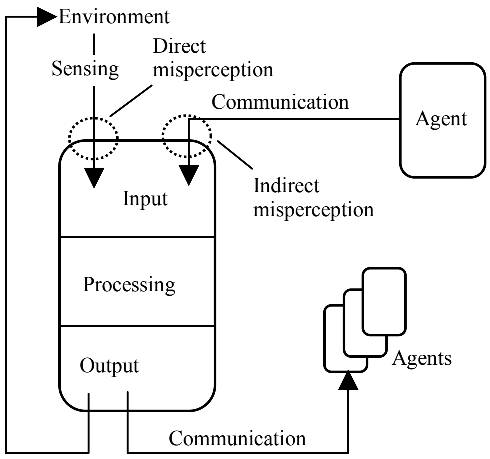

Fig. 2. Information flow and occurrence of misperception.

3. Model

3.1. Task

Our hypothesis is tested adopting a foraging task on a two-dimensional field where autonomous mobile robots (agents) wander in search of food resources (Fig. 3). Resources are distributed uniformly when initializing the field. They have fixed locations during a run. When an agent gains a resource, the amount of the resource becomes zero. Then, after a turn has passed, the amount of the resource is increased at a rate of one unit per turn at the same place until the maximum value.

3.2. Agent

Agents are distributed randomly in the field at the start of each trial run. Each agent has a resource map with information about location and amount of resources. This information is obtained either by using their own visual sensors or by communicating with other agents. Each resource map is expressed by a memory

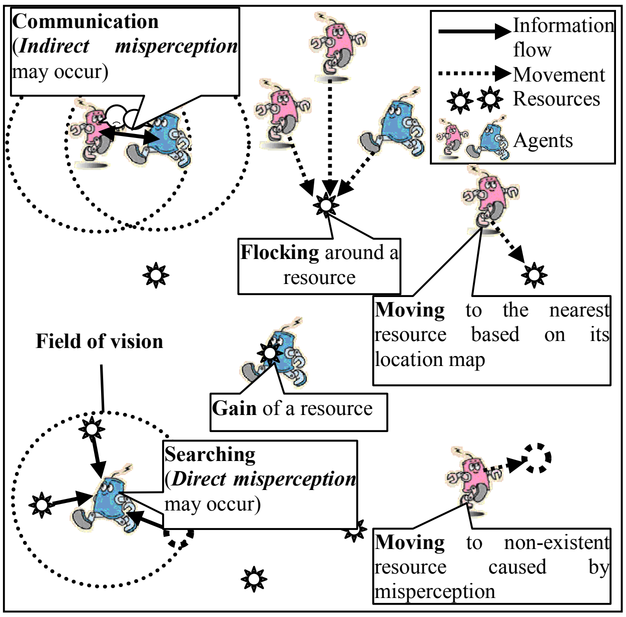

Fig. 3. Model for a resource-searching problem in a virtual multi-agent world.

area corresponding to the whole of the field, where each cell stores the information about whether resource exists or not, and the amount of the resource if it exists.

Each agent perceives both resources and the other agents in its field of sight that is represented as a square centering on the agent. The field of sight and the range of movement per turn are shown in Fig. 4. "A" in this figure expresses an agent, light gray cells express the field of sight and light gray cells and dark gray cells express the range of movement.

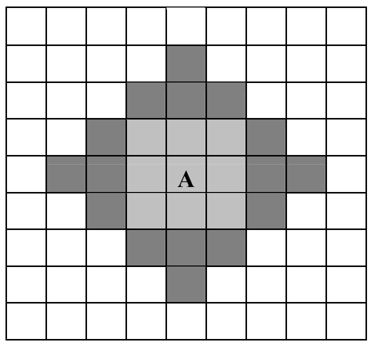

Fig. 4. Field of sight (light gray cells) and movement range (light gray and dark gray cells).

Agents cannot move into a cell occupied by another agent. Movement speed of each agent per turn is expressed by the number of grids. Agents perceive existence/nonexistence of resources in their field of sight, and in case of existence, they obtain information of the location and the amount of them by using their own visual sensors. Recognized information is overwritten in their resource maps.

