Adaptation
of multi-agent populations to environmental changes

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I will model a society composed of multitude of elements (the agents).

A multitude of "natural agents' in a society.

In my simulations the adaptive intelligent agents

are symbolized by

non-linear single layer perceptrons which has to learn to solve some pattern recognition task.

Learning (adaptation) processes of the agents differ in stimulation, emotions, value systems, etc.

The elements of the society are functioning in changing environments.

Thus, the elements have to be adaptive and ought to adapt to sudden environmental changes and survive.

In reality, the elements of the society are complex ones. We model a large number of the agents during a long sequence of changes.

Therefore, I am obliged to use very simple elements.

My to-say's presentation will be a little bit philosophic.

(I graduated TU, worked in Pattern Recognition, Multivariate Statistical Analysis, Artificial Neural Networks).

To-day I will speak about:

1) My point of view on risk: there are at least two sorts of risks: a risk of individual and a risk of the population.
2) Each individual is an intelligent adaptive agent. I model **adaptive** intelligent agents by means of single layer perceptron trained by back propagation algorithm.

   I will consider populations of SLPs' with inheritance.
3) I will analyze standard gradient descent training algorithm where difference between target values in classification problem could be interpreted as **stimulation strength** and pattern recognition tasks are changing in time (they mimic environmental changes).
4) I will present arguments that for survival of the population, higher risk of individuals is beneficial.

Thus, I am obliged to use very simple adaptive elements.

ADAPTATION

Genetic (inheritance)

Darwin, Baldwin, etc.

Learned by iterative procedure

Pavlov, Thorndike, etc.

nonlinear single layer perceptron (SLP)

trained by gradient descent algorithm

I inherit:

A length of training sequence

A level of corruption of training signals (targets),

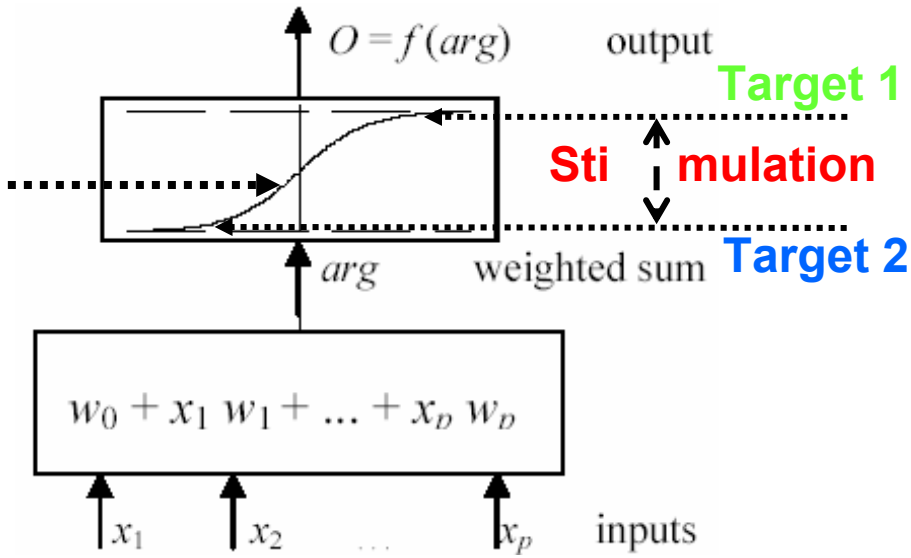
i.e. a noise injection to targets which could be interpreted as a risk level.

Examples of AIA could be:

1) a cell (for example a lymphocyte, neural cell – neuron, etc),
2) an individual (including a robot or intelligent computer program)
3) a group of people (small or larger enterprise)
4) an economic alliance, political group, 5) a state.

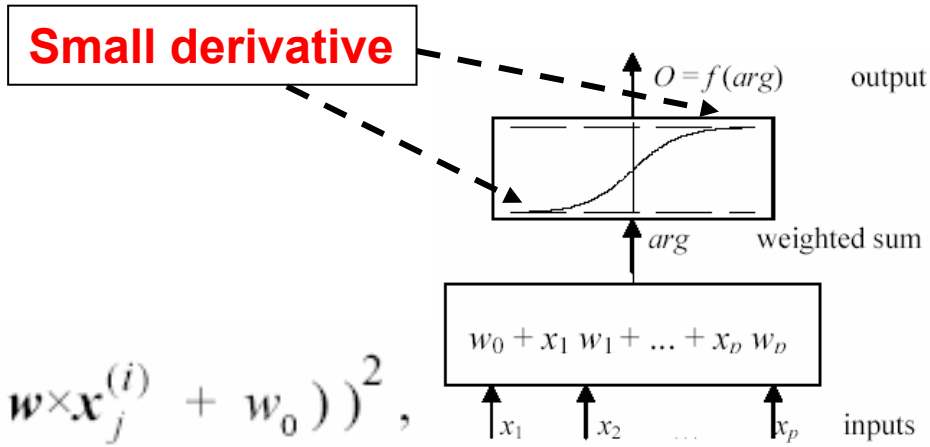
Classical approach in adaptive learning is rooted in psychology. Here learning takes place through a process of punishment and reward with the goal of achieving a highly skilled behavior.

We will model the intelligent agents by means of non-linear single layer perceptron (SLP) trained by back propagation algorithm.



