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Altruism in Evolutionary Algorithms for the Reconstruction of Brain Activity from MEG Measurements

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Abstract

Evolutionary strategies are a class of optimization algorithms. They emulate natural evolution based on a Darwinian „survival of the fittest". However, in natural evolution, altruism (unselfishness) is a commonly observed phenomenon, too. We have developed evolutionary strategies realizing different kinds of altruistic behavior. With the help of simulations on standardized mathematical optimization problems and data analysis involving source localization of magnetoencephalographic data we compared our new algorithms to each other and to equivalent algorithms without altruism. We found that only a certain amount of altruism improved the performance, too much altruism worsens the performance. The best results were obtained when including ostracism. In conclusion, for low dimensional optimization problems, altruism has a beneficial effect on the performance of evolutionary strategies.

1. Introduction

Evolutionary computing describes a group of probabilistic optimization techniques inspired by natural evolution, where random variation and natural selection shape the behavior of single individuals and entire species in order to fit the demands of their surroundings. It includes evolution strategies, genetic algorithms, and evolutionary programming (review e.g. in [1]). Such techniques are by no means the most efficient in terms of convergence speed (as compared to e.g. deterministic gradient based methods). However, they are less sensitive to entrapment in local minima. This is an important aspect in the reconstruction of brain activity, since for example in dipole localization procedures with more than one dipole, multiple minima often dominate the goal function.

The fundamental principle of selection in evolutionary computing is the Darwinian „survival of the fittest". On the other hand, altruism or unselfish behavior has been shown to be an intrinsic part of evolution (e.g. [2]) and is found in a variety of species including humans.

Consequently, the question arises in how far altruism can also modify the performance of evolutionary strategies. This paper investigates this question with the help of mathematical bench mark functions and source reconstructions based on magnetoencephalographic data.

2. Methods

The algorithms introduced here are based on the classical (5/5, 20) evolution strategy proposed by Schwefel and Rechenberg [3]. From 5 parent individuals, 20 children are generated by mutation and recombination. Then the best 5 are selected to form the next parent generation. Altruistic behavior is added in the following variants.

Different selections of next parent generation: S1 through S4 - In these algorithms, not the 5 best individuals, but other choices are selected for the next parent generation. *Selection dependent on goal function landscape: D1, D2 and D3* - These methods evaluate the difference between the fitness of the best and the second best individuals. If this difference is larger than 20 % of the dynamic range of the goal function values, a special selection scheme is used, otherwise the 5 best are taken. *Competing Populations (co-evolution): P1 through P5* - These algorithms work with 2 competing populations. They both use the same starting point and have 5 parents, but produce different numbers of children depending on their fitness.

Table 1: Selection of the next parent generation for different algorithms. The individuals are ordered according to their fitness, X means selection.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	…	25
S1		X	X	X	X	X										
S2	X		X		X		X		X							
S3	X	X	X			X			X							
S4	X	X	X		X		X									
D1	X	X	X		X		X									
D2	X		X		X		X		X							
D3	X			X			X			X			X			

3. Results and Discussion

Fig. 1 shows the performance of the new algorithms compared to the standard (5/5, 20) algorithm. We find for altruism between individuals, that only a certain amount of altruism improved the performance, too much altruism worsens the performance. Moreover, this type of altruism seems to improve performance only for relatively smooth goal functions. The best results are obtained when including ostracism (S1). Altruism between populations rather than individuals generally performs considerably better, in particular when the performance is assessed by the average of all individuals instead of by the best individual only.

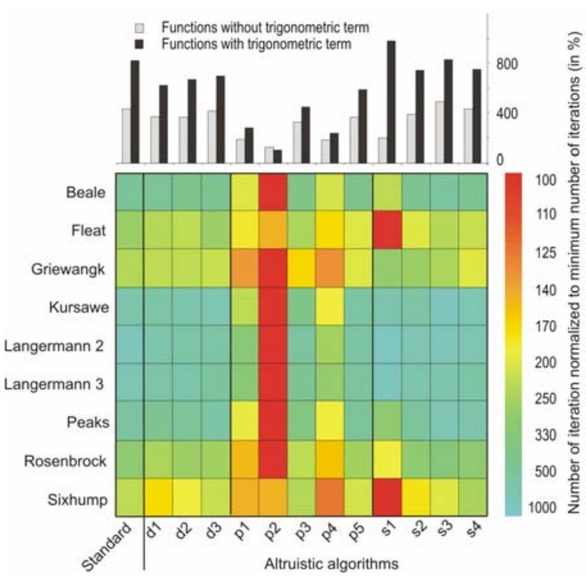

Figure 1: Numbers of iterations needed to reach convergence, normalized to the minimum number of iterations for the respective benchmark function. The average is over 100 repeated runs. The bar chart in the top panel represents the cumulative values over benchmark functions separated into functions with and without trigonometric term.

For source localization in an auditory experiment (Fig. 2), P2 shows the best and S1 the worst average performance. Moreover, P2 also consistently exhibits the smallest confidence intervals. There is a tendency (most clearly for P2) that initial dipole positions, which are further away from the optimal one, need more iterations.

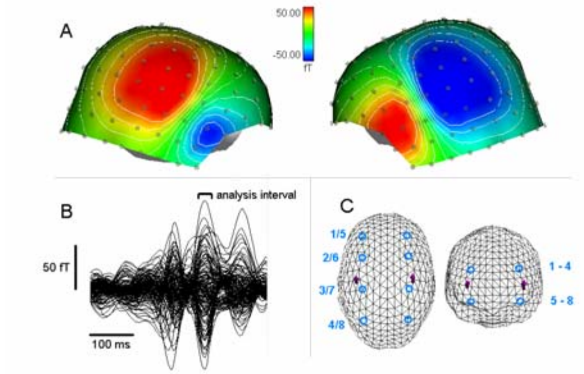

Figure 2: Experimental setting of MEG study. A: Color coded map of averaged magnetic field. B: Overlay of 148 averaged MEG traces. C: Best fitting dipoles (red arrows) and initial dipole positions (blue circlets) together with wire frame of computational model of the brain. The blue numbers refer to the 8 dipole pairs (with one dipole in each hemisphere) considered as initial positions.

The phenomenon of altruism is investigated in the studies of animal behavior, in psychology, and in experimental economy. For example, Hudson and Jones [4] analyze empirical data and perform theoretical calculations on voters altruism (selfish: lower taxes, altruistic: higher taxes for better education and welfare) and find that both self-interest and public-interest are influencing voters' decisions, where the social boundary conditions regulate the amount of altruism. The conclusion of that paper agrees with our study: a balance with a certain amount of altruism is necessary for optimal performance.

4. Conclusions

We provide evidence that a certain amount of direct altruism (preferentially between populations) can increase the possibility to find the global optimum in evolutionary computing.

5. References

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