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AGGRESSIVE AND PEACEFUL BEHAVIOR IN MULTIAGENT SYSTEMS ON CELLULAR SPACE

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One of the key issues in Multi-Agent simulation approach is a consolidation of great model variety. Many researches govern own unique models that are similar in basic principles but for complex adaptive systems such as Artificial Ecosystems slight difference in architecture and parameters calibration could affect crucially on the emergent properties of the model. As it was denoted by the pioneers of the Artificial Ecosystems modelling Robert Axtell and Robert Axelrod: variety of Multi-Agent models need introduction of methods and technics that allows consolidating of its results. In work we present modification of model similar to classic Artificial Life spatial lattice models and trace the exhibition of aggressive and peaceful behavior depending on the income resource. We consider results of both models' simulation as it was proposed in «docking models» method by Axtell and Axelrod.

INTRODUCTION

The methodology of Multi-Agent simulations are broadly used in the study of ecological complexity. Popularity of multi-agent approach springs from the early researches such as Sugarspace [1], Bugs [2] and Polyworld [3] models. One of the pioneer model of Artificial Ecology is a model of bugs on spatial lattice that was proposed by Norman H. Packard [2] denotes the importance of shift from extrinsic to intrinsic adaptation approaches in modeling of evolutionary processes. Packard proposed to change the point of view on fitness in models of biological systems. He claimed that the extrinsic approach of adaptation such that is defined by a priori fitness function that assumes averaging of environment and individual interactions into it, could inflict limitations on biosphere. As a result of first simulations of his model H. Packard introduced notion of o posteriori fitness function for intrinsic adaptation evolutionary process and demonstrated system features with its help. This change in the concept of adaptation shifts the focus to the emerging characteristics of the system that can be treated as a posteriori fitness function. The examples of such values could be population size over the time, sustainability of emerging community assemblies under different factors such as environmental changes or arm races and other system features. By focusing on a posteriori fitness we should stress the notion of phenotype — the general composition of agent treats that emerge from its genotype. The phenotype could be expressed as a set of the most frequently used responses for particular effectors e.g. running from the predator, wondering searching for food. In particular study phenotype is presented as agent strategy — a set of agent's actions performed in hypothetical model situation.

Michael Burtsev proposed model that resembles pioneer Artificial Life's Polyworld [3] and Bugs [2] models: the agents with simple behavior are acting in a simple space. In [4] author develops latter models introducing kinship and using artificial neural network as basis of agent's actions. In current model no agent was given a predefined strategy instead they were emerging as phenotype feature from the agent's actions, defined by neural network. By doing this, author achieved great variety of strategies that could take into account kinship of the object they interact with and are constructed from elementary actions as a result of evolution processes. Some of the strategies exposed cooperative behavior, it was shown that in such model emerge strategies corresponded to those in well-known game dove-hawk-bourgeois and moreover two new strategies of cooperative attack and defense emerge [4]. Observing results of artificial life modeling it can be concluded that such approach is not being controversial to game theory but on the contrary is an extension that provides new research horizons [4]. This model captured a general trend of increasing of the aggression level with a rising resource supply in primitive societies [5]. The correlation between population density and frequency of fight action for the case of rich resources in the model is similar to the analogous correlation extracted from ethnographic database [5].

One of the main achievements of this research is that agent speciation i. e. phenotypic grouping and distinction emerges without predefined fitness function [5]. Agents occupy niches that expose predator, prey or even more sophisticated behavior without extrinsic predisposition but as a result of evolutional adaptation process. There is also continuations of such researches such as novel artificial ecology class model with predator-prey behavior [6], where agents are driven by fuzzy cognitive map. By researching the model Burtsev proposed novel methodology to categorize agents behavior into strategies and to trace population genotype dynamic [7].

OBJECTIVE AND MODEL DESCRIPTION

Many similar models are developed in purpose to study social, ecological, swarming, artificial life and other issues. After several years of enriching innovation, a period of consolidation is necessary [8]. In this work we aim to present modification of existing Artificial Life model, make some comparison of gained results, and observe the similar model behavior patterns.