Non-linearity is a key element in analysis of aging, adaptation to changes …

Standard non-linear SLP. Its cost function



$$cost = 1/N \sum_{i=1}^{2} \sum_{j=1}^{N_i} \left(t_j^{(i)} - f(\boldsymbol{w} \times \boldsymbol{x}_j^{(i)} + w_0) \right)^2 ,$$

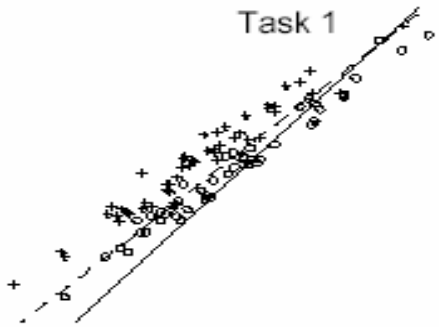
where $wx_j^{(i)} + w_0$ **is a weighted sum,** ***sum*** **(*arg*), and *f*(*arg*) is non-linear soft limiting activation function. Iterative gradient descent training**

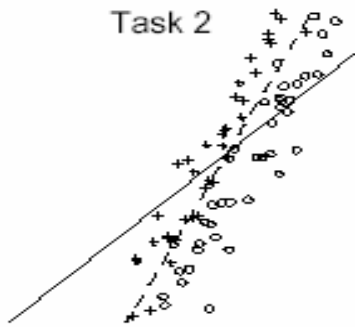
$$\boldsymbol{w}_{(t+1)} = \boldsymbol{w}_{(t)} + CT_{ij}^{t} , \qquad (2)$$

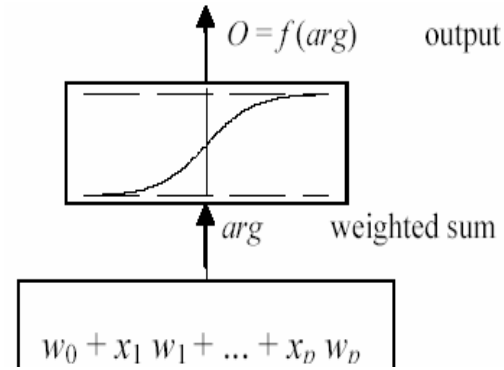
where $CT_{ij}^{t} = -\eta \times (t_j^{(i)} - f(sum)) \times (\partial f(sum)/\partial sum) \times (\partial sum/\partial \boldsymbol{w})$ is the correction term, η is called learning step parameter, $t_i^{(i)} - f(sum)$ is an error signal – a difference between the desired and actual outputs of the perceptron, $sum = \boldsymbol{w}' \boldsymbol{x}_j^{(i)} + w_0$, $\partial f(sum)/\partial sum$ is the derivative of the activation function and $(p+1)$-dimensional vector $(\partial f(sum)/\partial sum) \times (\partial sum/\partial \boldsymbol{w})$ is called a gradient.

When weights are large, sum is large too. Then derivative of the activation function (the gradient too) is small. Learning is slow!!!

Changes of the pattern recognition tasks







If the perceptron was trained to solve Task 1 **for a long time, its weights became large (if classification error rate is small and targets are 0 and 1 for standard sigmoid activation function). Then it is difficult to learn** Task 2 **rapidly (gradient is small). The agent (the individual, robot intelligent computer program) is old.**

When the weighs are large, learning is slow!!!

A chaos theory says that the same laws are valid in micro and macro scales. Moreover, it seems that many of the laws are working both in physics and in information sciences. For example, aging is common for human beings and computer codes.

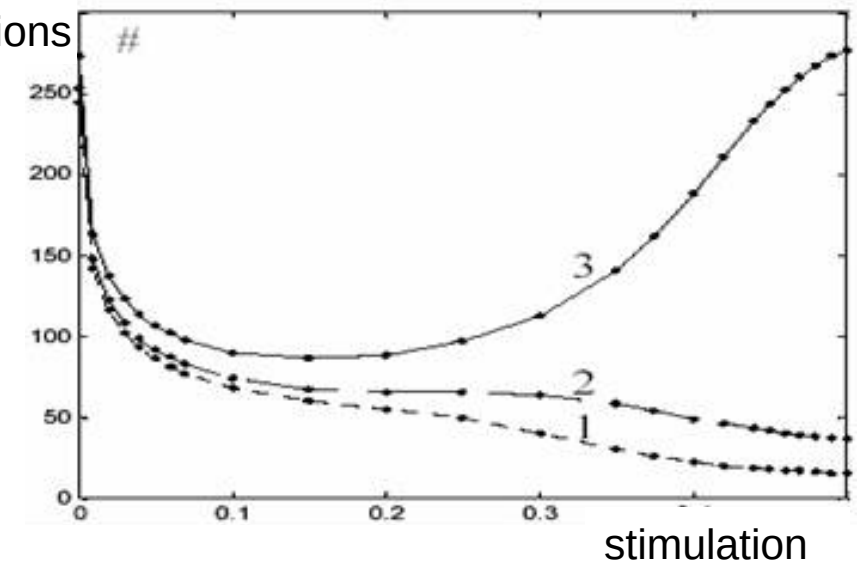
We are trying to explain ageing of human beings and computer codes by the same approach (model), *Int .J. Modern Physics, Ser C*. (Raudys, 2002)

How to affect aging? In means, how to slow down the weights growth?

How to affect training speed? How to slow down the weights growth?

