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Reputation-based cooperation – what if errors?

Related work

A simple, free of parameter model of the Evolutionary Prisoner Dilemma was proposed in [1] and developed in [2]. In this scheme, players could acquire reputation and modify their altruism, what in turn determined their choices of strategy. The probability of cooperation depended both on the player's altruism and the co-player's reputation. Agents could establish their strategies in repeated games. Each time a player cooperated (defected), his reputation went up (down). The game could lead to a collective behavior.

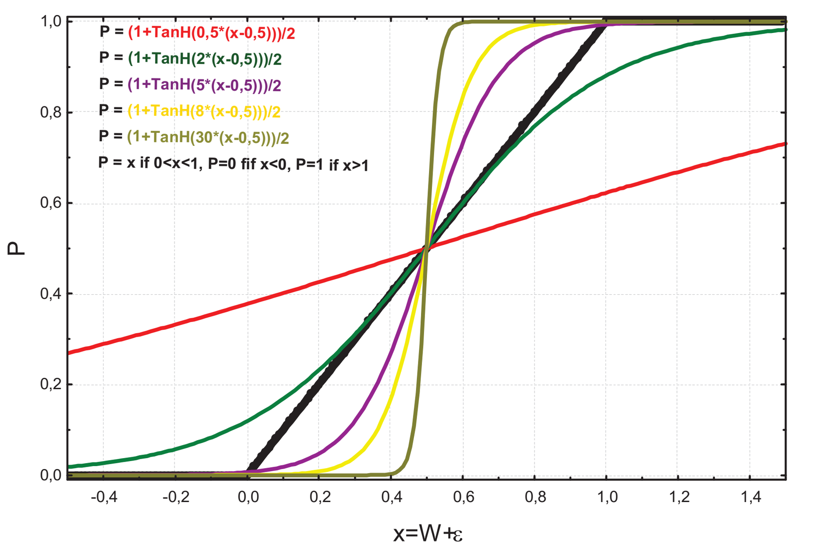

Fig 1) Visualization of different cooperation probability functions.

Motivation

The method of calculation of the probability *P* of cooperation in Prisoner Dilemma influences the game evolution. Authors of [1] assumed, that *P* was a linear function of both the player's altruism in range (-0.5, 0.5) and the player's reputation in range (0, 1). Accordingly, the range of values of *P* (-0.5, 1,5) was limited to (0,1) as follows: the result above 1 was set to 1 and the result below 0 was set to 0. Here we propose a modification of this probability function to a smooth one : namely the hyperbolic tangent [3] with coefficient *a*, which controls the shape of the curve, as shown in Fig.1. The altruism of all agents is set to zero. The aim of this work is to investigate the consequences and new options brought up by this choice of *P*.

Implementation

Here, for neutral altruism, the probability P(W(*k*,*i*)) that agent *k* cooperates with agent *i* is chosen as:

$$P(W(k,i),a)=\frac{1+\tanh(a(W(k,i)-1/2))}{2}$$

where W(*k*,*i*)∈(0,1) is the reputation of agent *i* in eyes of *k*. **Parameter 1/*a* can be interpreted as a measure of human error.** Note that in the limit of infinite *a*, the game is deterministic.