We have conducted simulation experiments under following two conditions: 1) Agents always have one-to-one communication with other agents if possible, 2) Agents never have communication with other agents. They communicate the information of the location and the amount of the resources among them in the former case. The information of nonexistence are not communicated. Communicated information is overwritten on their resource maps even if new information conflicts with old information. For example, an agent recognizes a resource at location A by using communication. Later, if the agent itself recognizes nonexistence of the resource at location A, this new information is overwritten in its resource map. In the case that information that comes from visual sensors and information that comes from the other agents through communication are contradictory to each other, the former is given priority over the latter.

Each agent moves toward the nearest resource based only on the information of its own resource map, which does not depend on the amount of resources. A target resource is selected randomly if more than one resource are at equal distances. Agents will perform a random walk when their resource maps have no information of resource existence. When agents move to the cell where a resource exists, they get all of the resource.

3.3. Occurrence of misperception

There is a possibility that misperception occurs when agents get information by their own visual sensors or through communication (Fig. 5). Three kinds of information concerning the resources (location, existence/nonexistence and amount) are communicated in this model. We have conducted simulation experiments on the condition that misperception can change the information of location and existence/nonexistence. When misperception occurs, one of the following two types of information is selected randomly with equal probability as follows. In the case that misperception of location happens, random location concerning the communicated resource is stored in the resource map of the agent while the other information is communicated precisely. In the case that misperception of existence happens, existence-nonexistence is reversed concerning the communicated resource.

3.4. Algorithm

Simulation experiments are conducted as follows (Fig. 6):

1) Resources and agents are distributed uniformly over the field.
2) Agents communicate with other agents within their sight.

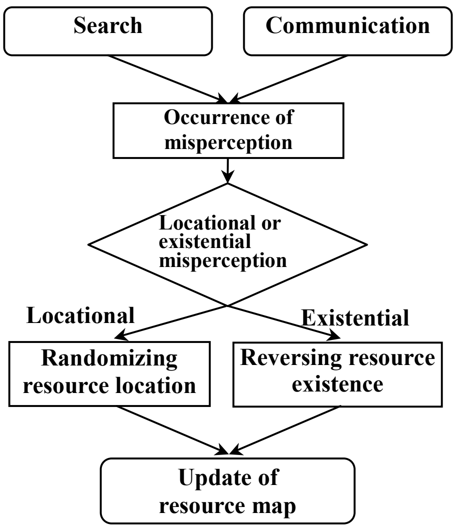

Fig. 5. Information flow and occurrence of misperception.

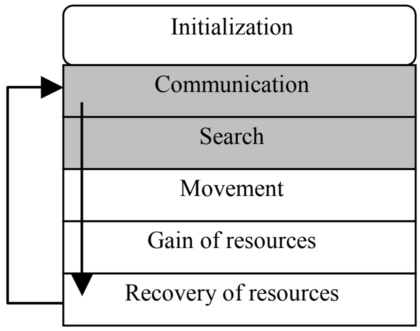

Fig. 6. Flow of the process.

3) Misperception might occur with a given probability (indirect-misperception rate).
4) Agents might perceive resources. If so, misperception might occur with a given probability (direct-misperception rate).
5) Each agent moves toward the nearest resource based on information of its own resource map. Agents with no resource in their resource maps move in a random direction at the specified speed.
6) Agents get the resources existing in their own cells. Resources will recover gradually in the same location.

The above cycle from 2) to 6) is termed “a turn” and will be conducted again and again.

4. Simulation experiments

4.1. Experimental Setting

We conducted following four simulation experiments so as to examine the effects of misperception on the behavior of the population in relation to the effect of communication (Fig. 7).

Experiment 1: Effects of direct misperception.
Experiment 2: Effects of communication.
Experiment 3: Effects of indirect misperception.
Experiment 4: Effects of indirect and direct misperception.