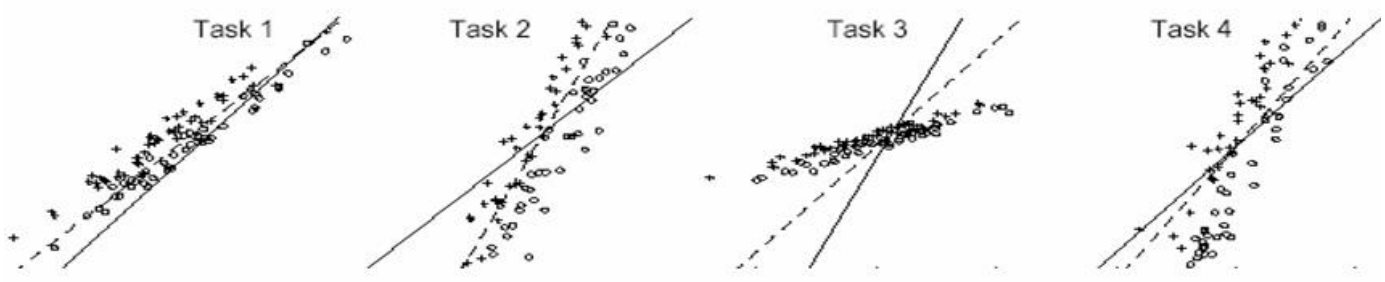
1. Change of stimulation

Yerkes-Dodson Law.



2. Adding a noise. We can interpret this as criminality, catastrophes, etc. And risk too.

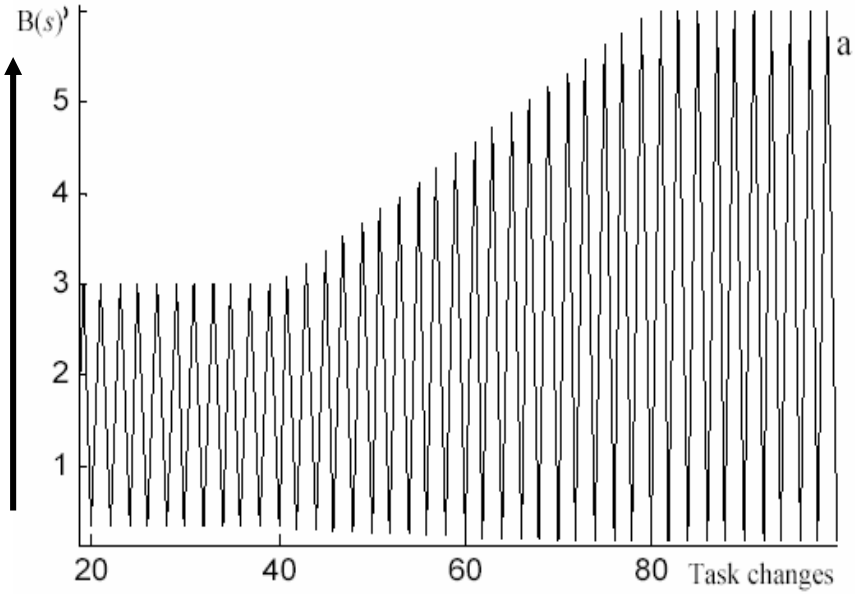
Changeability is inherent feature of the Universe. **I analyze populations with offspring acting in changing environments.**



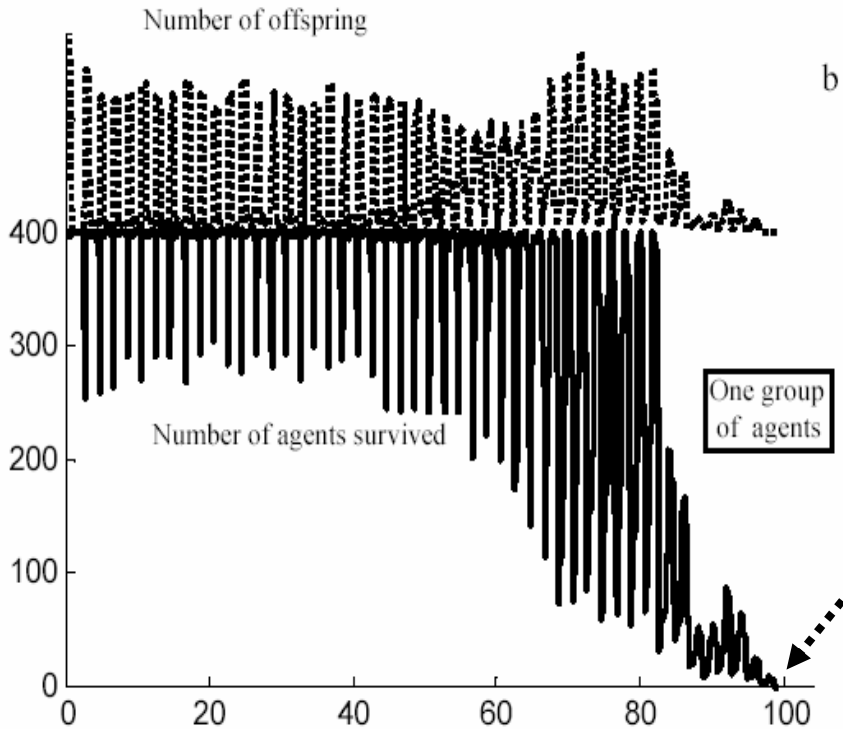
The agents are aimed to function in varying environments, adapt to the unexpected alterations, to comply the fitness function and survive. Failure to comply the survivability condition results in the agent being removed from the "society" and be replaced by a "newborn". The offspring inherits the level of the noise and a length of training sequence, etc.

The population of agents is split into many groups with moderate cooperation between the agents inside the group and very limited cooperation between the groups. To increase ability of agents to adapt to environmental changes more rapidly we suggest storing their gains accumulated during a period of last environmental changes, adding a noise to training signals and level of "survival threshold".