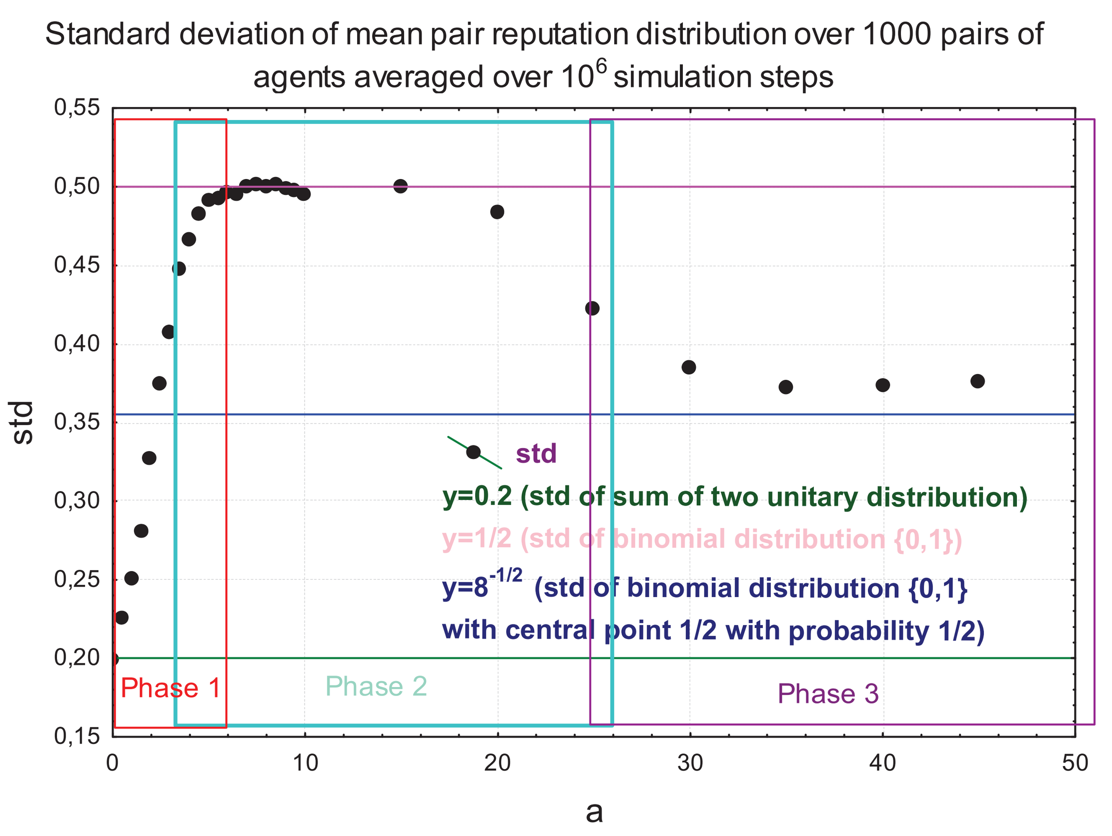

Fig. 2) STD of reputation in population with characterictic lines for comparable distributions.

