FLIGHT CONTROL BY MEANS OF ARTIFICIAL INTELIGENCE

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Abstract

Nonlinear predictable systems can be controlled by recurrent neural networks (RNN). Recurrent neural network can remember previous states and use it for prediction of next state. But there is disadvantage in difficult optimalization of their parameters like neuron bias, weight etc. There are many methods to do this, so it was chosen genetic algorithm (GA). The paper deals with using RNN for modelling of nonlinear system - a model of manoeuvring aircraft as target of guided missile. Both aircraft and missile are controlled by recurrent neural network. The coevolution of the genetic algorithms evolves to set of parameters for each recurrent neural network. Application also can visualize some combats for best aircraft and missile control networks.Selected results of simulation of air combat are discussed in the paper. Detail algorithms are presented as well.

INTRODUCTION

The optimization of the artificial neural network represents a difficult problem. This problem can be divided on the optimization of the topology and parameters optimization (weights and thresholds) of the artificial neural networks. The topology of the neural network can be determined by constructive or destructive methods (2, 7). The other methods use genetic algorithms. The back propagation algorithm is used for the determination of parameters of the artificial neural network. Genetic algorithms represent the alternative way for the determination of parameters of the artificial neural network.

Results acquired by research and simulation of artificial neural networks are very useful to understand function of those biological, eventually enable use of appropriate artificial neural network in such applications, where putting human should be dangerous to his life and health, or by the influence of various factors he wouldn't be able to decide in enough short time. One of thus applications is flight control of fighter aircraft or a missile.

The paper deals with the optimization of parameters of the recurrent neural network for flight control by modified genetic algorithm and coevolution of modified genetic algorithms. The modification of the using of genetic algorithms is based on the execution of two genetic algorithms, populations of which are impacted each other. The impact of each other populations with common fitness function is called the coevolution. The coevolution (evolution of the two or several competitive populations with common rate of the fitness) has some functions, which can extend the power of the adaptation of the artificial evolution

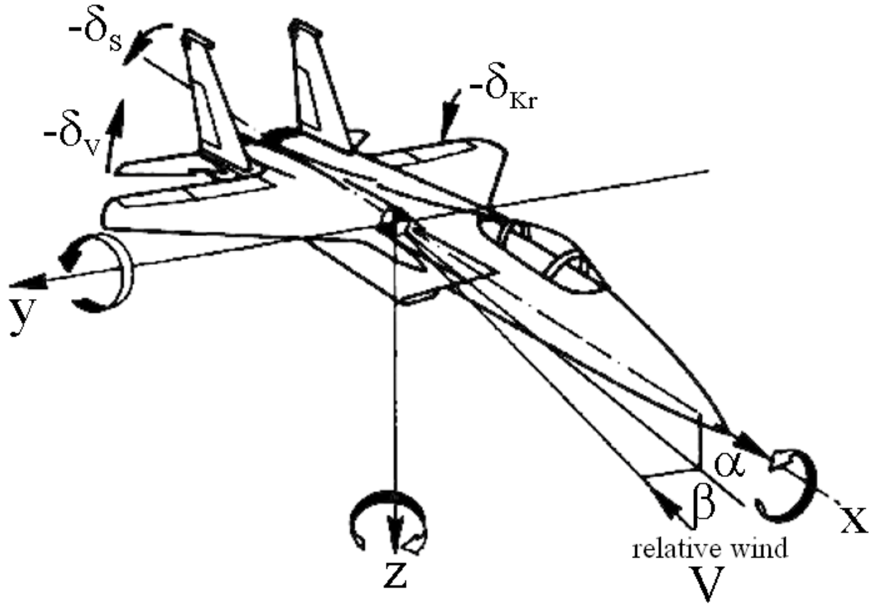

Figure 1 - Aircraft coordinate system

1 AIR COMBAT BETWEEN FIGHTER AIRCRAFT AND A MISSILE

Air combat between fighter aircraft and a missile is used as fitness function for evaluating individuals in genetic algorithm. The evading aircraft and the pursuing missile, both are governed by the following 6 DOF (degree of freedom) equations of motion (8). These equations are in form after LaPlace transformation. The coordinate system is shown in figure 1.

