



# Is evolution always “egolution”: Discussion of evolutionary efficiency of altruistic energy exchange

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## ABSTRACT

In the article I study the evolutionary adaptivity of two conceptual population models, based on either altruistic or egoistic law of energy exchange. During the extensive computational experiments, the models were compared by their ability to survive both “series of cataclysms” (fast extreme changes of the environment) and one radical change after a long stasis. The computational experiments show a convincing advantage of the altruists: there is a considerable area in the experiment’s parameter space where the altruists succeeded in both experiments; however there were no egoist populations found that could pass even the first trial. The examined models are pruned to the extent where the effect of energy exchange strategy is clearly visible. The obtained results could warm up the interest to the positive role of altruistic phenomena in evolution, ecology, technology and philosophy.

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## 1. Introduction

The origins and potential of self-developing complex processes is one of the most challenging topics today and will become one of the most important branches of science tomorrow. As a part of Earth’s biosphere we are familiar in practice with only one such a process – evolution. Although the evolution of biosphere on Earth may be studied in detail, there are no other known examples of natural self-developing complexity, which leaves us with our imagination and modelling on the way to the essence of autonomous systems’ organization and complication. One of the recently proposed instruments to cope with the lack of heterogeneous examples is *radical reimplementation* (Lehman and Stanley, 2015), where experience in some vague subject is variegated by achieving the key aims using the most unusual means. This article is focused on the radical reimplementation of selfish energy consumption among the organisms in evolving populations. In particular, I study the effectiveness of adaptation of the populations in changing environment where the behavior of *each* model organism is characterized by a high degree of altruism.

Evolution is usually considered as a process driven by individual reproduction gain. Even altruistic phenomena like reciprocal altruism (Clutton-Brock, 2009; Trivers, 1971) including mutu-

alism (Bronstein, 1994) and eusociality (Nowak et al., 2010) with its mechanisms of inclusive fitness (Gardner and West, 2014) often thought to be evolved on the basis of individual gain. There are many works devoted to the *appearance* of altruistic phenomena in the world of competition, where more adapted leave more offspring (see, e.g. (Axelrod, 1984; Burtsev and Turchin, 2006; Cooper and Wallace, 2004; Hamilton, 1964; Kropotkin, 1902; Lehman and Keller, 2006; Lewin-Epstein et al., 2017; Smith and Szathmari, 1995; Uyenoyama, 1979; Wu et al., 2016)).

Despite the origination of altruism is studied relatively well, the comparative quantitative effectiveness of altruistic behavior for the successful adaptation of the population received little scholarly attention. I am familiar with only a few papers, where altruism is considered as a preliminary inherent property of the model and directly competes with the egoistic-based model in efficiency (Cesta et al., 2011; Kreft, 2004; Pfeiffer and Bonhoeffer, 2003). The current paper continues this competition: altruistic- and selfish-based models with simple homogeneous population structure are exposed to the evolution process in a changing environment with the purpose to explore quantitatively which strategy provides more efficient adaptation and survival.

Compared with the well-studied approach of *evolutionary games* (Bomze, 1986; Hofbauer and Weibull, 1996; Smith, 1982; Weibull, 1997), in this study both altruistic and selfish strategies struggle *not against each other*, but against natural obstacles lurking for a population in mutation-selection process. Such experiments with “homogeneous” populations whose organisms adhere to one single strategy of energy exchange allow to make conclusions about

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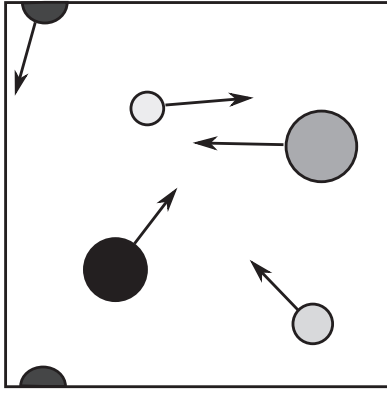


Fig. 1. Experiment field.

adaptation flexibility and application potential of each particular strategy (see Section 3 for a more detailed discussion of the role of energy in the model populations).

The model populations consist of moving colored circles, where circle's radius is energy and RGB-color is 3-genes genotype (Fig. 1). Each time two circles meet they exchange energy in either altruistic (the larger one gives a half of its energy to the smaller one) or selfish (the larger strips a half of the smaller's energy) way. If an organism becomes large enough, it disappears giving birth to 2 new organisms. The probability of such replication depends on the organism's fitness – the correspondence between the current “environmental conditions” (which may be visualized as the color of the background field and may be thought of as the current “target genotype”) and the organism's genotype. Successive changes of the background color forces the populations to move through the “labyrinth of adaptation.” In the classification from intriguing work (Queller and Strassmann, 2009), the altruistic populations, showing high cooperation and low conflict, correspond to the type “*organism*”; the case of the selfish behavior, where the elements of the populations show low cooperation and high conflict, corresponds to a “group of competitors.”