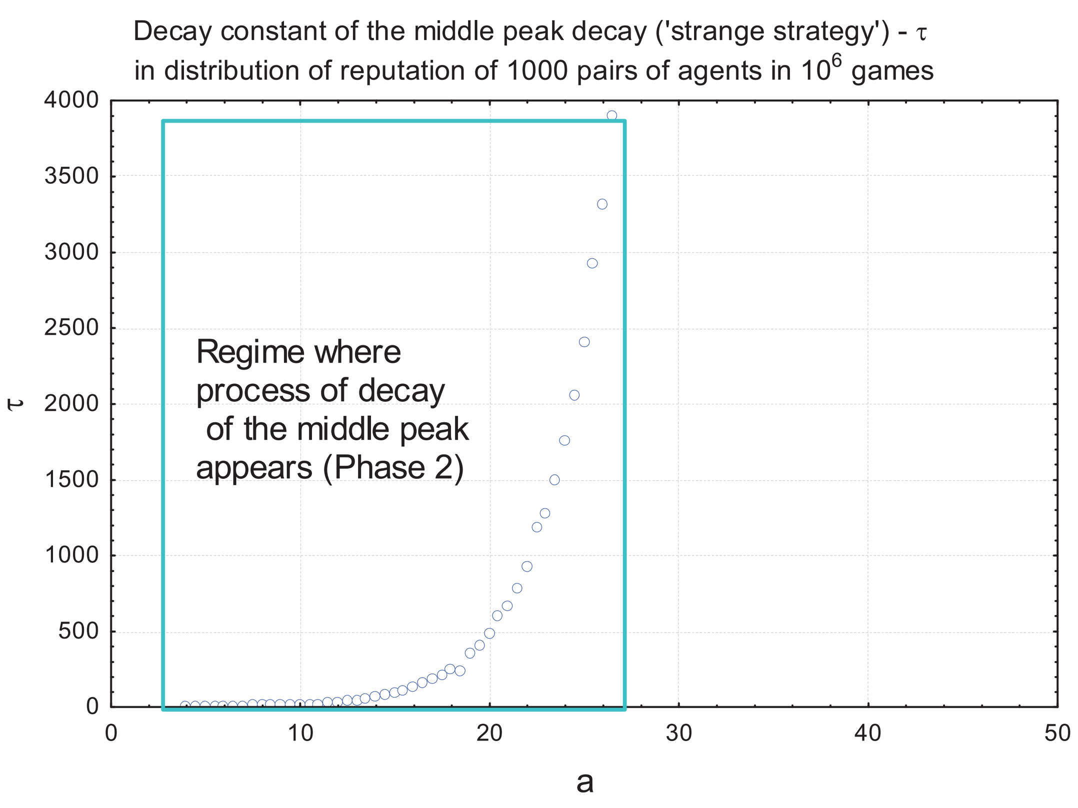

Fig. 3) Estimation of decay constant *τ* representing 'strange' strategy from phase 2.

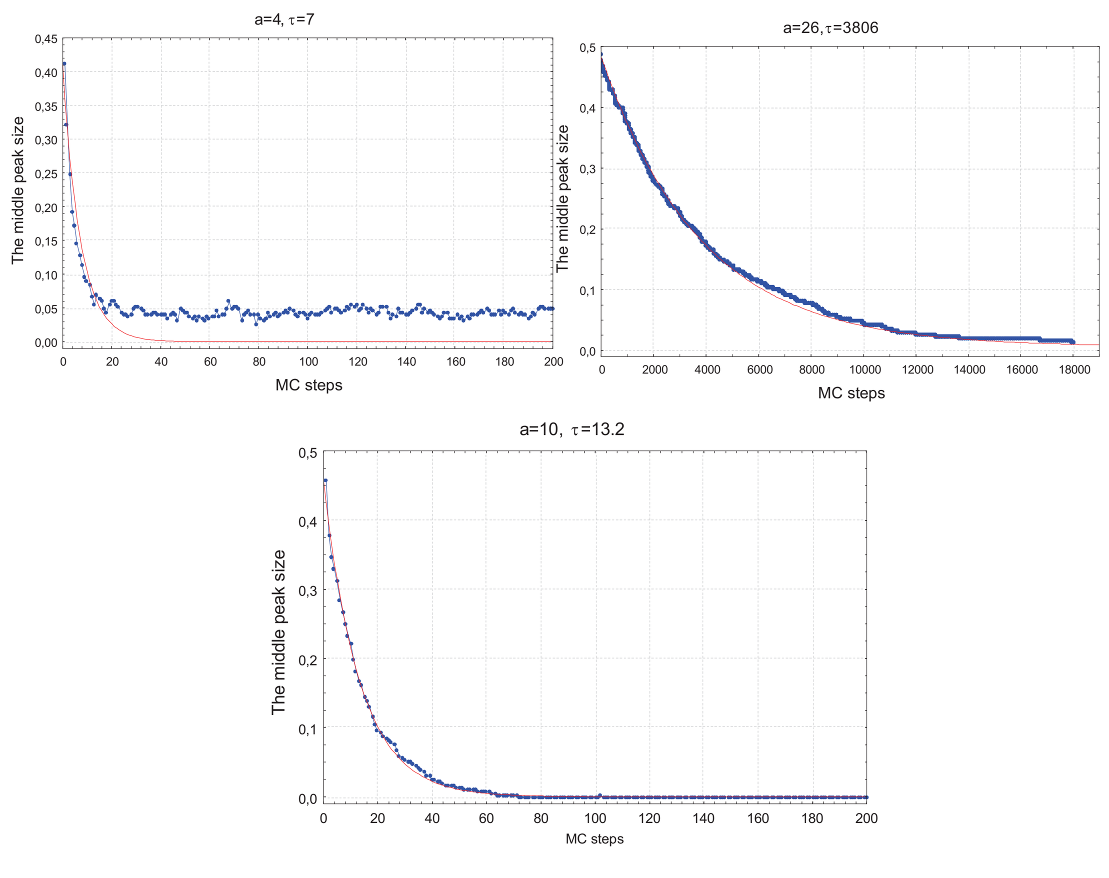

Fig. 4) Fits of decay function with intensity of the middle peak for characteristic *a*.

