The Neural-Fuzzy Management Method of Development of High and Critical Technologies in Engine-Building Manufacture

S. G. Selivanov
Department of machine-building technology
Ufa state aviation technical university
Ufa, Russia
e-mail: S.G.Selivanov@mail.ru

S. N. Poezjalova
Department of machine-building technology
Ufa state aviation technical university
Ufa, Russia
e-mail: Poezjalova@mail.ru

Abstract [1]

The functional model of ASSR-technologies is offered and application of the neural-fuzzy management method of development of high and critical technologies in engine-building manufacture is shown in the form of information technology of work integrated-regression networks and use of fuzzy logic for formation of united technologies of aviation engines of new generation. The rational functions describing development of fighters and innovative-investment projects for creation of competitive production are revealed with use of artificial intelligence techniques. Innovative project, innovative-investment project, neural network, fuzzy logic, functional model, sigmoid, logistical function, united technologies, node technologies

1. Introduction

Automation of technical preproduction (*ASTPP*) is the basic method of reduction terms of creation and adoption on manufacture of new products for the rapid development of the innovative projects. In the present publication it is offered to add known methods of *ASTPP* with the means of artificial intelligence which provide mathematical modelling and optimization of the objects of designing.

2. Publishing

It is recommended to build the functional model "The automated system of scientific researches of high and critical technologies" (*ASSR*-technologies) in innovative projects and programs for development of preliminary complete sets of the technological documentation providing creation of technics of new generations. This system has been developed with a view of technological maintenance of creation of new generation aviation engines. The offered functional model of *ASSR*-technologies (fig. 1), is developed in *BPWin* 4.1 (*IDEF*0), contains 4 blocks of tasks and 10 automated subsystems (software products) which are necessary for automation of the solution of given tasks. The offered model which is basic for technological maintenance of works on designing and creation of new generation aviation engines (in the form of united, basic, node, high and critical technologies, and also complete sets of perspective and directive technological processes) allows to show sequence of actions on performance researches for maintenance of research and development with the means of innovative designing of aviation engines.

We will consider in details the blocks of tasks of ASSR-technologies:

1. Block of tasks is the analysis of a technological level of aviation engines. The definition of requirements on technological maintenance of competitiveness of new products is the result of functioning of the given block;
2. Block of tasks is the analysis of the patent information. The conclusions and the substantiations on application of high and critical technologies during the further researches and development of aviation engines of new generation are the result of functioning of the given block;
3. Block of tasks is formation of united technologies of new generation aviation engines for system-technical development of innovative projects. The cession of rights on united technologies is the result of work on this function;
4. Block of tasks is development of node and basic innovative technologies. This functional block includes not only preparation of complete sets of the technological documentation of innovative projects, but also construction of calendar plan-schedules, development of business plans which are necessary not only for technological designing, but also for an estimation of efficiency of investments into creation of aviation engines of new generation.

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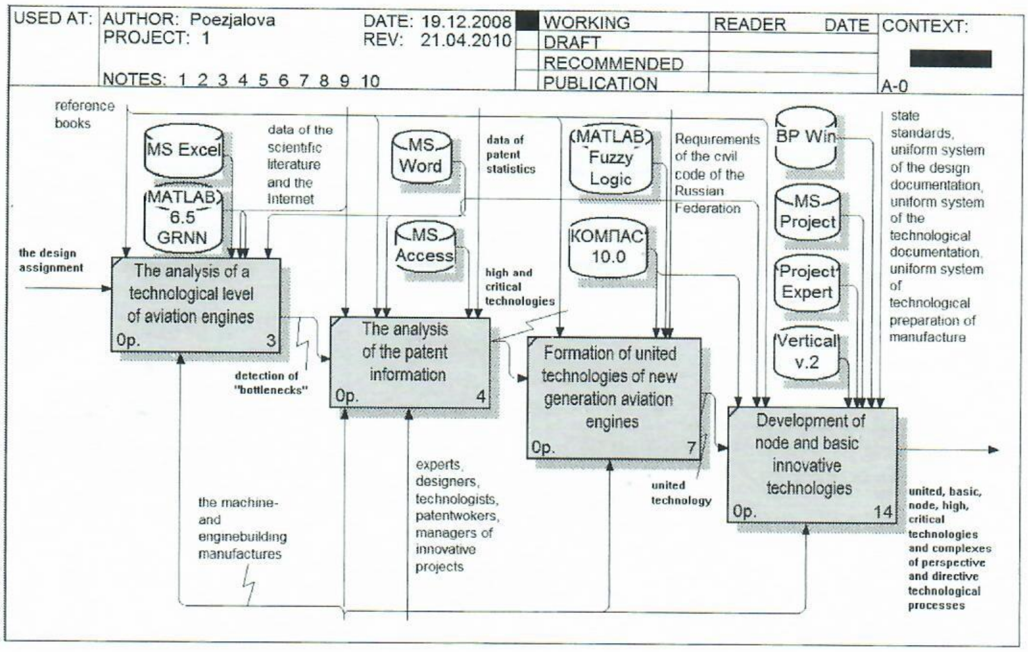

