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INFORMATION SUPPORT OF COMPLEX TECHNICAL SYSTEMS ON THE BASE OF SOFT COMPUTING TECHNOLOGIES

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Abstract. Intelligent components of life cycle information support system for complex technical system are considered. The usage of genetic algorithm for optimizing complex technical system structure based on product data management database (PDM) is proposed. Complex of neural networks is used as "through life cycle" intelligent model to solve the tasks of technical state diagnostics and estimation of remaining internal resources and its' consumption.

Keywords: complex technical system; life cycle; information support; neural networks; genetic algorithms.

1. INTRODUCTION

The autonomous mobile system of small size is considered as the complex technical system exploited without any human service during long-term periods in our case. Operator could control complex technical system remotely in short sessions; for this aim operator sends commands and sets temporal programs for complex technical system exploitation with aid of software-hardware interface. Main purposes of complex technical system are collecting, processing and transmitting objective information about its environment and also transportation, mechanical and other operations with environmental objects [1].

Complex technical system contains various technical subsystems, micro electromechanical components and mechanisms; therefore it is high technological product, which is created within international cooperation on the base of commercial-off-the-shelf mechanical and software-hardware components.

Efficient exploitation of complex technical system during its short active lifetime has to be assured. Efficiency increasing of exploitation and objective usage requires creating an integrated hardware – software system for information support of complex technical system life cycle [2, 3].

Design of autonomous mobile systems of small size is needed in some scientific and commercial applications. One of the modern ways to achieve efficiency of life cycle of such systems is application of intelligent information support in design, production and exploitation.

One of the problems for engineer is that he needs to take into account the essential conditions of uncertainty which are caused, for example, by failures of onboard software-hardware subsystems, energy losses, information distortion, external noise influence, etc. if we want to reach the design goal.

2. LIFE CYCLE OF COMPLEX TECHNICAL SYSTEM

As we know the life cycle of complex technical systems can contain some of following stages:

Prototyping →
Designing →
Manufacturing →
Implementation →
Operation →
Utilization.

But only the 5th stage usually provides profit. For today for stages from 1st to 4th their duration is approximately equal to the duration of exploitation stage. From an investor point of view the introductory stages remain rather expensive. So, to optimize expenditures it is necessary to decrease durations of the life cycle stages from 1st to 4th and increase the useful effect on the stage 5th.

For example, duration of 1st to 4th stages (t_1), 5th stage (t_2) and stage 6th (t_3) and the charts for functions of benefits $P(t)$ and total costs $Z(t)$ are shown on the Fig. 1 [4–6].

Effectiveness of life cycle of complex technical system could be estimated on the base integral equation:

$$E(t) = \int_0^t (P(t) - Z(t))dt. \quad (1)$$

When planning and correcting cycle operations, making exploitation programs it is required to either estimate useful effects and forecast probable negative after-effects – for example, complex technical system resource degradation [ ]. In this case it is possible to find suboptimal solutions not only on each step of life cycle but for the whole life cycle:

$$E_{\mathrm{LC},i} = E_\tau + E^{\mathrm{FC}}_{\mathrm{T}-\tau} = \int_0^\tau (P(t) - Z(t))\,dt + \int_\tau^{\mathrm{T}} (P(t) - Z(t))\,dt.$$

$$E_{\mathrm{LC}} = \max_i \{E_{\mathrm{LC},\,i}\}. \qquad (2)$$

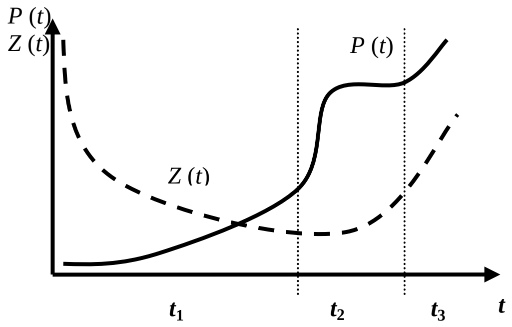

Fig. 1. Charts for benefits and total costs

The following tasks of information support have to be solved in order to obtain positive effect:

- intelligent support on all stages of life cycle;
- supporting actual, operational and authentic information about the state of complex technical system;
- estimating and forecasting the complex technical system state;
- decision making support using intelligent models to estimate the goal function on the different stages;
- simulation of "suboptimum" and "worst-case" cases on the base of multi-agent simulation system;
- diagnostics on the base of mathematical and intelligent models of complex technical with the help of onboard computer.

These tasks can provide the economic efficiency of life cycle of complex technical system due to effective interactions of all information subsystems on all stages.

3. SOFT COMPUTING TECHNOLOGIES OF LIFE CYCLE INFORMATION SUPPORT

Due to possible essential uncertainty factors influencing on design, manufacturing and exploitation effectiveness, soft computing technologies become urgent for life cycle information support.

The suboptimal solution of this task is based on evolution designing of information model of complex technical system. The second problem is that on stage of exploitation we must to diagnose technical state of remote system and to estimate value of internal resources and provide process of monitoring on the base of telemetry data stream.

The third, we must have simulation model for choosing an optimal strategy and for avoiding worst-case situations.

3.1. Genetic optimization of system design stage

In our case, information model of complex technical system is combined with PDM information system [7].

We need to generate the set of design solutions variants for our system. Then we can optimize design solution with appropriate criteria (functionality, reliability, accuracy, total cost and weight, etc.) and different constraints on the base of evolution algorithms.

Our information model has hierarchical multilevel structure and can be represented as tree graph, root node in which is our system itself (Fig.2).

On the second level of this graph model are subsystems; on the next lower levels are aggregates, components and items.

Terminal nodes are characteristics, different attributes of the system and also complex information objects, such as documents, data models and others. The terminal nodes of the graph are colored (Fig. 2.).