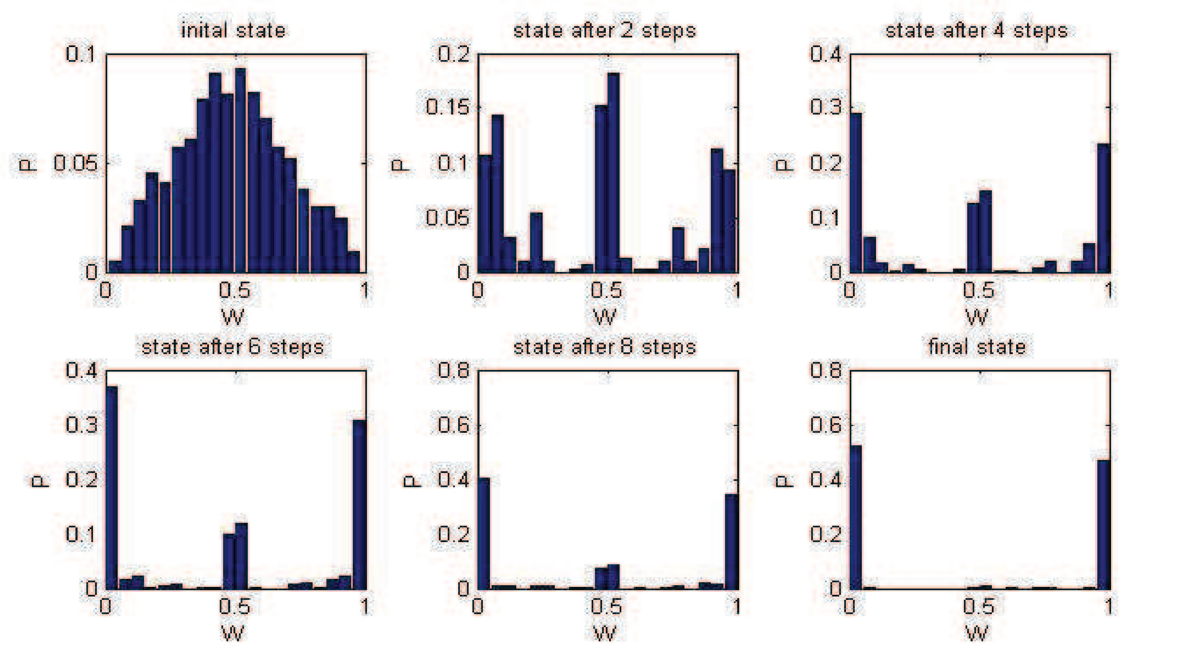

Fig. 5) Histograms of mean reputation of 1000 pairs in different time steps for *a*=8.