Fig. 1. Functional model of development of preliminary projects of the technological documentation for creation of aviation engines of new generation

We will consider in details each of the named blocks of the tasks which are parts of functional model of development of the preliminary complete set of the technological documentation.

2.1 1st block is the analysis of a technological level of aviation engines and following blocks

Offered for definition of laws and tendencies of development of aviation engines the general regression neural network (*GRNN*) solves problems of definition of regresses by approximation of various functions (fig. 2).

For the description of work of the named neural network in the beginning we will assume, what there is a training sample $((x^1, y^1), (x^2, y^2)\ldots, (x^N, y^N))$ (pairs of the data an input-output) which is generated by unknown function $F(x)$, deformed by noise. The problem of approximation by means of a network is to find an estimation of unknown function $F(x)$ and definitions of its values in other points. The *GRNN*-network copies into itself all training supervision and uses them for response estimation in any point (1). The definitive target estimation of regression dependences in an artificial neural network [3] is the weighed average of outputs on all training supervision:

$$y = \frac{\sum_{k=1}^{N} y^k \cdot \varphi \cdot \left(\frac{\left\| X - X^k \right\|}{\sigma} \right)}{\sum_{k=1}^{N} \varphi \cdot \left(\frac{\left\| X - X^k \right\|}{\sigma} \right)}, \tag{1}$$

where X^k, y^k – points of training sample. Thus, artificial neural network *GRNN* [2] is the integrated model (fig. 2) of development of any innovative project, set of innovative projects of analyzed generation of technics and technologies, and also regularities of diffusion of new technologies.

Sigmoid – it is a smooth monotonous nonlinear *S*-type function which is often applied for "smoothing" of parameters values analyzed innovative projects. Earlier in the innovative activity scientific literature sigmoid was considered to be only logistical function of development of technics and technologies. In the present publication it is shown that earlier applied logistical laws – it's only particular cases of local logistical dependences of Fisher-Pray, Pearl, Morris and other foreign authors [4]. A logistical function (2) or a logistical curve is a sigmoid *S*-type curve [3, 8], represented on fig. 3. It models a curve of growth of probability of a certain event, in process of change of operated parameters of development. The elementary logistical function can be described in the formula:

$$P(t) = \frac{1}{1 + e^{-t}}, \tag{2}$$

where variable *P* can be considered as a number of some objects (products, technologies, number of people etc.) and a variable *t* can be considered as time. Though the area of admissible values of *t* coincides with set of all real numbers from a minus to infinity plus because of the essential nature of indicative function *exp(-t)* it is practically enough to calculate values only in rather narrow interval.