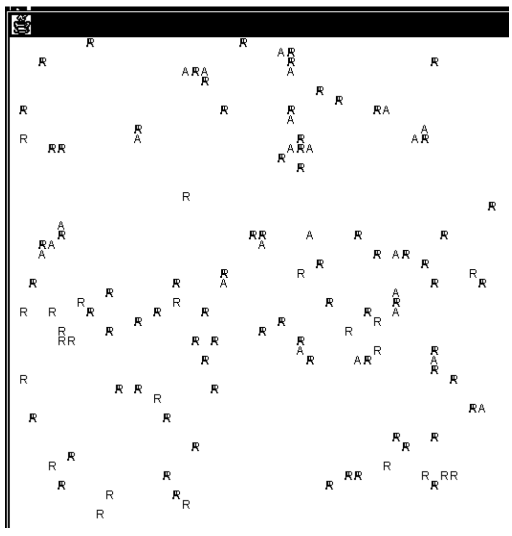

Fig. 7. Screen shot ("A": agents, "R": resources).

Experiments were conducted using following parameters:

Number of turns in a trial run:	10000
Field size:	50 * 50 (non torus)
Number of agents:	150
Sight:	3 * 3
Speed:	3 / turn
Resource density:	5 %
Maximum amount of each resource:	1
Number of trial run (Experiment 1, 2):	6
Number of trial run (Experiment 3, 4):	60

The amount of the average obtained resource by all agents is evaluated as a fitness value of the population in all of the experiments in this paper.

4.2. Effects of direct misperception

Agents searched for resources by using their own visual sensors, and didn't communicate with other agents. Thus, only direct misperception could happen in this experiment. We changed direct-misperception rate from 0% (without misperception) to 100% (with misperception at all times), and investigated effects of direct misperception.

The results of the experiment are shown in Fig. 8 and 9. Fig. 8 shows the effect of direct misperception on fitness when varying direct-misperception rate. It is shown that the fitness has a peak when direct-misperception rate is around 1%. The fitness in the case that direct misperception is 1% is about 35% greater than the fitness in the case that no direct misperception happened (0%). The reason is supposed to be that the search range was enlarged because direct misperception diversified individual behavior.

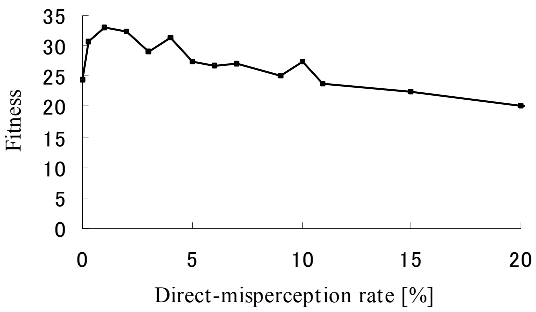

Fig. 8. Effects of direct misperception.

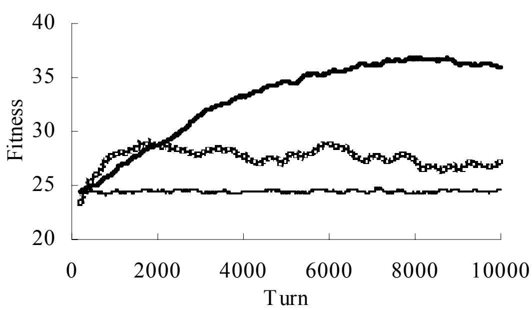

Fig. 9. Fitness transition under the effects of direct misperception (direct-misperception rate; thin line: 0%, thick line: 1%, gray line: 10%).

Fig. 9 shows time transition of fitness by moving average, where each line corresponds to each value of direct-misperception rate. Before 2000 turns, fitness in the case that direct-misperception rate is 10% is larger than the one in the case with 1%. After that, fitness was stable at the value around 28. The cause of this result is that behavioral diversity made by direct misperception (10%) was larger than diversity in the case with 1%, which caused the search area to be wider. On the other hand, however, the fitness in the case with 10% was lower than the case with 1% because agents could not gain resources surely because the misperception rate was too high.

As a result, it has been shown by this experiment that direct misperception diversifies collective behavior, which extends the search range as a population. This means that misperception could be adaptive.

4.3. Effects of communication

We introduced communication among agents in this experiment. Agents can obtain information by using their own visual sensors or by communicating with other agents. Misperception during communication was not investigated (indirect-misperception rate is 0%) in this experiment in order to grasp the effects of communication itself. We examined the influence of varying direct-misperception rate from 0% to 100%.