Trajectories of reputations

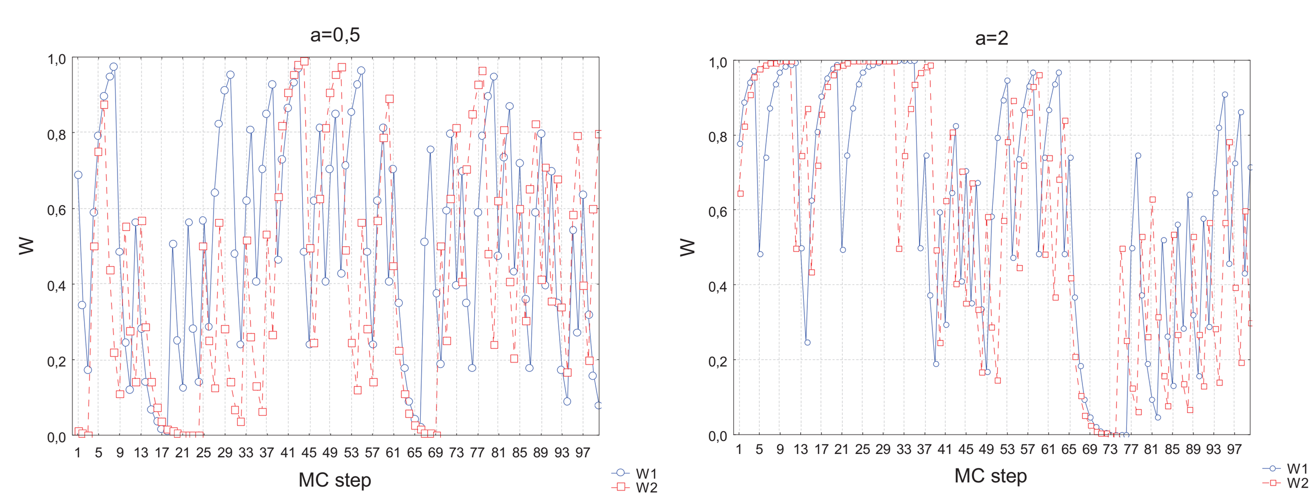

Fig. 6) Phase 1. For small *a* reputations evolve quite randomly.

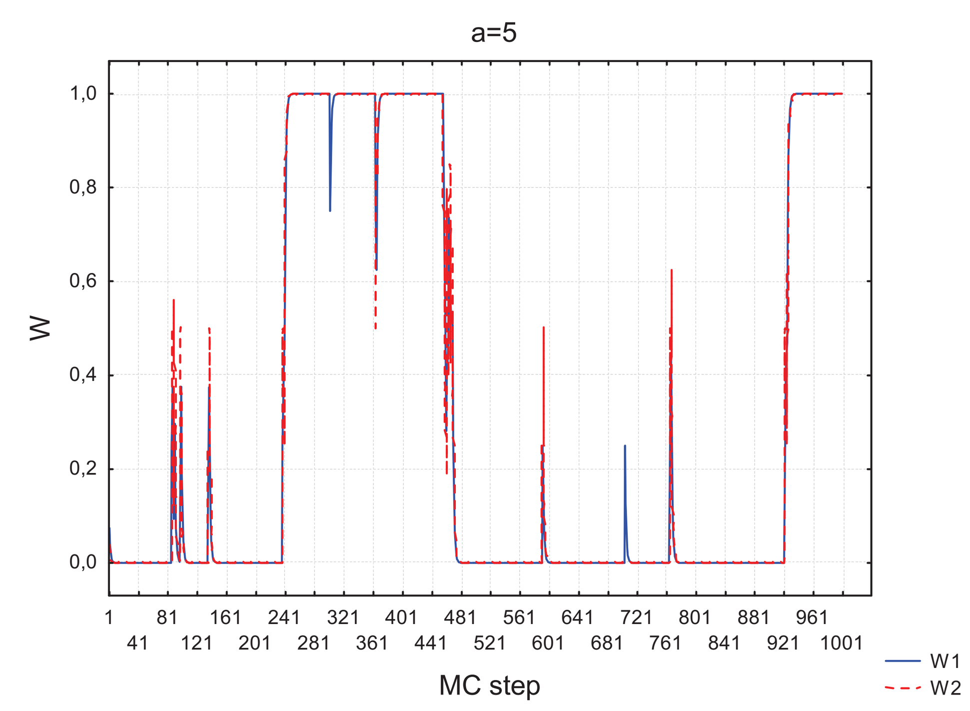

Fig. 7) Cross-over Phase 1&2. Characteristic depolarisation.