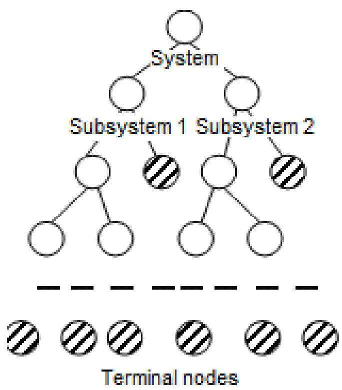

Fig. 2. Information model as hierarchy of genetic individual

Let multilevel structure describes procedures of evolution for individual structure of our system. Middle nodes of multilevel structure are subsystems and aggregates (for example, power supply, engine, cameras and etc.). It may be presented as chromosomes of any individual structure. The terminal nodes are characteristics and attributes. It may be presented as genes. The populations of so-

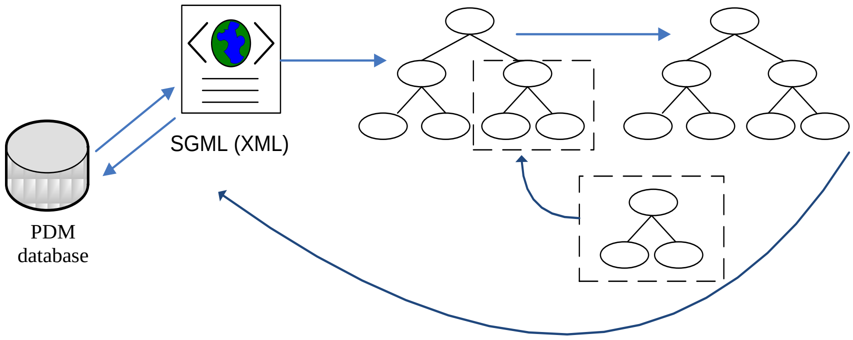

Fig. 3. Transitions between PDM database and individual hierarchy

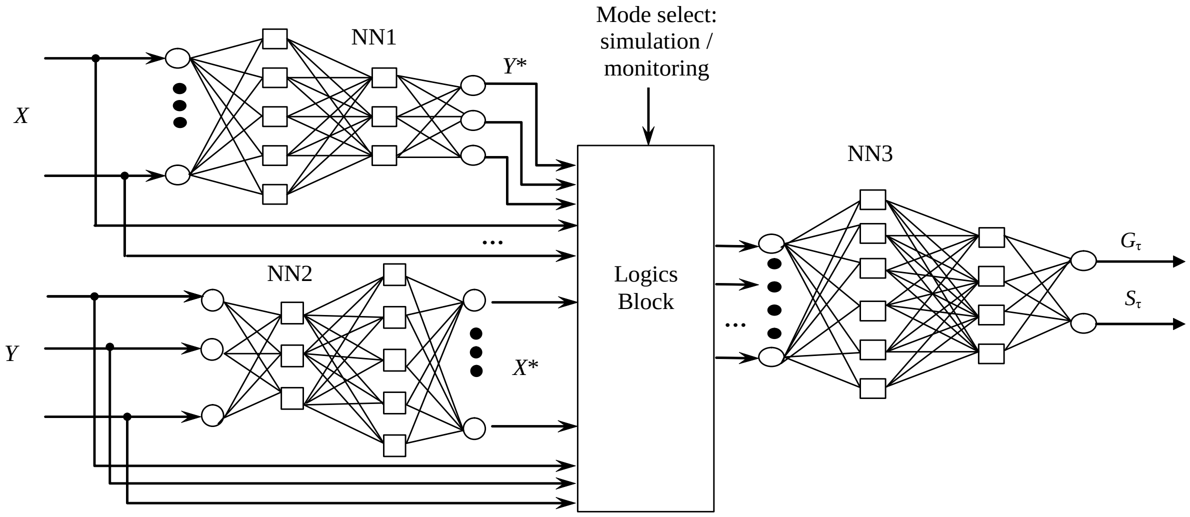

Fig. 4. Complex of neural networks NN1–NN3

lutions generated through genetic algorithm of designing within crossover and mutation operations, allow producing set of different versions of complex technical system structures. Then individual structure can be selected with help of chosen criteria or fitness function.

The transitions between PDM database and individual hierarchy could be realized via SGML (XML) transformations (Fig. 3) [8].

3.2. Trough life cycle neural network models

As usual, it is hard to develop analytical models for diagnosing technical state of complex technical system and state of internal resources within required accuracy and performance. On the other hand essential amount of information is collected in designing process and test procedure. It can be used for development of through life cycle intelligent model, for example, with application of neural networks technology. On the exploitation stage, intelligent model provides the automated solutions for such tasks as estimation of remaining internal resource and its' consumption, technical state diagnostics and failures detection [7, 9, 10].

The through life cycle intelligent model contains 3 neural networks in our case: NN1–NN3, which are have multilayer perceptron structure trained with back propagation algorithm. Complex of neural networks NN1, NN2, NN3 and logics block is shown on the Fig. 4.

Data from database of simulations, telemetry and control data, settings and additional information are used for training process for complex of neural networks. This information is separated into vectors of input data *X* and output data *Y*.

4. CONCLUSION

Design of autonomous mobile systems of small size is needed in some scientific and commercial applications. One of the modern ways to achieve efficiency of life cycle of such systems is application of intelligent information support in design, production and exploitation. Intelligent models and methods for life cycle information support on the basis of genetic algorithm and neural networks are proposed. Genetic algorithm realizes mechanisms of intelligent search and optimization for system structure with help of PDM database. Complex of neural networks as through life cycle model for information support on exploitation stage is presented . It can help to solve task of estimation of remaining internal resource, its' consumption, technical state diagnostics and failures detection.

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