# About realization of aggressive behavior model in group robotics

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**Abstract.** One of the actively developing approaches of group robotics systems creation is the use of social behavior models. Aggressive behavior is one of the underlying mechanisms forming social behavior. In this paper, the application of aggressive behavior concepts is considered by analogy with animal aggressive behavior that can be used for solving tasks of group robotics. As a role model, an ant – a true social insect – is proposed. It was shown that in aggressive behavior of ants, the numerical factor and imitative behavior play an important role. Agent's aggressive behavior model depending on accumulated aggression and the number of other nearby agents is proposed. The results of computer experiments for territory defense tasks are presented. The results show that aggression is a stabilizing factor for an approximately equal number of agents in different groups. By an increase in group size, aggression becomes a way of capturing foreign territory.

**Keywords:** group robotics, social behavior models, aggressive behavior, territory defense task

## 1 Introduction

One of the actively developing approaches to the creation of group robotics systems is the implementation of social behavior models as unified methodological bases [1-3]. The main idea of this approach is to propose a set of methods and mechanisms of their realization based on animal social behavior models. We suppose that these biologically inspired methods will allow us to solve a wide range of tasks in the field of group robotics.

Ethologists believe that agonistic or aggressive behavior is one of the main social behavior mechanisms [4]. In the framework of evolutionary theory, aggressive behavior is understood to encourage survival of the fittest, disperse populations, aid adaptation to threatening environments, and generally improve the probability of individual and species survival [5].

Aggressive behavior is an integral part of various social behavior models; therefore, in the present study, the implementation of this mechanism is essential to create higher level models. Aggression is seen as conflict resolution and as a factor for territory division between robot groups.

## 2 Aggressive behavior

Many ethologists consider that aggression is one of the main factors determining the formation of community [4, 6-7] in particular: (1) the maintenance of population spatial structure; (2) mating behavior; (3) the care of offspring; (4) the maintenance of a dominance hierarchy of cooperating individuals in a social; (5) the maintenance of group (family) homeostasis. Generally, aggression contributes to the survival of the species. We need to explore the basic mechanisms of aggressive behavior, because we will use it for realization of some social behavior models in group robotics.

Agonistic behavior consists of threats, aggression and submission. The threats appear as fixed action patterns [4], which are highly stereotyped models of behavior that are characteristic of a particular species. Aggression usually occurs when a competitor appears. We will consider only aggression against the competitor which is individual to the species because intra-species aggression plays a key role in complex social behaviors. In most cases, contests are settled through the use of non-injurious aggressive behaviors such as demonstration and trials of strength. Actual fighting is rare because of the risk of injury to both participants. Various factors limit the escalation of aggression such as elimination of the causes (competitor, interference, etc.) or demonstration of submission by the other individual.

For solving problems of group robotics, researchers often use ants for "role models." Also, many researchers study features of social behavior with ants as representatives of eusocial (true social) insects. Therefore, ants are a convenient object for study of aggression.

Aggressive behavior in ants and the role of aggression is examined in detail, for example, in [8]. With the help of aggression, ants defend their territory from ants of another nest (and other species of ants). In this case, the number of ants plays some role. When two ants from different nests encounter each other on the aft area where friends are absent, they prefer to disperse peacefully. But if any forager is carried away and gets too close to a foreign nest, where there are many opponent ants, the forager will be attacked and must flee. Thus, aggression is involved in process of forming social behavior.

In a number of works, aggressive behavior is used to find solutions to some problems in robotics (for example, [9-10]). Also, the term "aggression" is sometimes applied in multi-agent systems [11]. Unfortunately, the authors mentioned in the above works using the concept of aggression and sometimes even referring to the works of ethologists, preferring a formal approach.

We are interested in a constructive, biologically based model of aggressive behavior that can be applied to the solution of specific problems in group robotics.

## 3 Aggressive behavior model

We simplify the real situations that take place in nature and do not take into account the features of individuals. Let's assume aggression occurs only when the competitor appears. Aggression between groups is determined partly by willingness to fight, which depends on a number of factors including numerical advantage and distance from home territories [12]. The current aggression level of individual $\boldsymbol{A}$ is defined by three parameters:

$$A = (C, E_{ob}, D_{other}), \qquad (1)$$

where $C$ – is "actual aggression," i.e., the aggressiveness accumulated to this point in time; $E_{ob}$ – the presence of the object of aggression; and $N_{other}$ – the number of other individuals of the species. The emergence of a competitor definitely leads to the manifestation of aggressive behavior (the sensitivity threshold equals zero).