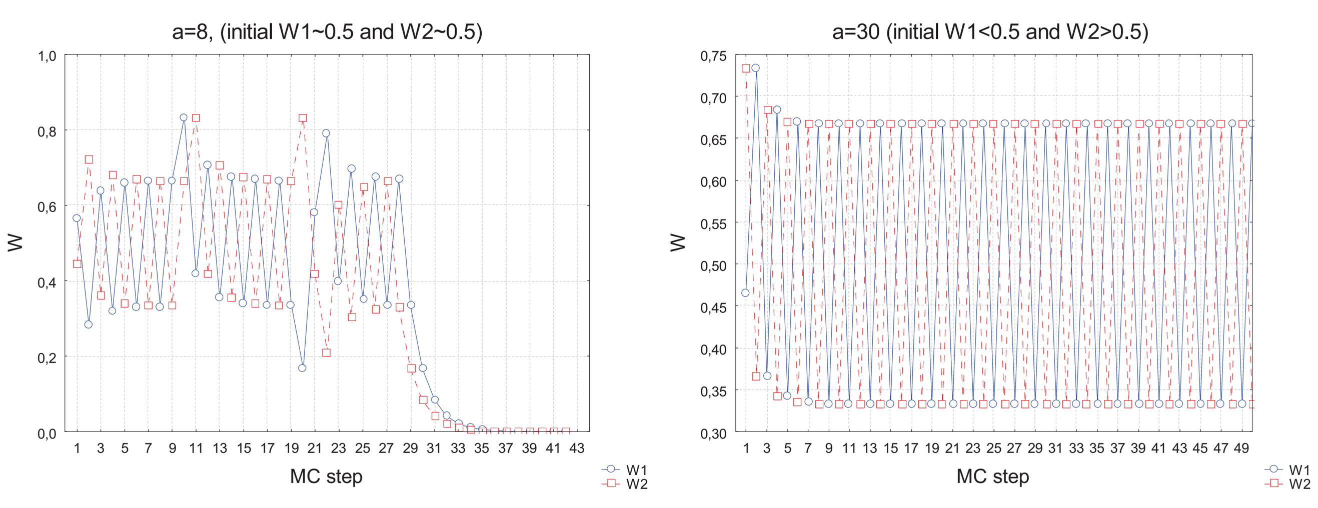

Fig. 8) Phase 2 (left), Phase 3 (right). Cycles around mean W=0.5.

Conclusion

The proposed parameterization of the cooperation probability allows to investigate an influence of errors of players on the overall system dynamics.

Results

We observe three modes of behavior (termed 'phases' for brevity from now on) for different ranges of *a*, as shown in Figs 2-5. However, the boundaries between these phases are fuzzy: some properties overlap.

(Phase 1)
For *a* smaller than about 4, strategies seem to change randomly in time [Fig. 6].

(Crossover Phase 1&2)
For *a* around 5, players choose in most cases the common strategy (both cooperate or both defect) and play this for some time. A state can switch to the opposite one with some probability, as shown in [Fig. 7].

(Phase 2)
For 5 < *a* < *25* the common strategies dominate. During a few initial steps of the simulation usually the players quickly choose some common strategy. Still, some 'strange' strategy is also possible, where mean reputation of both players is around 0.5, i.e. close to the center of the range [Fig. 8 left]). This means that when one of players cooperate, the other defects; in the next step the roles are exchanged, and so on. Yet after some time, only the common strategies survive. The disappearance of the 'strange' peak of mean reputation can be described as exponential decay ~exp(-*t*/*τ*) [Fig. 3,5]. The 'strange' oscillating scenario cannot persist because the system is not fully deterministic. Namely, it is always possible that the cycle is broken by an 'error': an agent selects a strategy despite its small probability. In a consequence, one of two common strategies prevails. The best fit of the exponential decrease of the strange behavior is around *a*=10 [Fig. 4]. In general, the intensity of the 'strange' peak does not decrease to zero for smaller *a,* because the probabiliy of switching back to the strange state remains positive. On the other hand for larger *a* the relaxation time is very large.

(Phase 3)
For *a*>25, the spectrum of strategies does not vary in time. We observe pairs of agents who play the common strategy: both cooperate or both defect. This happens for a half of the simulated population (0.25+0.25). For the remaining half of population, the mean reputation is 0.5 [Fig. 2], what reflects the oscillating of strategies. The probability of this 'strange' strategy does not decrease in time and it coexists with the common strategies [Fig. 8 right] . Asymptotically, for infinite *a*, the probability function P turns into the stepwise one and the system is no stochastic any more. In this situation, the time evolution can be predicted from the initial state. In particular, the 'strange' strategy is a consequence of the initial state where one player has reputation above 0.5, and the other – below 0.5. In each step, one player looses his reputation but another gains, in the next step the opposite and so on.

Refences:[1]Kułakowski, K, Gawroński, P. To cooperate or to defect? Altruism and reputation, Physica A, 388 (17), pp. 3581 (2009)
[2]Jarynowski, A, Gawroński, P, Kułakowski K. How the competitive altruism leads to bistable homogeneous states of cooperation or defection, LNCS 7204, pp. 543 (2012)
[3] Santos, F, Pinheiro, F, Lenaerts, T, Pacheco, J. The role of diversity in the evolution of cooperation, Journal of Theoretical Biology 299, pp 88-96, (2012).