It should be noted that the test and «docking» of different models written in the direction of artificial life is not new but still quite a few unexplored area. «Docking» is a procedure introduced in [9] that suppose aligning different models to achieve similar emergent behavior. The need to study the results of similar models of identity is a common thing, especially when it comes to the results of the theory using mathematics as a tool [10]. «Docking» models created by different authors and those that essentially cut off from one another, usually requires significant changes. For example, the first models for which the study was conducted in was the model of cultural dissemination by Robert Axelrod [1] and Sugarsapce model of authorship Joshua Epstein and Robert Akstell [10]. In this study the models are not so different, but are written by different authors on different programming platforms.

An Agent-based lattice foraging model with possible predator-prey behavior that resembles classical artificial life models [2, 3, 4] was developed in this work. This model could be considered as modification or replication of Burtsev cellular automata model [5] because of slight difference in their architectures.

Agent's neural architecture is very important factor for such kind of Artificial Life models. The scope of predator-prey behavior considered in this study can be achieved by a simple artificial neuronal network with no hidden layer as it is implemented in the model. More complex behavior such as group hunting and wandering could be simulated using more sophisticated methods of neuroevolution such as, for example, NEAT (neuroevolution of augmented topologies) [11]. In work [11] authors use NEAT algorithm to evolve effective predator group or group of collective foragers. The crucial advantage of NEAT instruments for multiagent modelling is naturally introduced agents' grouping by genotype affinity that could provide useful insights on agent behavior emergence.

Each agent's sibling inherits neuronal matrix perturbed with some mutations after birth. Each agent is characterized by affinity marker: 3-dimentional vector which coordinates can take possible integer values in [–2, 2] interval. Agents are treated as relatives if Euclidean distance between theirs markers are less than 0,2 threshold.

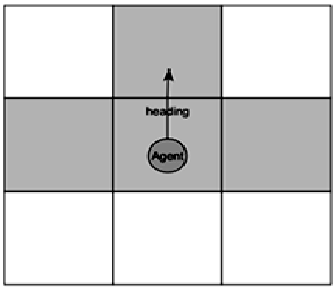


Fig. 1. Agent in cellular environment and his perception

Agent occupies one grid in cellular space (Fig. 1), he is driven by heading that defines a cell in front where could exist object agent interact with. Agents pay some amounts of resources — energy to perform an action, they could refill energy level by consuming vegetation and other agents. Agent percepts certain environmental values that are defined in Table 1.

Table 1. Input signals for agent and values that they take

Input signal	Value
s_0 — bias	rMax
s_1 — resource in current cell	energy of resource is placed agent's cell
s_2 — resource in front	energy of resource is placed in front cell
s_3 — resource in right cell.	energy of resource is placed in right cell
s_4 — resource in left cell	energy of resource is placed in left cell
s_5 — agent in front	rMax, if there is non-relative agent placed in front
s_6 — agent right	rMax, it there is non-relative agent is placed right
s_7 — agent left	rMax, it there is non-relative agent is placed left
s_8 — current resource (r)	current resource value (r)
s_9 — (rMax - r)	(rMax - r)
s_{10}— agent from the back	rMax, if there is an non-relative agent is placed backwards
s_{11}— relative in front	rMax, if in front cell is placed relative agent
s_{12} — relative right	rMax, if relative agent is placed right
s_{13} — relative left	rMax, if relative agent is placed left

In reply to the input signals agent performs the following actions: «rest», «turn», «move», «attack», «escape», «divide», he pays a fee for each of this actions. Maximum energy value that agent can accumulate is rMax and equals to 5000. Probability to be succeed in attack is equals to ratio of victim's and attacker's accumulated energy. If agent is attacked, he can ask neighbor relatives in area of his vision for help. If victim agent finds relatives nearby, he will add theirs ratio corrected coefficient (0,3 for all experiments) to defense threshold. If agent wins in combat with the victim he consumes it and gains all of its energy. When agent decides to give a birth to an offspring he places it to nearby empty cell and gives a half of own energy to him.

Agent's actions are categorized and vector of agent strategies is generated using the methodology firstly presented in [4]: to show agent phenotype behavior, each agent was placed in hypothetical situation as if he interacts with other agent under various conditions, i. e. agent's internal energy indicator and agent's relative affinity. Thus, agent is being stressed with six input test vectors and then strategy vector was generated according to his reaction (Table 2). For example, strategy '020202' is so-called crow strategy [4]: regardless of internal agent energy level, he will attack any stranger in his area and make no harm to relatives.