The results of the experiment are shown in Fig. 10 and Fig. 11, where they are compared with the result of the previous experiment. Fig. 10 shows that the fitness was reduced by several percents by introducing communication among agents when direct-misperception rate is less than about 20%. The reason is supposed to be that the diversity of collective behavior was reduced owing to the share of the information concerning resources in the population. It was also shown that introduction of accurate communication slightly increased the fitness when direct-misperception rate was 0%, though it is not easy to see from this figure.

Fig. 11 shows the transition of the fitness. We see from this figure that the fitness fell with progress of time when direct-misperception rate was 1% and 10%. This means that

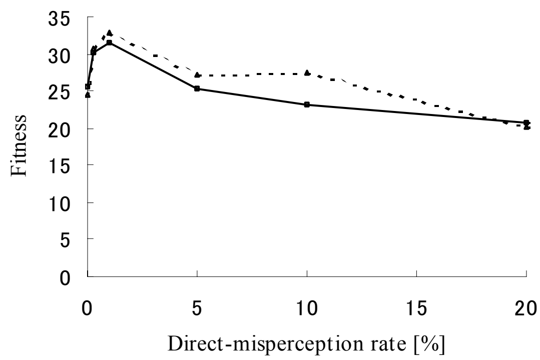

Fig. 10. Effects of communication without misperception (continuous line: with communication, dotted line: communication is not used).

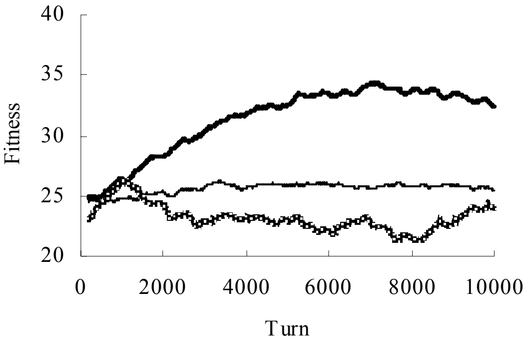

Fig. 11. Fitness transition under the effects of commun ication without misperception (direct-misperception rat e; thin line: 0%, thick line: 1%, gray line: 10%).

communication propagated the information and reduced adaptive diversity of collective behavior generated by direct misperception which was investigated in the previous experiment.

In this context, it is considered that communication can be unadaptive regardless of the truth of its content.

4.4. Effects of indirect misperception

We investigated the effects of indirect misperception on fitness under the condition that direct-misperception rate was fixed at 0% and direct-misperception rate was varied between 0% (receivers receive exactly what senders have sent) and 100% (receivers always misperceive what senders have sent).

The results of the experiment are shown in Fig. 12. The fitness was increased about 1.5% compared with the case of accurate communication when indirect-misperception rate was less than 40%.

It has been shown from this experiment that indirect misperception can prevent communication from decreasing the diversity in collective behavior, and can make communication adaptive.

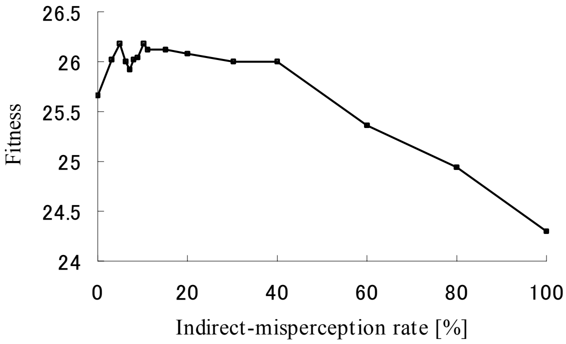

Fig. 12. Effects of indirect misperception.

4.5. Correlative effects of direct and indirect misperception

We investigated the fitness when direct-misperception rate was varied from 0% to 20%, and at the same time indirect-misperception rate was varied from 0% to 100%. The result of the experiment which applied direct misperception and indirect

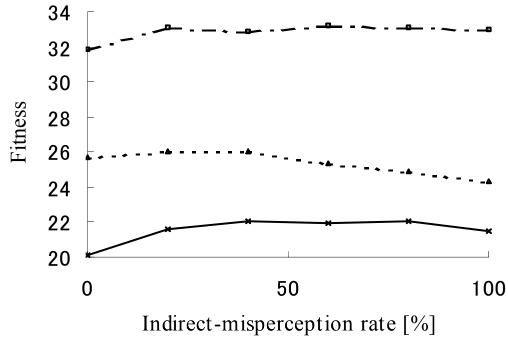

Fig. 13. Correlative effects of direct and indirect misperception (direct-misperception rate; dotted line: 0%, dotted-broken line: 1%, continuous line: 20%).