The observation of the Formicidae ant behavior shows that an individual is more likely to become aggressive if other group members are nearby. On the border territories of the two ant species, the density of individuals is higher than in those areas where the territory is not contiguous with the territories of other species. According to Dlusskiy [13], ants can quickly come together to reflect "neighbors" at the slightest danger. Thus, in ants, actual aggressiveness depends on a distance from home territory. Let's assume that the actual aggression C is inversely proportional to the distance R from its "nest": C= 1/R.

The model should include conflict resolution rules based on a comparison of aggression levels. After the collision, the less aggressive ant runs away and the more aggressive ant rushes in pursuit or stays in place. Also, the proximity of other group members plays a big role for ants. Therefore, the following rules of conflict resolution are offered. When the individual detects a competitor, it summarizes the aggression levels of ants of its own species among neighbors (individuals are considered to be neighbors if distance between the individuals is less than some value X):

$$A_{other} = \sum_{j=1}^{m} C_j, \; A = C + A_{other}, \qquad (2)$$

where $C_j$ are actual aggression levels of neighbors; $m$ – the number of the neighbors; and $A$ – current aggression level of the individual. Similarly, the total aggression level of the "foreign" individuals ($A_n$) is calculated. The individual wins the conflict with probability $p = A/(A + A_n)$ and loses with probability $(1 - p)$.

## 4 Simulation experiments

As a model task, a territory defense task is proposed. In collective robotics, this task is usually reduced to the problem of territory division or patrolling. The problem of territory division is considered only between individual robots, but not between groups (for example, in [14]). The solution of the patrolling task is to optimize the route which involves robots [15].

Under the territory protection task, we see the problem solved by animals through aggressive behavior: they banish individuals of other families (nests) from their territory to maintain the spatial structure of the population [7]. For an aggressive behavior demonstration using the proposed model for territory protection, place two "nests" (anthills) where individuals of a certain group (type) "live" on the ground. They are able to distinguish their own and “enemies,” and only show aggression towards individuals from another anthill.

A series of experiments of two types were carried out. The experiments were conducted with the help of the framework of the ROS-based modeling system. In the first type of experiments, agents didn’t show aggression and moved freely on their own and someone else's territory. The ratio of the number of agents from different nests (n1:n2) varied from 1:1 to 1:6; ten experiments at 300 cycles of simulation were conducted for each ratio. The results for the series without aggression are shown in Fig. 1. As a test indicator, the total time spent by agents of each group on foreign territory was used.

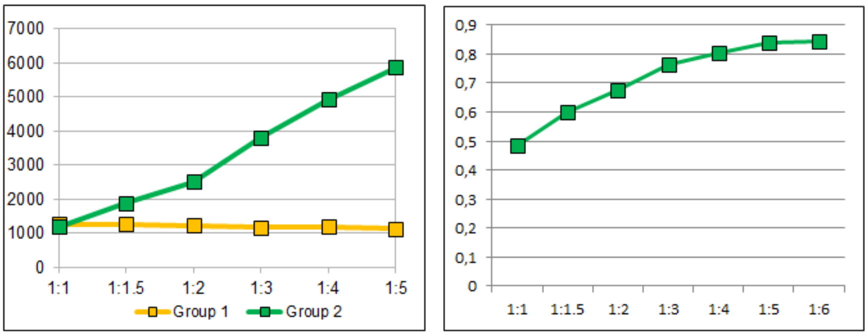


**Fig. 1.** The results for no aggression behavior series: a) total time spent by agents of both groups on foreign territory (t1 – Group 1, t2 – Group 2); b) ratio t2/(t1+t2)

The first series (no aggression) shows apparent results: in the absence of aggression, the total time spent by individuals of each group on the "foreign" territory, in fact, is directly proportional to the number of individuals in the group.

In the second series, individuals show aggression toward “outsiders” (see Fig. **1**).