The first question under experimental investigation is plain survival of the populations equipped with one of the two strategies in a rapidly and roughly changing environment (*stress-test*). The populations that succeed to beget consequently all the 8 given target genotypes without stumbling across genetic bottlenecks (Nei, 2005; Nei et al., 1975) or stasis (Stenseth and Smith, 1984) are then compared by speed of adaptation.

The second question is how long a population can stay in a constant environment (and thus “overspecialize”) while preserving enough genetic variety to be able to survive and adapt when the environment finally radically changes (*idyll-test*). The results of the conducted experiments suggest that the altruistic populations are much more flexible in the process of artificial evolution.

Although the considered model is simple, it is a “complex system” in the classical sense (Sayama, 2015): “Complex systems are networks made of a number of components that interact with each other... Complex systems may arise and evolve through self-organization, such that they are neither completely regular nor completely random,... permitting the development of macroscopic properties that are hard to explain simply from microscopic properties.”

## 2. Model description

The population structure and evolution process models are rather simple and resemble bacterial life in a changing milieu.

**Organisms.** Each organism  $O$  is represented by a circle, whose radius  $rad(O)$  corresponds to “energy,” and 3-component RGB-color  $(r(O), g(O), b(O)) \in \overline{1, 255}^3$  corresponds to 3-gene “genotype”. The position of the center of each organism is given by the two coordinates  $(x(O), y(O))$ ; discrete-time dynamics is determined by the constant speed vector  $\mathbf{v}(O)$  with the randomly chosen unchangeable direction  $\alpha(O)$  and the length equal to 2. Every *step*, each organism is shifted according to the simple linear rule:

$$x(O) := x(O) + |\mathbf{v}(O)|\cos(\alpha(O)),$$

$$y(O) := y(O) + |\mathbf{v}(O)|\sin(\alpha(O)). \quad (1)$$

The speed-vector length 2 is just a practical compromise: its increase intensifies evolution speed (which is a plus as it allows to conduct more computational experiments), but also enhances the chance of contact inaccuracy (the situation where two small organisms moving discretely can just step over each other without contact).

**Field.** The organisms live inside a discrete plane square field  $\overline{1, 100} \times \overline{1, 100}$  with rather common toric topology, which means that if an organism moves behind a border it appears out of the opposite border with the same speed vector (see Fig. 1).

The only reason to introduce the field and movement into the model (instead of plain interaction probabilities) is the provided visualization script (see (Ivanko, 2017)) so one could observe the destiny of the populations in the evolution labyrinths.

**Population.** Each population initially consists of 100 organisms, and this is the maximum allowed number of organisms in the population. There are three important parameters that characterize each population:

- mature size ( $ms$ ), an organism that possesses less radius can not divide;
- die size ( $ds$ ) is the radius falling below which an organism dies and its remaining energy dispels without any use for the other organisms;
- newbie size ( $ns$ ) is the radius of any newborn organism.

The initial conditions – positions, radii and colors of the population's organisms – are chosen uniformly:  $(x, y) \in \overline{1, 100}^2$ ,  $rad \in \overline{ds, ms}$ ,  $(r, g, b) \in \overline{1, 255}^3$ .

It is evident that any viable population has to receive more energy, than it spends. In the following experiments, the energy input is provided by two simple conventions (see comments in the next section):

- $ns > ds$  – an evident survival constraint (a newborn organism possesses enough energy not to die at the moment of birth);
- $ns \leq ms \leq 2ns$  emulates a reasonable energy input to the model; this is an analog of plentiful food; large newbie size corresponds to the imaginary situation where descendants appear on the field and start to participate in energy exchange (social life) only when they are grown to some extent (like it happens with many species).

**Contact.** The energy exchange between two organisms takes place when they “touch”, after which they continue to move with the unchanged speed vectors. Formally, two organisms are considered to be in touch at the current step if

1) the distance between their centers does not exceed the sum of their radii,

$$\sqrt{(x(O_1) - x(O_2))^2 + (y(O_1) - y(O_2))^2} \leq rad(O_1) + rad(O_2); \quad (2)$$

2) the condition (2) was not true at the previous step (this is a purely technical condition to avoid repeating back and forth energy exchange while the organisms stay close).

**Energy exchange.** When two organisms  $O_1$  and  $O_2$  touch each other they exchange energy in either *altruistic* or *selfish* way. In an

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