A strength of the task changes

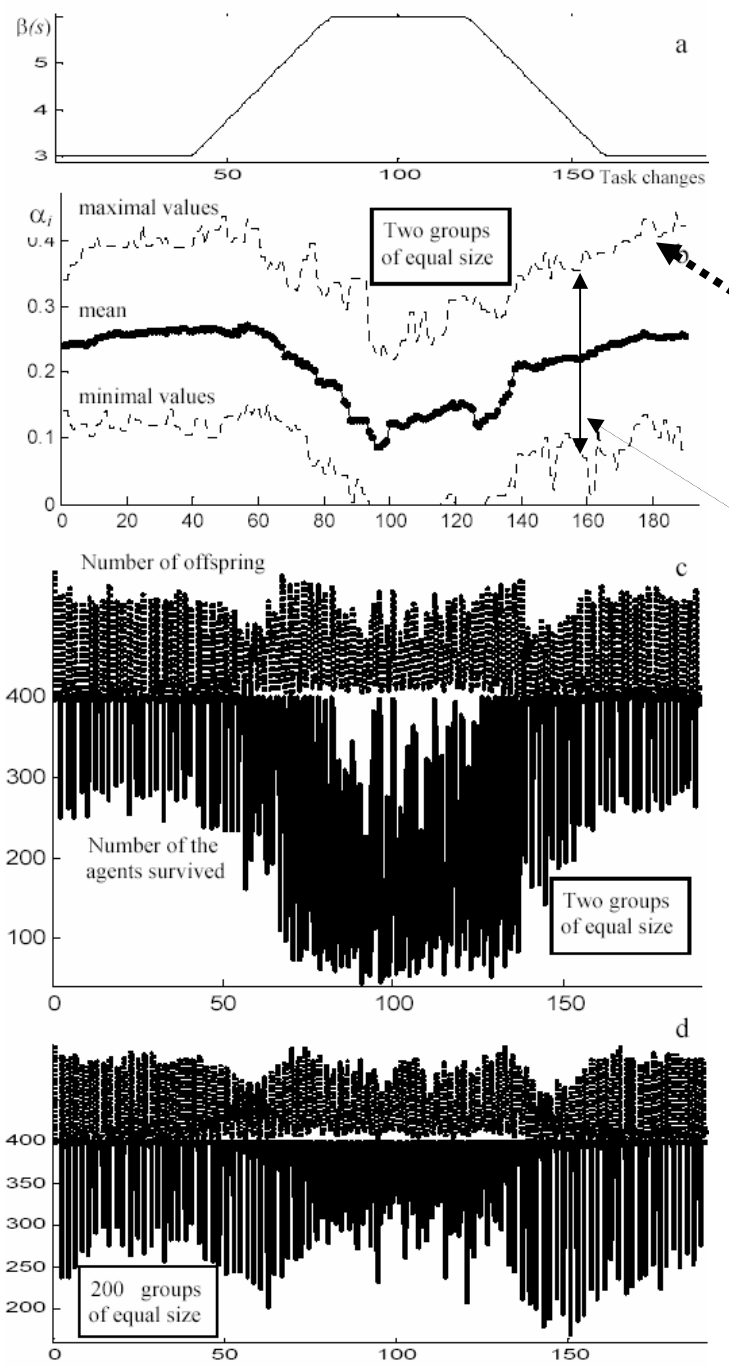


Variation of data changes (rotation)



A death of the population

In present research we found that synthetic emotions are useful



Dynamics of strengths of the changes

Dynamics of noise injection intensity. An interpretation of the noise injection is arbitrary. Criminality in central and eastern Europe? Various value systems? Could the noise injection intensity be interpreted as the RISK level?

Up to 40 % of training directives are corrupted

Dynamics of a number of agents survived (solid) and offspring (in dots) and during sequences of 190 pattern classification tasks.

The agents in the population must be different !

Functional Model of Criminality: Simulation Study

Sarunas Raudys[1,2], Aini Hussain[3], Viktoras Justickis[1,*],
Alvydas Pumputis[1], and Arunas Augustinaitis[1]