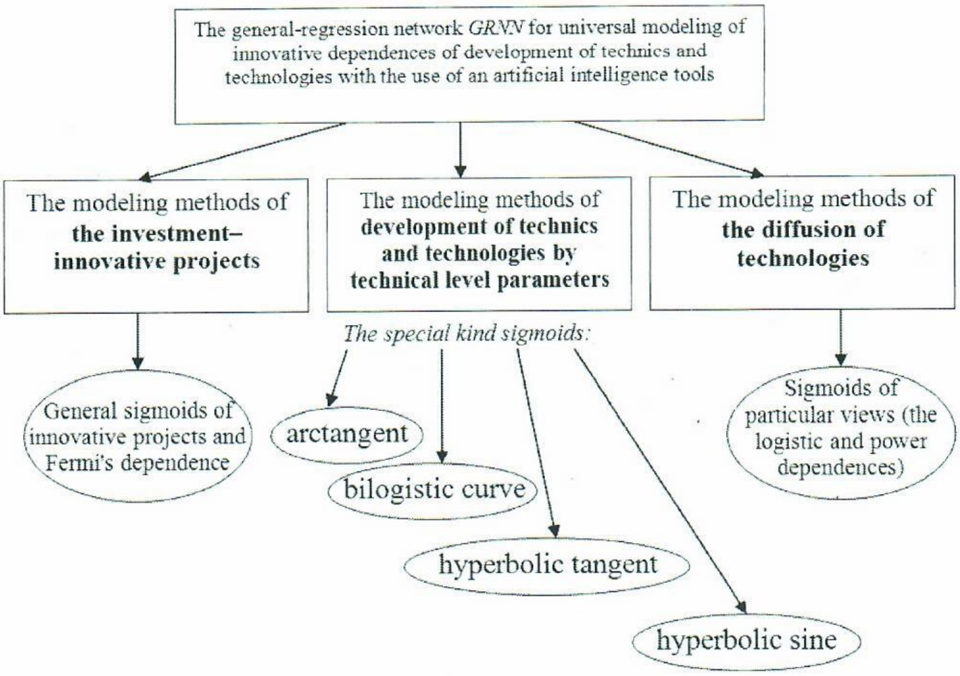

Fig. 2. Kinds of sigmoids and their application in neural networks

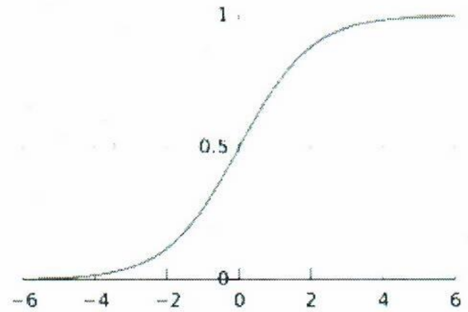

Fig. 3. A general logistical function (sigmoid)

A logistical function in general view (fig. 3) can be presented as the decision of the simple nonlinear differential equation of the first order (3). This equation is also known as the equation of Ferhjulst (named after the Belgian mathematician who has formulated him). It has initially appeared for consideration of model of growth of a population. The equation of Ferhjulst looks like this [8]:

$$\frac{dP}{dt} = P \cdot (1 - P), \qquad (3)$$

where P – a variable, which depends a time (t) and with boundary condition $P(0) = 1/2$.

Beside the considered logistical dependence it is also possible to consider a double logistical sigmoid curve (fig. 4).

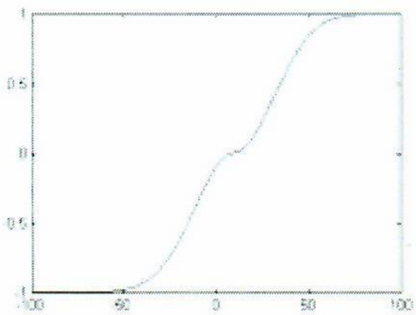

Fig. 4. A double logistical function

A double logistical function (4) is similar to logistical function (fig. 3) with numerous variations of sigmoid [3, 8]. Its general formula looks like:

$$y = sign(x - d) \cdot \left(1 - \exp\left(-\left(\frac{x - d}{s}\right)^2\right)\right), \qquad (4)$$

where d – the local centre,

s – the steepness factor.

The comparative analysis of investment of separately taken innovative project [5] (fig. 5) has allowed to establish essentially best results of use of Fermi's function in comparison with logistical dependence (5–8).