1.1 Vertical plane equations

$$\Theta = \frac{1}{p + a_y^{\Theta}}\left(a_y^{\delta_{POM}}\delta_{POM} - a_y^V V - a_y^{\alpha}\alpha\right) \tag{1}$$

$$\vartheta = \frac{1}{p\left(p + a_{m_z}^{\omega_z}\right)}\left(a_{m_z}^{\omega_V}\left(-\delta_V\right) - a_{m_z}^V V - \left(a_{m_z}^{\alpha} + a_{m_z}^{\dot{\alpha}} p\right)\alpha\right) \tag{2}$$

$$\Theta + \alpha - \vartheta = 0 \tag{3}$$

Where:

- a_x^V, a_x^{α}, ... - measurable aerodynamic derivations (coefficients describing aircraft properties),
- δ_{POM} - thrust,
- δ_V - pitch control,
- ϑ - pitch angle,
- V – relative vertical velocity,
- α - angle of attack,

- Θ - vertical fly path angle.

1.2 Horizontal plane equations

$$\Theta_h = -\frac{1}{p}\left[a_z^{\gamma}\gamma + a_z^{\beta}\beta\right] \tag{4}$$

$$\gamma = \frac{1}{\left(p + a_{mx}^{\varpi x}\right)}\left[a_{mx}^{p_{KV}}\left(-\delta_{Kr}\right) + a_{mx}^{\varpi s}\left(-\delta_S\right) - a_{mx}^{\varpi_y} p\Psi - a_{mx}^{\beta}\beta\right] \tag{5}$$

$$\Psi = \frac{1}{p\left(a_{my}^{\varpi y} + p\right)}\left[a_{my}^{\delta_s}\left(-\delta_s\right) - a_{my}^{\varpi x} p\gamma - a_{my}^{\beta}\beta\right] \tag{6}$$

$$\Theta_h + \beta - \Psi = 0 \tag{7}$$

Where:

- δ_S - yaw control,
- δ_{Kr} - roll control,
- Θ_h - vertical yaw angle,
- γ - roll angle,
- $a_z^{\beta}.....a_z^{\gamma}$ - aerodynamic derivations,
- β - side slip,
- Ψ - course angle.

1.3 Simulation of the air combat

Flow graph of the simulation of the air combat is shown in the figure 2. First step of the simulation is data initialization (position, speed, …). In the next step there are computed flight data for aircraft and missile. In the next is computed input vector for recurrent neural network. Computed output data from RNN are used for flight model. Condition for the end of the simulation are finishing of the duel due hit aircraft by missile or realisation of defined number of the time step for air combat.