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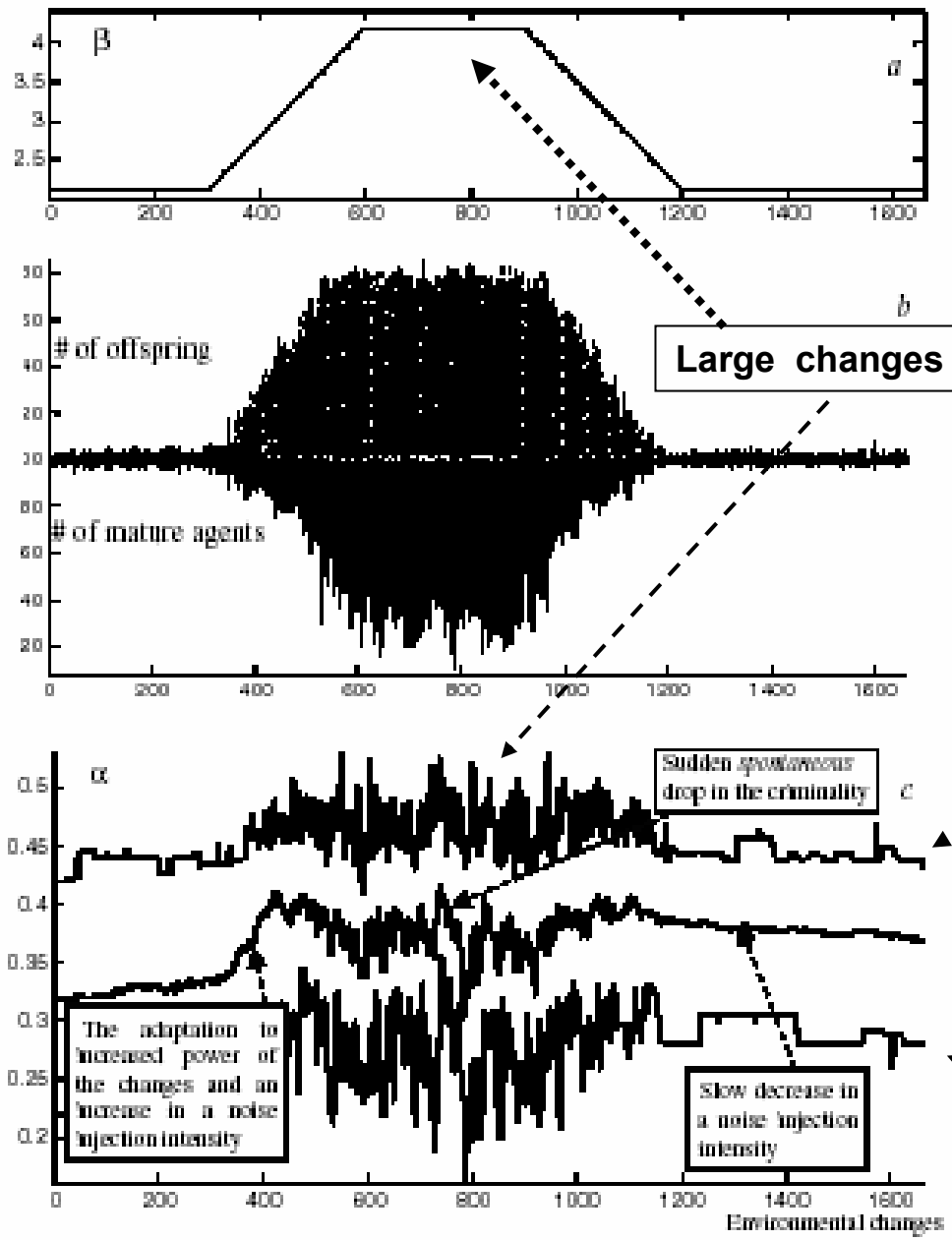
A. Dey et al. (Eds.): CONTEXT 2005, LNAI 3554, pp. 410 – 423, 2005.



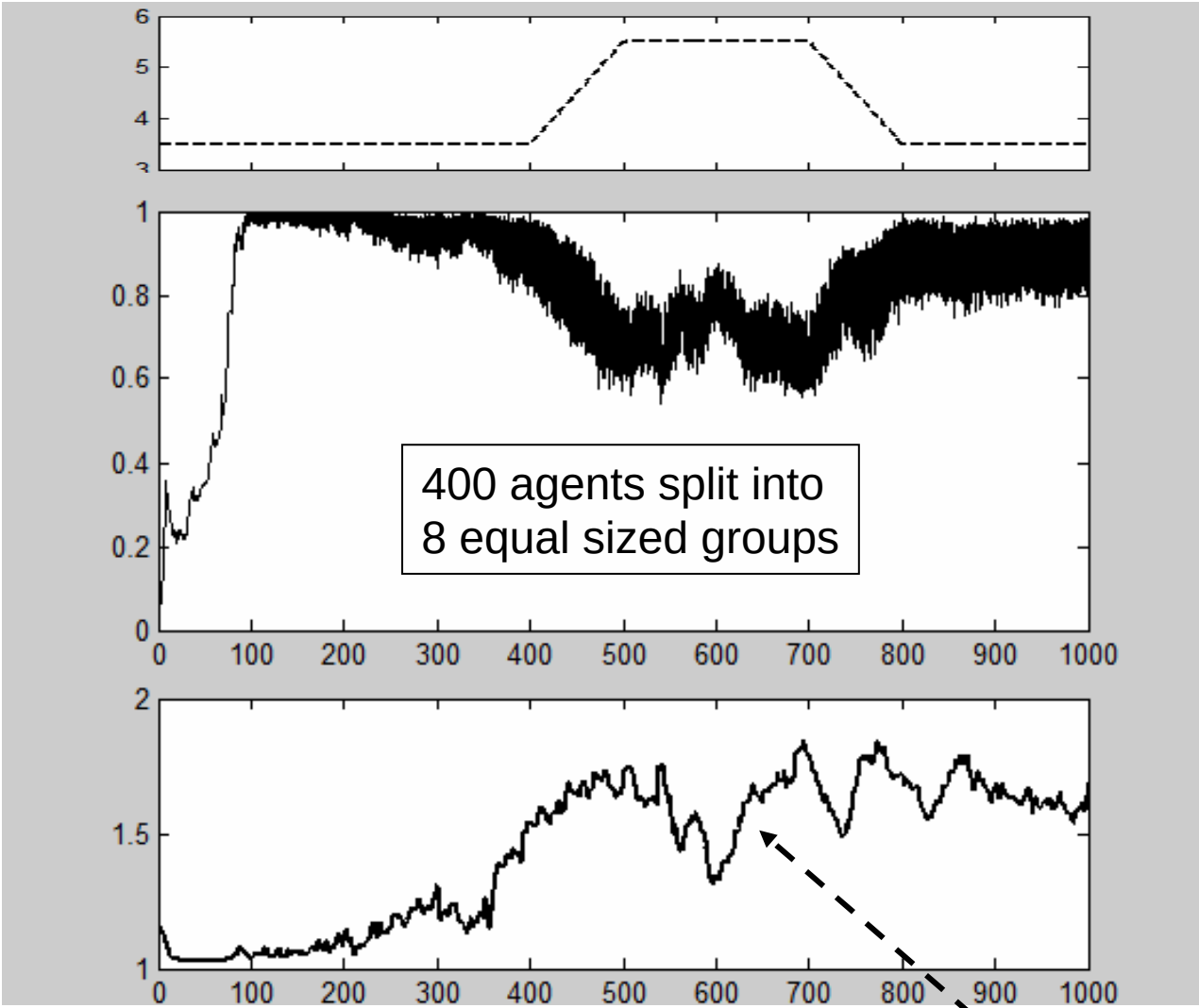
Mean + st. deviation

Mean

Mean – st. deviation

Fig. 3. Simulation result of *infrequent* environmental changes with t_{change}=250 epochs