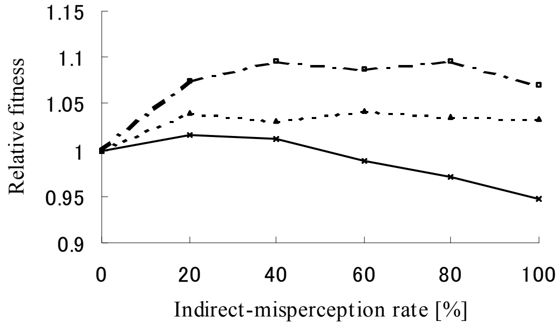

Fig. 14. Fitness ratio of each indirect-misperception rate (direct-misperception rate; continuous line: 0%, dotted line: 1%, dotted-broken line: 20%).

misperception simultaneously is shown in Fig. 13. The fitness when direct-misperception rate was 1% and indirect-misperception rate was 20% is approximately 1.5% greater than the fitness when direct-misperception rate was 1% and agents have no communication (this case is shown in Fig. 8). In other words, the results of the case when both direct and indirect misperception were allowed could be better than the case when either of the misperception was allowed. This fact implies that both of the misperception has mutually complementary effects on fitness of collective behavior.

We also investigated relative fitness when indirect-misperception rate was varied compared with the case that it was fixed at 0%. Fig. 14 shows the results of the experiment. This figure shows the tendency that the more the direct-misperception rate is, the larger the effect of indirect misperception becomes. Fig. 14 also shows a tendency that the optimal indirect-misperception rate becomes larger as direct-misperception rate increases, which is contrary to what we expected. Our understanding is as follows: When direct-misperception rate is large, communication makes more false information be shared in population and thus the fitness of population becomes low. Therefore, larger rate of indirect misperception is necessary for being optimal because it prevents population from sharing false information.

5. Conclusion

Our hypothesis regarding the adaptive property of misperception was proposed, and simulation experiments were conducted so as to test it. The experimental results have shown quantitatively that misperception could increase diversity in behavior of agents, thus could be adaptive, while accurate communication could decrease a diversity of agent behavior, which might decrease fitness. The paper also discusses a complex relationship between direct misperception and indirect misperception, besides detailed description of the simulation experiments.

We believe that this series of study on adaptive property of misperception based on multi-agent modeling would shed light on following challenging themes: 1) Human cognitive function - Can we comprehend imperfect human cognition or defective human discriminative organs based on evolutionary explanation?, 2) Memetics - Can we figure out the mutation of the memes based on the diversity in meme population?, 3) Engineering - May further improvements in sensors of robots (e.g. soccer robots) lead to decrease in system performance caused by decrease in behavioral diversity of robots?

References

[1] J. Doran, “Modeling Collective Belief and Misbelief,” *AI and Cognitive Science '94* (ed. M Keane, et al.), Dublin University Press, pp. 89-102, 1994.

[2] J. Doran, “Simulating Collective Misbelief,” *Journal of Artificial Societies and Social Simulation*, Vol. 1, No. 1, 1998 (http://www.soc.surrey.ac.uk/JASSS/1/1/3.html).

[3] T. Arita, “*Artificial Life: A Constructive Approach to the Origin/Evolution of Life, Society, and Language*,” Science Press, 2000 (in Japanese).

[4] T. Arita and Y. Koyama, “Evolution of Linguistic Diversity in a Simple Communication System,” *Artificial Life*, Vol. 4, No. 1, pp. 109-124, 1998.

[5] J. Akaishi and T. Arita, “A Multi-agent Model for Investigating Adaptivity of Misperception,” *Proc. of FAN Symposium ’01*, pp. 229-234, 2001 (in Japanese).