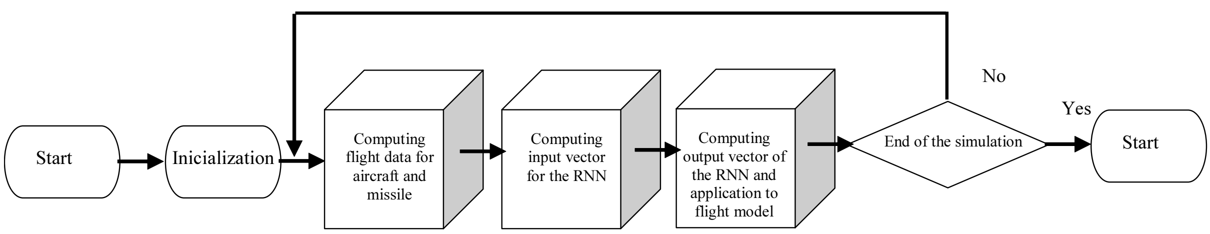

Figure 2 – Flow graph of the simulation of the air combat

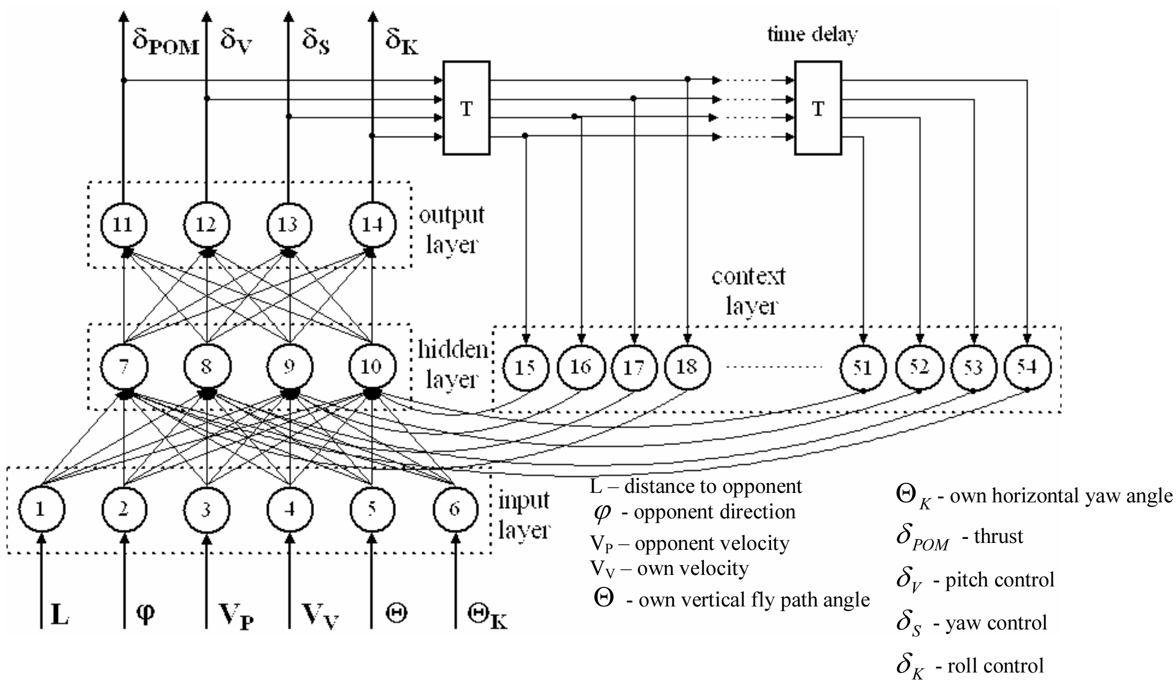

Figure 3 - RNN topology

2 The topology of the recurrent neural network

It was used RNN topology (shown in figure 3) based on Jordan topology of recurrent neural network. Context layer can remember 10 previous output states through the time delay blocks creating a time window. Each neuron has sigmoidal activation function and its rate of rise is part of optimalized parameters as well as weights and neuron biases.

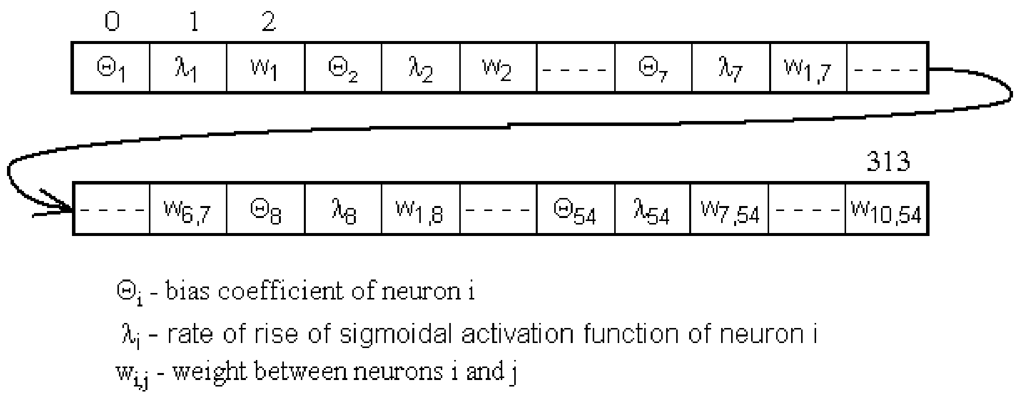

Figure 4 - Chromosome representation

3 GENETIC ALGORITHM

Genetic algorithms are search algorithms based on the mechanics of natural selection and natural genetics. They combine survival of fittest among string structures with a structured yet randomised information exchange to form a search algorithm with some of the innovative flair of human search. In every generation, a new set of artificial creatures (strings) is created using bits and pieces of the fittest of the old; an occasional new part is tried for good measure. While randomised, genetic algorithms are no simple random walk. They efficiently exploit historical information to speculate on new search points with expected improved performance.

Modification of standard genetic algorithm consists of chromosome representation application and modification of standard genetic operators of selection, crossover and mutation. Chromosome represents the string of neuron parameters (shown in figure 4) and its constant length is 314 real numbers. As selection methods I used both roulette and tournament selection with elitism. This option can be set in application before optimalization starts. Crossover operators are standard one point crossover or uniform crossover with random mask. Mutation changes the genes values by random number in specified range. This range can be adapted if convergence of population is too slow.