Synthetic Emotions. S. Raudys Vilnius



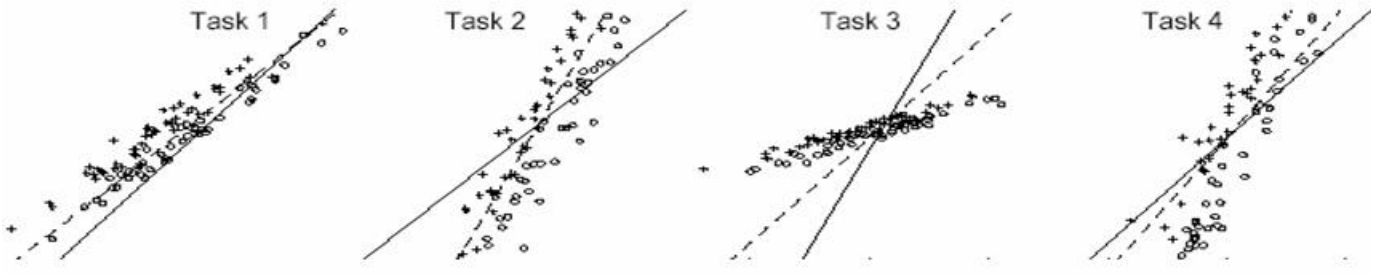
Dynamics of strength of environmental changes (data rotation)

Dynamics of stimulation strength

Dynamics of synthetic emotions

Double feedback chain ⟹ chaotic behavior.
It challenges new investigations.

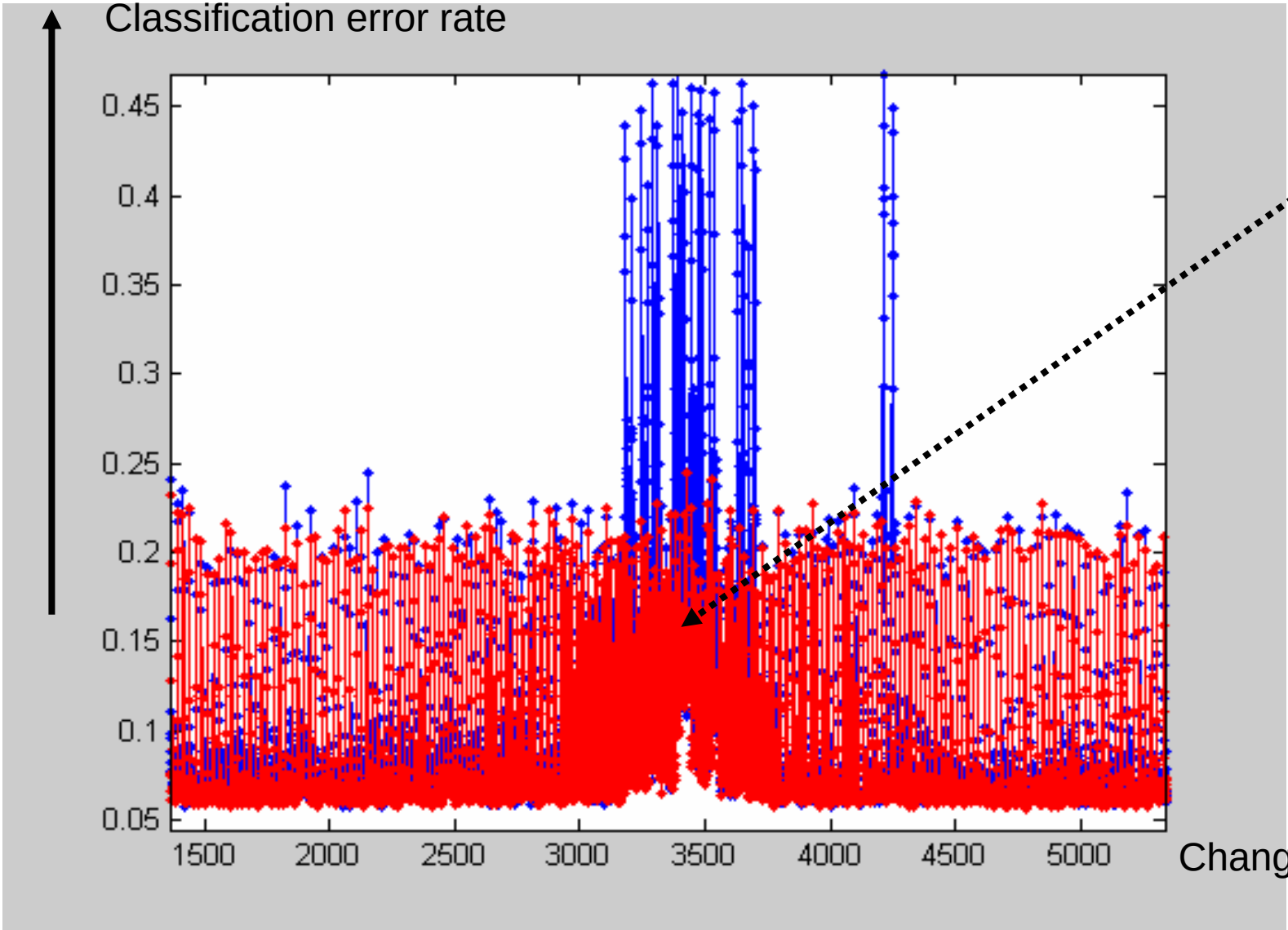
Now we will consider how to reduce risk in changing environments.