According to the statistical data sigmoid regularities submit to following equations of regress:

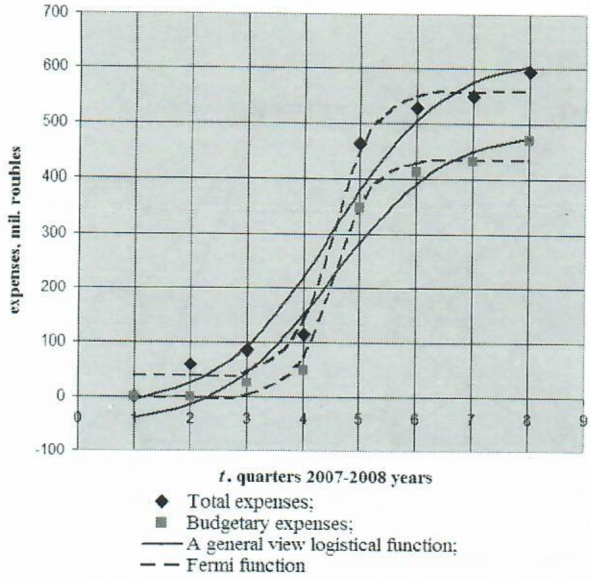

Fig. 5. Change of expenses of the innovative-investment project

- The logistical curve of total deductions:

$$F(t)=\frac{647{,}024}{1+e^{-(t-4{,}5)}}-24{,}236, \qquad (5)$$

$R^2 = 0{,}9547$.

- The logistical curve of budgetary deductions:

$$F(t)=\frac{545{,}602}{1+e^{-(t-4{,}5)}}-55{,}435, \qquad (6)$$

$R^2 = 0{,}9465$.

- Fermi's function of total deductions:

$$F(t)=\frac{517{,}793}{1+e^{-2\cdot 1{,}38(t-4{,}5)}}+38{,}652, \qquad (7)$$

$R^2 = 0{,}9865$.

- Fermi's function of budgetary deductions:

$$F(t)=\frac{435{,}083}{1+e^{-2\cdot 1{,}494(t-4{,}5)}}-1{,}638, \qquad (8)$$

$R^2 = 0{,}9901$.

As we can see from the presented equations Fermi's function (7,8) has essentially the best convergence in comparison with logistical function of a general view (5,6), therefore it is more rational to use in the tasks of graphics and a substantiation of the innovative-investment projects. The analysis of the second class of tasks of innovative designing (2) on use of methods of modelling of development of technics and technologies on technological level parameters (fig. 2) indicates smaller preference of logistical dependences for the analysis of innovative projects. We will consider the possibilities of application of artificial neural network GRNN [2] (fig. 6) for the analysis of laws of development of aviation engines.

The fragment of the text of the program to find approximation of function of an arctangent for engines of subsonic fighters of the first generation is stated below (*x*– years of the first flight of the plane with the new engine, *y* – value of the maximum traction of the jet engine, kg [1]):

x = [1942; 1942; 1946; 1946; 1947; 1947; 1947; 1947; 1947; 1947; 1947; 1948; 1948; 1949; 1950; 1953];

y = [442.748; 442.748; 720.352; 720.352; 1019.580; 1019.580; 1019.580; 1019.580; 1019.580; 1019.580; 1019.580; 1750.000; 1750.000; 2480.420; 2779.648; 3027.263];

Name of the neural network requested in system *MATLAB* 6.5 [2]:

b=newgrnn (x, y, 0.2);

As a result the neural network defines intermediate values of points on the set of points of an axis of abscisses set by the operator:

y1 = sim (b, [1943; 1944; 1945; 1951; 1952])

As a result of work of artificial neural network GRNN we receive values of function on an axis of ordinates:

y1 = 1.0 e + 003 * {0.4427 0.5815 0.7204 2.7796 3.0273}.

The received number sequence defines the first regression dependence (1) on fig. 7 for aviation engines of subsonic fighters of the first generation. In this case the main indicator defining perfection of the engine is traction (kg) [1]. Its changes submit eventually to the general laws of innovatics [4]. The changes are presented on fig. 7.

In the same way it is possible to receive sigmoid regularities for aviation engines:

- fighters-interceptors (3) as a bilogistic dependence;
- multipurpose, highflexible fighters (fighters-bombers) (4);
- planes of a vertical take off and landing (5).