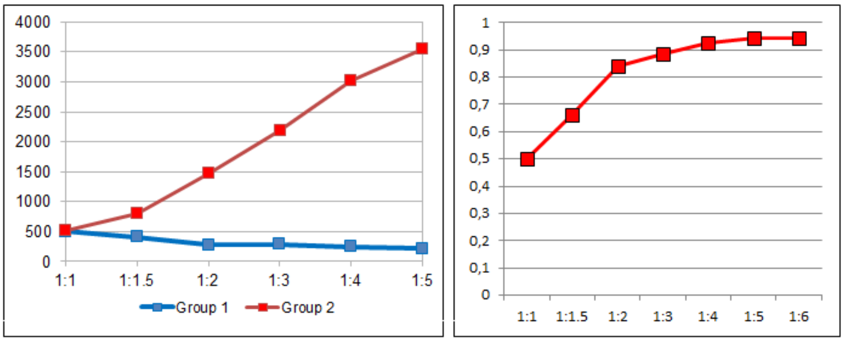


**Fig. 2.** Simulation results – series with aggression: a) total time spent by individuals of both groups on foreign territory (t1 – Group 1, t2 – Group 2); b) ratio t2/(t1+t2)

In the second series, rules of aggressive behavior were consistent to the proposed model, and the aggression level was calculated when individuals detected individuals from the other group. The losing individual immediately returned to his anthill, eliminating the cause of aggression. Other conditions were similar to the conditions of the first series: the ratio of the individuals number from different nests (n1:n2) was also changed from 1:1 to 1:6 and for each ratio 10 experiments at 300 cycles of simulation were conducted. In the results of the second series, emergence of aggressive behavior for equal groups sharply (about 2-2.5 times) reduces the total time spent by individuals of each group on “foreign” territory.

Thus, the experimental results confirm that aggression is a stabilizing factor allowing the group to defend its territory. Besides, the increase in number of one of the groups serves to increase the time that individuals of this dominant group spend on “foreign” territory, as well as reduce the number of individuals from the subordinate group that penetrate into “foreign” territory. Therefore, we can assume that aggression is also a factor of foreign territory “capture” by the larger group. This is clearly seen from Fig. 3, which shows graphs of the series with aggression and without.

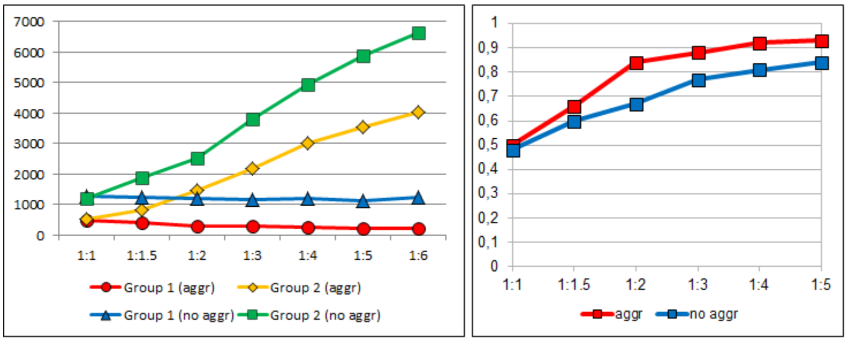


**Fig. 3.** Comparison of simulation results – “aggression” (aggr) and “no aggression” (no aggr): a) total time spent by individuals of both groups on foreign territory; b) the ratio of time spent by individuals of both groups on foreign territory

It is interesting that the aggressive factor is most significant in the range from 1:1.5 to 1:2. Simulation results show that the time which the dominant group spends on foreign territory increases unevenly. Maximum growth is achieved by the numerical superiority of one group over another from 1.5 to 2 times. This suggests that at this ratio, aggressiveness makes the greatest contribution to the redistribution of territory in favor of larger groups. With a further increase in number of any group, this group just “pushes” the other in the mass; aggressiveness has less influence on the situation.

## 5 Conclusion

In this paper, a territory behavior model based on the proposed aggressive behavior model was implemented. Experiments confirmed that for equal groups of agents, aggression is the stability factor that allows each group to defend its territory. If ratio of agents number in groups changes, aggression becomes a way of seizing foreign territory and leads to a redistribution of the territory in favor of larger groups.

This mechanism of competition (conflict resolution) should be the same for different cases and should not depend on the resource. Further, we intend to check proposed model to solve other tasks, in particular a foraging task to resolve a conflict for food. And when the number of individuals increases, they often collide with each other and spend time to disperse. This conflict can also be resolved using aggression.

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