Table 2. Vector of agent's strategies. Where A {0: «rest»; 1: «escape»; 2: «attack»; 3: «divide»}, i = 1, 2, 3, 4

Low resource, $r = 0{,}02r\max$		Half of resource, $r = 0{,}5r\max$		Many resources, r = $0{,}98r\max$	
relative behind	non-relative behind	relative behind	non-relative behind	relative behind	non-relative behind
a_i	a_i	a_i	a_i	a_i	a_i

MODEL COMPARISON

A set of simulations were executed model, they were characterized by various income resources level to environment. The goal of this runs was to validate the model and observe link between its results and behavior of similar original model [4], due to the notion of model «docking» that was mentioned before.

The key differences between current model and its prototype is that only one agent can occupy the cell rather than any agent's quantity and that are no chromosome vector that is the bit string which codes the presence or absence of individual sensory inputs and actions. Considering this, we could stress possibility of successful modification of model into current one and obverse similarities and alterations between the features.

Dynamic of agent's population count reliant of resource income from model [4] is depicted in Fig. 2. There are different configurations that define presence of several agent's features such as differ relative and attack other agents; we introduced its analogies in current model:

1. No aggressive behavior, agents do not differ relatives.
2. Agents can attack each other, agents do not differ relatives.
3. Agents can attack each other, agents differ relatives.

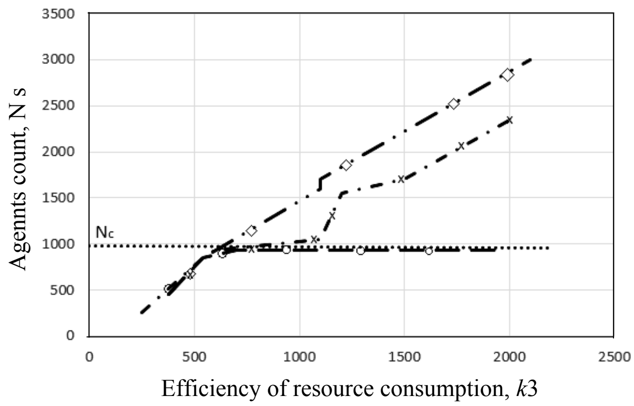


Fig. 2. Dependency of agent count from input resources in original model (plot resembles agents' population dynamic from the research [3])

In Fig. 2 first type of configuration is similar to one tagged with sign «◊», «o» responsible for second case, «x» values can be considered in accordance to results of simulations on third case. As follows in Fig. 2 is shown that dynamic of agents count is directly proportional to input resource in case of absence of aggressive behavior [4]. For experiments in second case, results are divided in situations when agent cannot satisfy himself with resource by staying in one cell permanently and when agents fill all space (Nc — count of cells in environment) but cannot share cell resources with anyone other. For results that respond to third configuration agent count dynamic firstly has behavior of second situation in second configuration and then «switches» to behavior of first situation [3].

Experiments under the model developed on research were executed for various values of input resources. Consider now the plot of results of experiments with the model implemented in the study (Fig. 3).

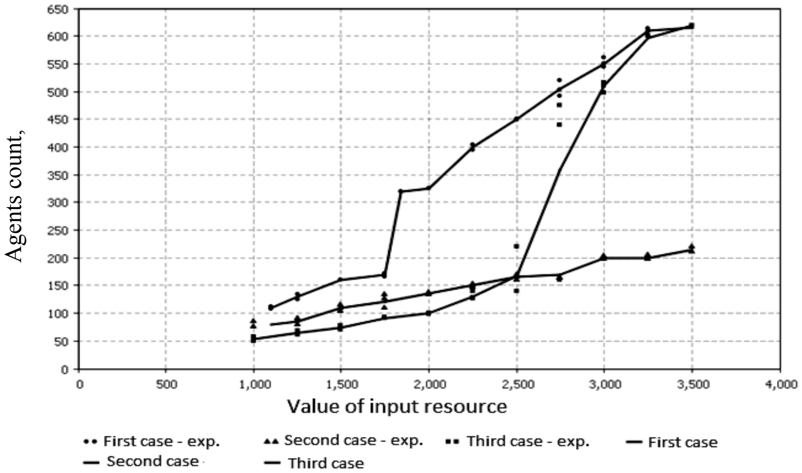


Fig. 3. Plot of population size on the number of resource input. The set of experiments is depicted