The analysis of dependences (fig. 7) also allows to conclude that typical regression dependence in the form of an arctangent (a curve №2, the dashed line) describes unsatisfactorily regularity of development of aviation engines for interception aircrafts. It is connected with displacement of a curve because of negative results of flight tests of some planes and engines of the given type (R-11F-300, R-15, R-15-300, R-21F-300, R-13F-300, R-11F2-300) in the early sixties of XX century that has caused a delay in development of sigmoid of the generation of technics by formation of a small horizontal platform.

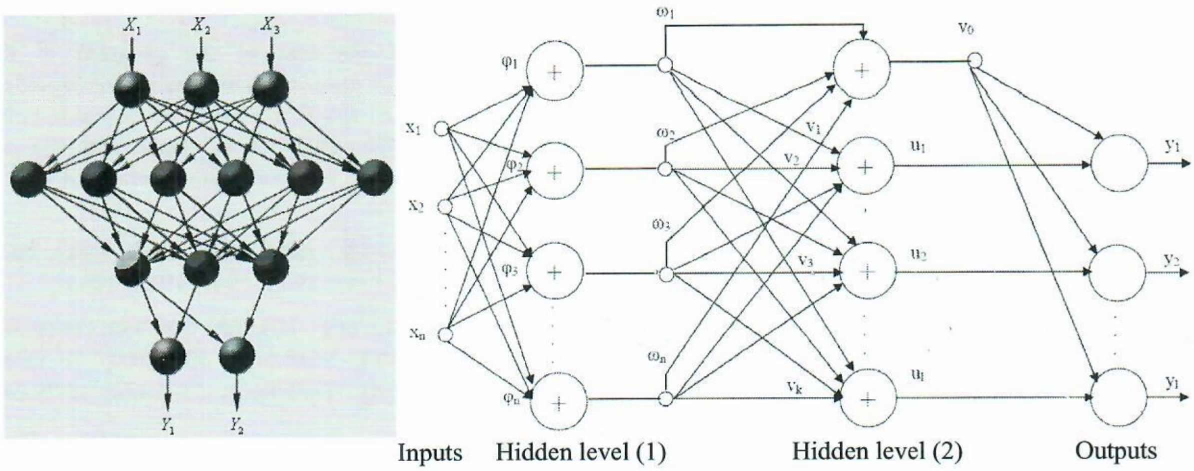

Fig. 6. Overview general regression the network (*GRNN*)

Table 1. Received equation (fig. 7)

№ sigmoid (fig. 7)	Received equation	Convergence R2
1	F(t)=930*arctg(t-1948)+1750	0,7957
2	F(t)=5700*arctg(t-1957)+9800	0,6445
3	$F(t) = sign(t-1976,65)\cdot\left(1-\exp\left(-\left(\frac{t-1976,65}{30,6}\right)^2\right)\right)+10250$	0,8992
4	F(t)=4000*arctg(t-1966)+8450	0,8780
5	F(t)=3900*arctg(t-1985)+11650	0,9515

The further development of aviation engines [1] for this type of planes is characterized by use oneshaft gas-turbine engines with tailpipe burner from cruise missiles on fighters-interceptors that has continued development of sigmoid, but now as a bilogistic dependence (a curve №3). The received regularities (fig. 7) are expressed by the equations presented in table 1.

In the following blocks (2,3) of the functional model of *ASSR*-technologies (fig. 1) the analysis of the patent information on new generations aviation engines is carried out and united technology of new generation aviation engines is formed [6,7]. In these functional blocks it is recommended to use means of artificial intelligence, for example, a method of indistinct logic (Fuzzy Logic) [2] for automation of technological designing.

In system *MATLAB* 6.5. [2] by means of a package "Fuzzy Logic" a search of "a kernel of decisions" can be carried out which is based on results of the analysis of patent statistics (the block 2) and the expert estimations consisting in selection of the best technical suggestions concerning node technologies in order to create jet engines of new generation.

In the spatial form set of node technologies available in an electronic database can be presented in the form of a surface (fig. 8) where axes have estimations according to the patent statistics (traction, degree of compression of the compressor, temperature on the turbine), and on a vertical axis of ordinates is located the points of a variant of technology.

As we can see from fig. 8 the unpromising node technologies of jet engines creation are located in the bottom area. The high technologies realizing most progressive and original innovative decisions are located in the top area. In an interval between these areas intermediate technologies take place.