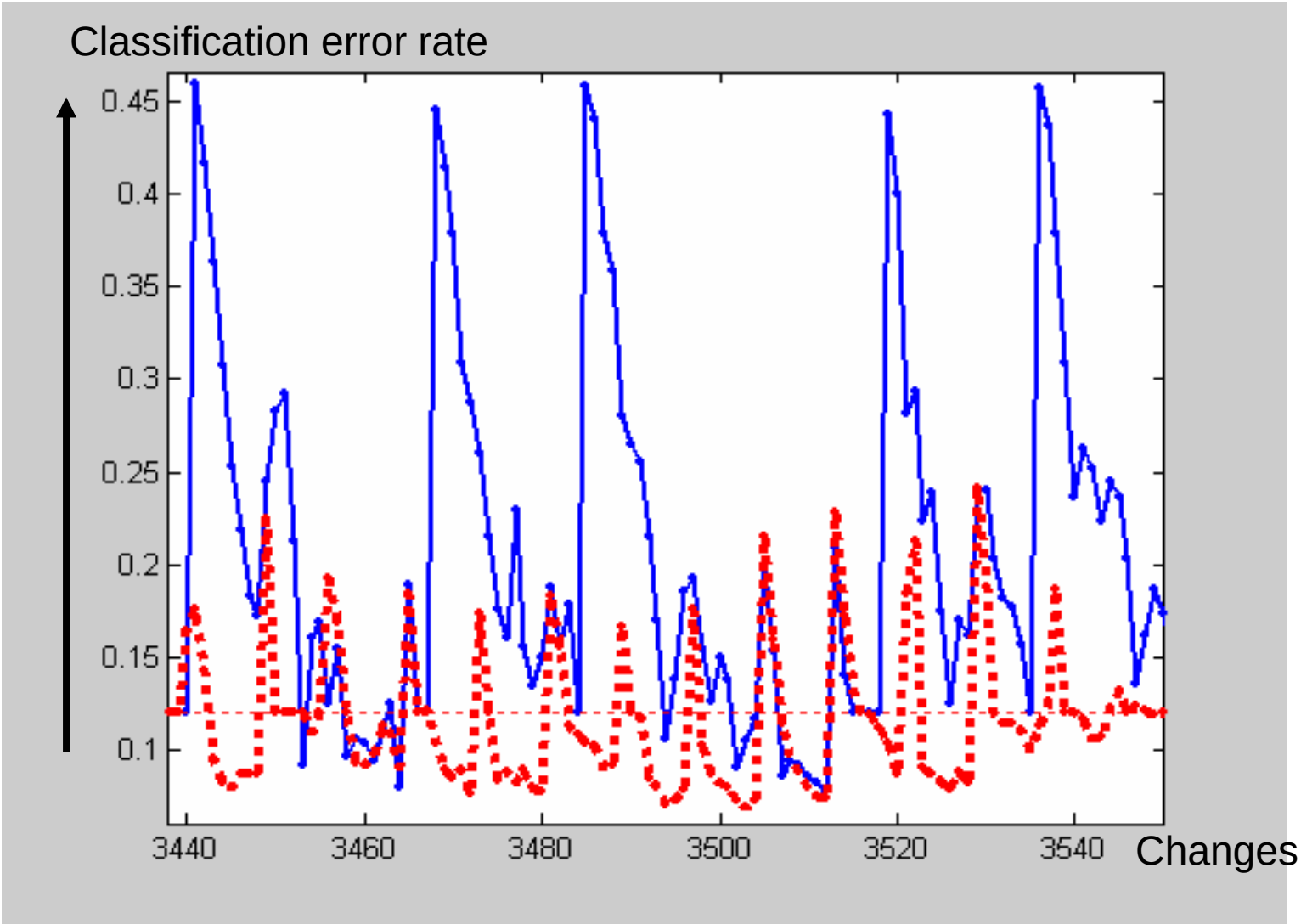
If the Pattern Recognition task has changed, old data ought not to be used for training. The agent, however, do not know about the task change. So, it uses the old and new data.

300 agents (SLP) are solving the same Pattern Recognition tasks. They differ in the length of training sequence and noise intensity. These 2 parameters are inherited from successful agents.

BLUE – single agent. RED – MAS composed of 300 agents. The 10 best agents are voting in subsequent time moment.