Figure 3 shows that the results of the first case of the simulation also lie on a straight line, indicating a proportional relationship between resources and population size. The results are also consistent with the dynamics of population in generic model in second and third cases. Up to a certain value of the resource plots of second and third cases are similar, while the later dynamics of the number of agents in the third case goes to the level curve of the population for the first case. Considering the results of comparison we can infer that prototype and replica models have similar population count behavior patterns. Following the notion of o posteriori fitness function for intrinsic adaptation evolutionary process firstly introduced by Packard [2] we want to emphasize that population size feature could be treated as such system fitness.

AGGRESSIVE AND PEACEFUL BEHAVIOR

Model is a plausible playground for studies of dependence of aggressive and peaceful behavior from the number of input resources and types of interaction between groups of related agents. We propose to observe simulation results for third case of modeling: agents can attack each other, agents differ relatives and find the references of aggressive behavior occurrences between particular and prototype model. The option of cooperative defense was disabled for observed cases in this chapter.

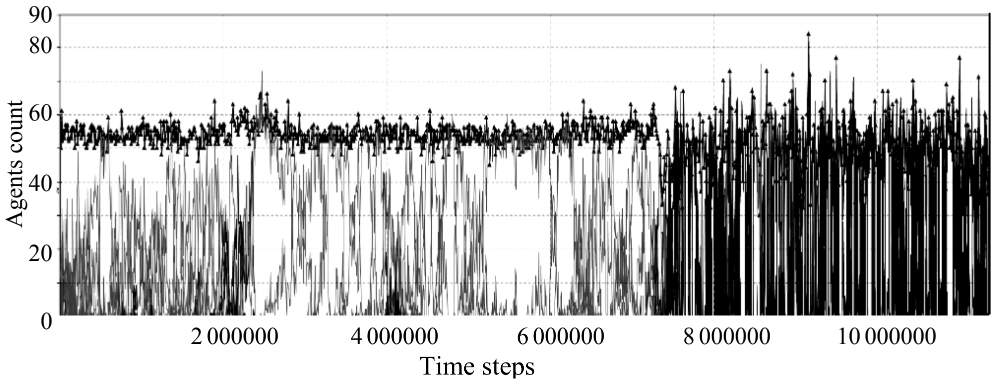


Fig. 4. Example graphics strategies for simulation of resource inputs 1,000 units. Value of each curve point is the count of agents adopted the strategy that corresponds to this curve

The graph (Fig. 4) shows a number of strategies for agents that in some time clock comply with the relevant strategy. If agents choose action attack, the color range of their strategies shifted to black, other action — spectrum shifts to gray. The curve marked by triangles reflects the size of the population of agents.

Thus, we see the dominance on the significant amount of time peaceful strategies aimed mainly search and acquisition of the resource. The behavior of a population over time is divided into two conventional stages: peaceful phase (7,4 million cycles), and aggressive (later 7,4 million cycles). These periods are inherent to the small number of cases for the small resource count that goes on.

Therefore, the low amount of resources one of the most effective strategies are peaceful strategy when agents either do not distinguish between family and prefer to rest (for example, the strategy 000000), either run away from the family in order to avoid competition for resources (eg , strategy 000010) or escape of strangers feeling threatened, and other variations of these strategies. Frequencies of strategies agents that do not distinguish relatives and takes kin affinity into account differences vary slightly toward the predominance of a cooperative strategies. Under the notion cooperative it should is considered strategies that distinguish kin and adjust their behavior to benefit from it, such as absence of aggression in kin neighborhood, thus agent can finding protection in the event of a threat or leave area filled with relative, which reduces competition for local resources between them.