On fig. 8 one of *S*-type curves of development of node technologies (in particular, the fan of the aviation engine) is conditionally shown, and thus the surface represents set of variants of development of node technologies from which can be found "a kernel of decisions" for development of united technology of new generation engine.

The fourth block of functional model (fig. 1) is intended for development of the preliminary complete set of the technological documentation during innovative designing of jet engines of new generation [7].

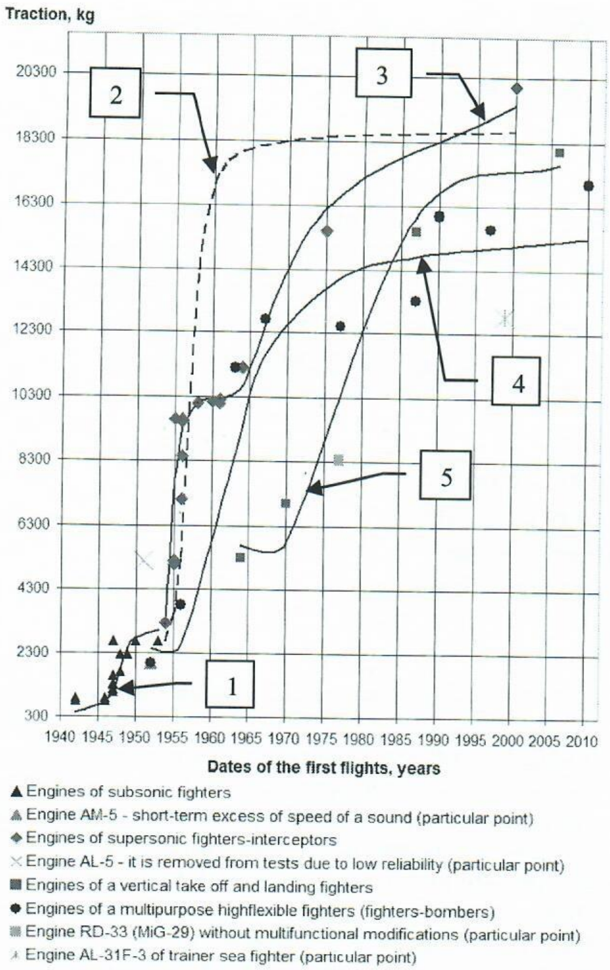

Fig. 7. Integrated sigmoid dependences development of aviation engines domestic fighters

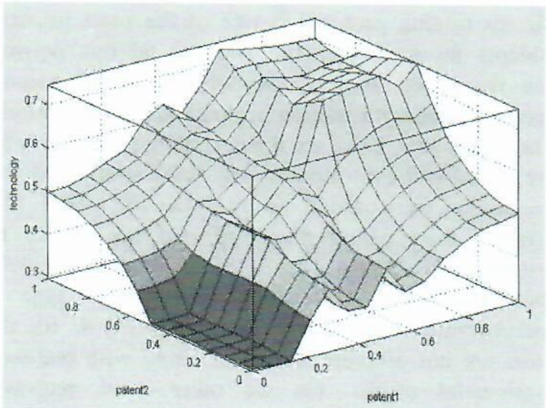

Fig. 8. A surface of development of united technologies

3. Conclusion

- The offered functional model of the *ASSR*-technologies developed with a view of technological maintenance of creation of aviation engines of new generation, generalizes scientific regularities, dependences, mathematical models, methods and the technologies used in applied innovative activity and innovative designing.
- It is established that *GRNN*-type artificial neural network is the generalized model of development of any innovative project, set of innovative projects of development of technics and technologies, and also regularities of diffusion of new technologies.
- It is proved that for innovative-investment projects the rational function describing development of the project is Fermi's function, and for development of generation of technics and technologies the rational function is the "arctangent"-type sigmoid regularities and legitimacy of the given statement is confirmed for regularities of development of aviation engines.
- It is established that application neural-fuzzy management method of development of high and critical technologies in engine-building manufacture in the form of information technology of work general regression networks and also use in the form of fuzzy logic in *ASSR*-technologies allows to form united technologies of new generation aviation engines, to develop designed perspective and directive technological processes to manufacture of new aviation engines.

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