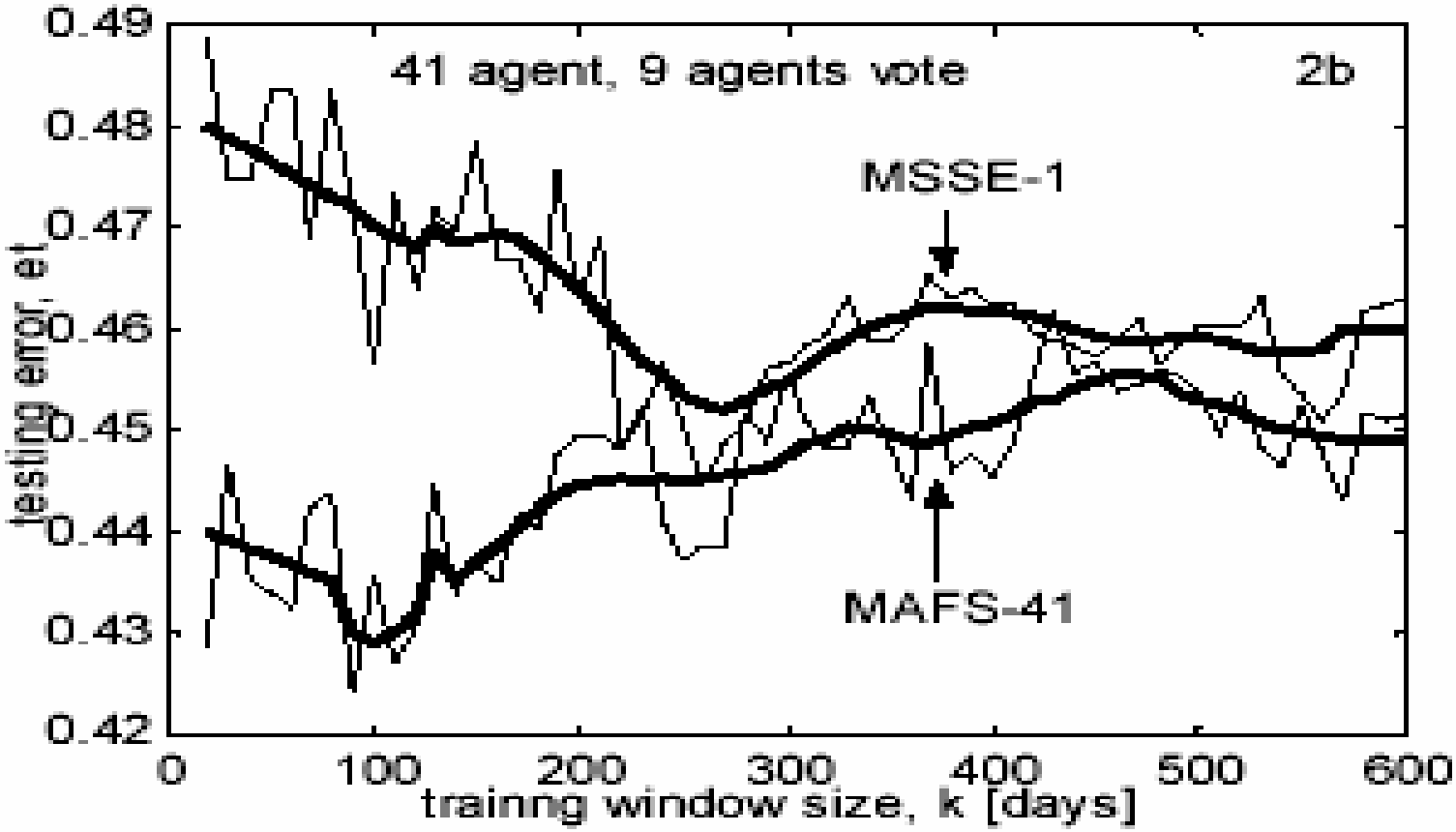
BLUE – single agent. RED – MAS composed of 300 agents. The 10 best agents are voting in subsequent time moment. Details.



The Multi-Agent System for Prediction of Financial Time Series

[1]Sarunas Raudys and [2]Indre Zliobaite

Zakopane, June, 2006



Concluding Remarks

I take for granted

Everything is changing permanently. Changeability is a normal behavior. Intelligent agents have to adapt to new conditions permanently.

To obtain general conclusions we need to analyze as simple models of adaptive agents as possible. To explain some primary trends like origin of emotions, aging, grouping of agents into clusters it is worth also to analyze populations of adaptive agents which are solving common goal - survival in permanently changing environments. The population of SLP with inheritance is simple, however, useful model to understand many of real world phenomena.

The simulations gave arguments that for survival of the population, higher level of risk of individuals could become beneficial.

Concluding Remarks

The simulations gave arguments that for survival of the populations, higher level of risk of individuals could become beneficial.

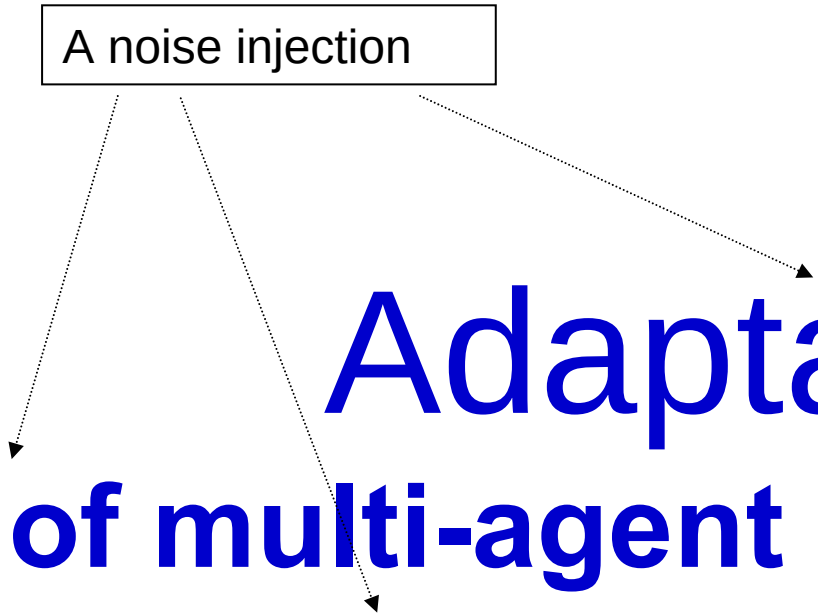
We do not need to protect our children from difficulties too much, from incorrect behavior with them.

We do not need stimulate our children too much (small gifts, mild punishments, etc.)

It is a reason why in the Bible it is written:

Thank to Good for misfortunes He has sent to you.

It makes the nation more strong and allows us to overcome future catastrophes more easily. ***Etc.***



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