For smaller amounts of resources peacfull strategies playing an important role. With an increasing number of resources, almost all strategies show aggression. Peasfull strategies can no longer last such significant periods of time as in the previous cases. Almost all strategies exhibit aggressive behavior and are very volatile. Charts conduct population dynamics of repeated aggressive period that was mentioned in the case of a small number of resources. It should be noted that the vast majority strategies differ relatives in at least one case for the value of the resource in the test vector. Increased value of environment population capacity as in the time interval of 600 thousand – 800 thousand iterations (Fig. 5), ussually caused by domination by fully cooperative strategies, that is, those that distinguish relatives in all cases the value of the resource in the test vector strategies: 020202 (a strategy known as «crow» in [4]), 020213 («escape» from relatives to reduce competition for resources), 020203 (action «divide» to ensure the protection from the surroundigs relatives).

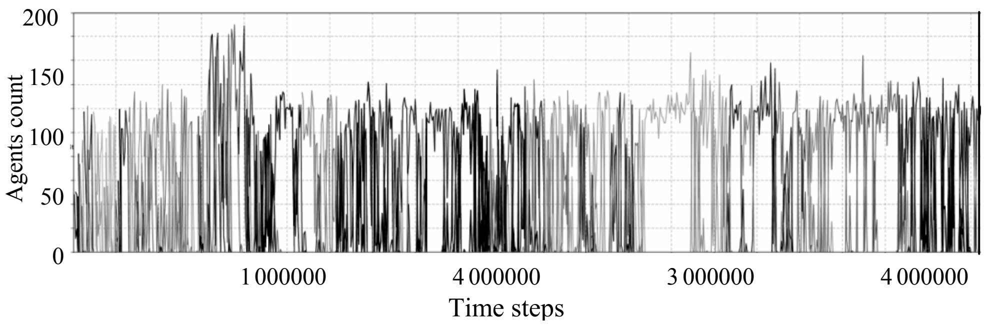


Fig. 5. Strategy for a population the average number of resources. Value of each curve point is the count of agents adopted the strategy that corresponds to this curve

For a large number of resource inputs agents have the ability to completely fill the grid space and competition between strategies becomes sluggish. Thus by the amount of resources when all cells are filled with aggressive agents and peace strategies are stable and rarely changing each other (Fig. 6).

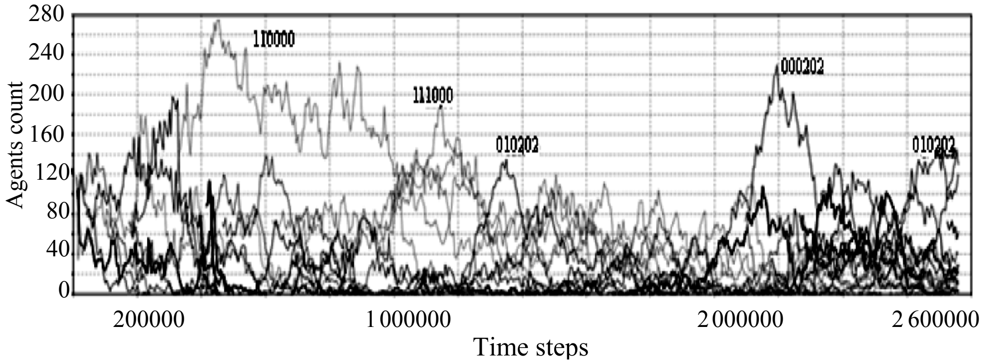
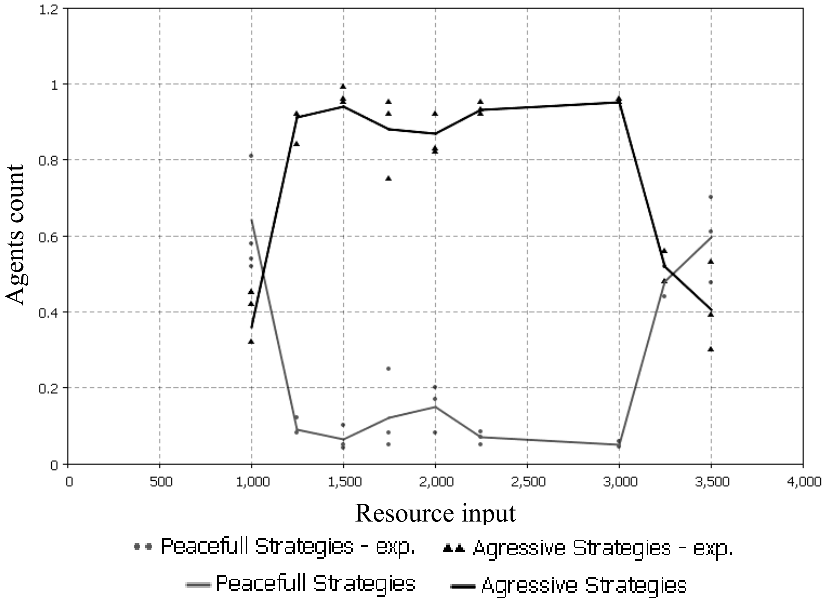