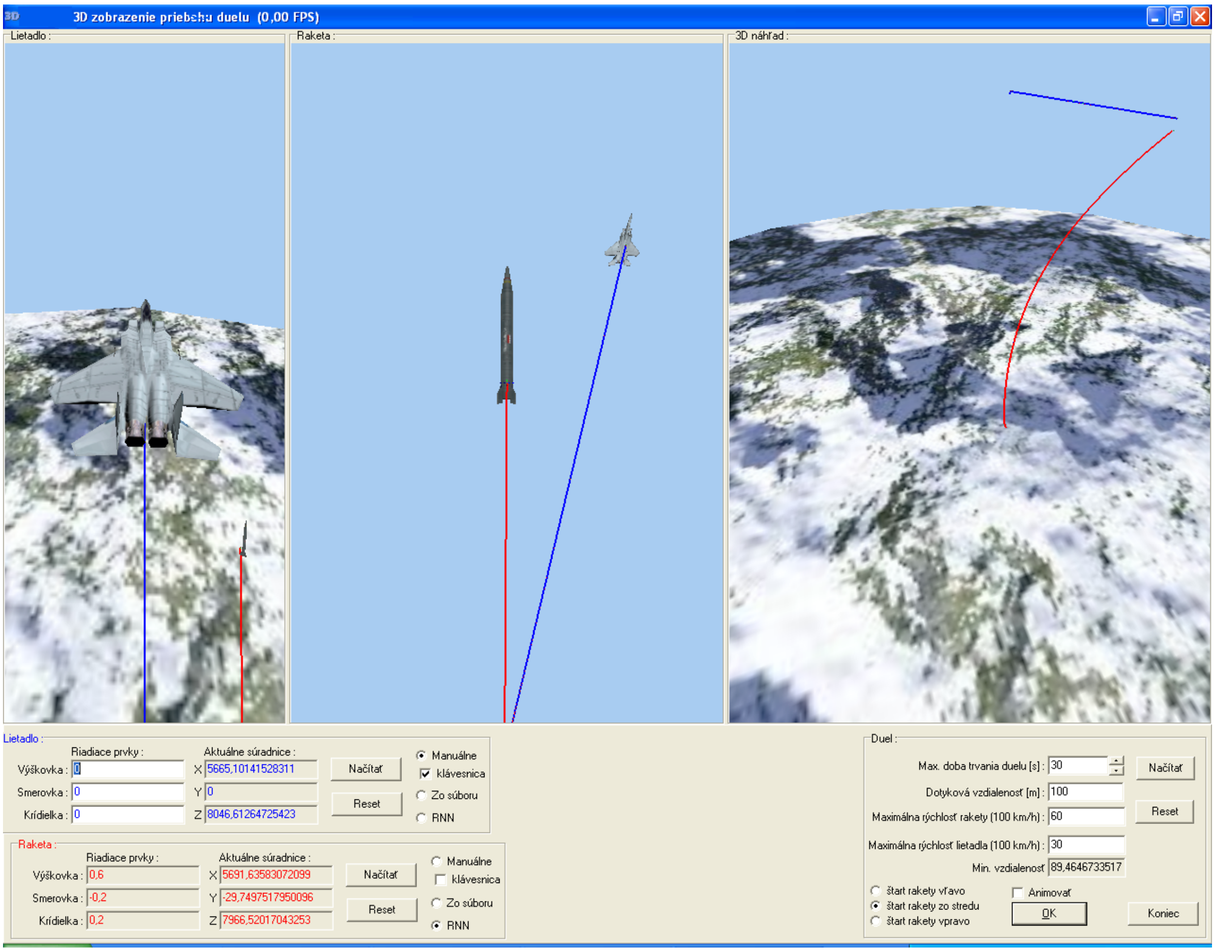

Figure 5 – 3D view of air combat between aircraft and missile

CONCLUSION

The standard methods for optimization of the ANN are depending on one criterion function, which isn’t changed. The optimization of the ANN by coevolution changes the criterion function. The criterion function is affected by external environment.

In this paper there were presented methods for optimization of artificial neural networks used as flight control element in fighter aircraft and missile. Results shows, that recurrent neural networks with right optimization method can be used as control element for complex nonlinear dynamic systems. The advantages of genetic algorithms are simple using, implementation and versatility of optimization method. On the other hand the solution of complex optimisation problem has big time complexity. Time complexity of the genetic algorithms can be decreased by using parallel genetic algorithms.

The coevolution of the two or more populations with the similar or opposite goals can be used for solving different problems like optimization of the ANN. The design of the simulator for the different field of applications is a possible problem. The simulator is adapted to the behaviour of a human, whose behaviour is successive. The results of the simulation in the next step will be a failure, if human uses the same behaviour. The goal of the design is the simulator, for which the stereotyped behaviour of a human to win can't be used.

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