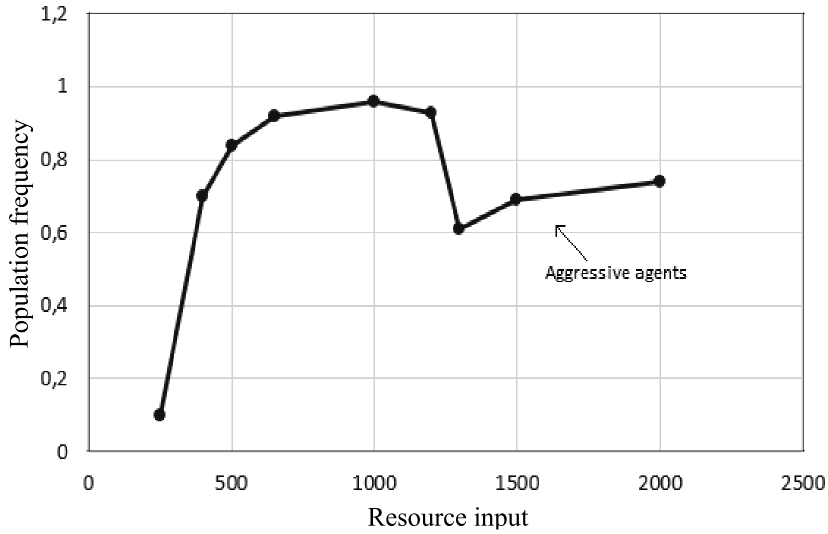
Fig. 6. Agents' strategies for a large number of resource. Value of each curve point is the count of agents adopted the strategy that corresponds to this curve

Considering dependence of aggressive behavior from input resources, we can compare to analogues pattern of prototype model and find the similarities.

That is the dynamic of aggressive strategy frequency corresponds for both models (Fig. 7). Strategy is treated as aggressive if it have at least one «attack» action in its legend.



a



b

Fig. 7. Dependency of peaceful and aggressive behavior from input resources; *a* — strategy frequency for current model; *b* — frequency of aggressive strategies is population in prototype model. Picture resembles aggressive agent's population frequency dynamic from research [4]

DISCUSSIONS

This work is generally dedicated to the experience of model modification and comparison of behavior patterns between the models. We can conclude successful modification of existing model into one that has slight differences. We observed similar features and extended the horizon of simulations under the model. Peaceful and aggressive strategies intensity was tested for its dependence on the availability of resource in multi-agent system. The dependency of aggressive and peaceful strategies competition from the number of available resources was illustrated. Simulation results between replicated and prototype models of AL were similar.

As possible further development of the particular model from the family of artificial life, we considered resolving the following issues: overcoming the great computational complexity of the experiments, improving interaction between the agent and the environment, replacing the discrete space type to continuous, introduction new types of interaction between agents and building new tools of analysis of populations of agents.

Software enhancement of model application that allows running it on high computation performance environment would give the possibility to observe long-term trends that provide valuable efforts for understanding of models of such type.

The important issue is introduction and usage of novel analysis method for agent-based complex adaptive systems. For example, Burtsev proposed promising methodology that considers evolving agents' population as a dynamic system in [7].

Open question is the research of agent groups' competition and establishing the intensity of the impact of various factors, such as aggression and phenotype transition strategies, on the success in the competition.

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