Computer Aided Design of Pneumatic Driving Systems

In the Division of Control Systems computer aided design system of pneumatic driving systems has been developed. The system works in the MSWindows environment:

1. A new algorithm of designing pneumatic systems fitted for needs and requirements of CAD has been proposed. Introduced approach enables optimisation of complex system.

2. A module of calculations and selection of elements from a catalogue has been programmed:
   - algorithms of calculations and selection proposed by manufacturers of devices have been implemented;
   - a possibility of results comparison obtained with the use of different algorithms has been ensured;
   - a system sorting results of selections, that allows a designer to undertake optimal decisions, has been worked out;
   - a module collaboration with MatLab Simulink environment has been ensured, what allows to evaluate actuator motion time;
   - a possibility of system collaboration with AutoCAD has been tested, creating parametric library of elements.

3. A set of programmes aiding in design of functional structure of pneumatic system has been worked out. A software supporting creation of control programmes for PLC (Programmable Logic Controller) has been also created.

4. Two new selection algorithms of control valve have been proposed. They allow to use traditional calculation algorithms and selection of valves described in a catalogue by flow parameters compatible with standards.

5. Computer models of pneumatic drive have been worked out and experimentally verified:
   - mathematical models used in analysis of pneumatic drive have been collected,
   - multi–variant computer models of pneumatic drive have been programmed (in MatLab Simulink and Borland Delphi environment), they take into account characteristics of programming environment and pneumatic drive,
   - an experimental verification of computer models used for generation of learning data has been carried out.

6. Artificial neural networks (ANN) have been worked out, for:
   - counting over a sonic conductance C and a critical ratio of static pressures b to a flow coefficient m,
   - calculations and selection of control valves from the catalogue,
   - evaluation of motion time and maximal velocity value of pneumatic actuator,
   - drive optimisation.

7. Experiences concerning application of ANN to solve technical problems have been acquired:
   - a modification of learning algorithm by change of optimisation criterion. In technical problems it is often important to keep an relative error at a constant level. It befalls, that artificial neural networks learning algorithm forces them to produce a small mean square error, but cases with considerable discrepancy between computed and real values are present. In this case it seems advisable to use a relative error as a criterion.
   - an adequate rescaling of output variable values in learning set with the purpose of "deceiving" the learning algorithm, and through that to decrease the relative error of obtained results,
   - course approximation of a single dynamic object is far more easier that identification of the object's single instance in a class. That indicates how precise and thoughtful the tests of the obtained model have to be, in order to talk about achieving a success,
   - an analysis of an artificial neural network learning course can indicate whether learning set is "correct". A rapid drop of error value and after that its establishment on relatively high level

irrespectively of changes in network structure, can indicate that there are gross errors in the learning set,

- formulating a task for a network one has to answer a question if there are any other alternative solutions (for instance if it is possible to solve the problem using any algorithm) and what advantages over these solutions gives us ANN.

A usage of artificial neural networks in aided design is not widespread yet, and it can provide an impulse to development of CAD systems. In many centres in the world intensive research are carried out. Most of the work apply to recognition of images, speech and searching similarity between technical objects. There is not much work done in a field of aided engineering computations. In some centres research in the field of aided design of hydraulic systems are carried out. Our research in the field of pneumatic drives can be considered (under the literature studies) as pioneer. It seems that continuation of development work in that field is purposeful. Particularly advisable we see:

1. Verification of the conclusions concerning the use of ANN in solving technical problems on another examples. This will allow to generalize conclusions and to define guidelines for the future designers – neural networks users.
2. Development of commercial versions of artificial neural networks and attempt to implement them into pneumatic drives market.
3. Experimental and simulation study of energy–saving systems. These works should result with an optimisation procedure that enables selection of structure and elements of the system.
4. Modification and development of the existing computer CAD system for pneumatic systems.

Selected publication:

1. Kiczkowiak T., Tarnowski W., Grymek Sz.: *Robust Procedure for Flow Coefficient Calculation*. In Nikos E. Matorakis (Ed.): *Recent Advances in Simulation, Computational Methods and Soft Computing*. WSEAS Press 2002, pp. 152÷155.
2. Grymek Sz., Kiczkowiak T.: *About certain optimisation task in pneumatics.* In Nikos E. Matorakis (Ed.): *Systems and Control: Theory and Applications.* World Scientific and Engineering Society Press 2000, pp. 316÷319.
3. Grymek Sz., Kiczkowiak T.: *Neural models of dynamic plants in optimisation. Continuation.* V Konferencja Sieci Neuronowe i Ich Zastosowanie (V Conference on Neural Networks and Their Applications), Zakopane 2000, pp. 407÷412.
4. Grymek Sz., Kiczkowiak T.: *Algorithms of artificial intelligence in design of pneumatic driving systems.* In Borkowski A. (Ed.): *Artificial Intelligence in Structural Engineering*. WNT Warszawa 1999, pp. 121÷130.
5. Grymek Sz., Kiczkowiak T.: *Selection of a Pneumatic Valve. Neural Approach.* Tenth World Congress on the Theory of Machines and Mechanisms. Oulu, Finland, June 20÷24 1999 Vol. 5, pp. 2105÷2109.
6. Kiczkowiak T., Grymek Sz.: *Algorithm of design of pneumatic driving systems suitable for CAD*. Tenth World Congress on the Theory of Machines and Mechanisms. Oulu, Finland, June 20÷24 1999, Vol. 5, pp. 2032÷2036.
7. Grymek Sz., Kiczkowiak T.: *Application of ANN to the Selection of a Valve from the Catalogue.* In Springer–Verlag series: *Perspectives in Neural Computing*. London 1998r. pp. 851–856.
8. Grymek Sz., Kiczkowiak T.: *Optimisation of Pneumatic Driving System by means of Artificial Neural Networks.* VII Krajowa Konferencja Naukowo–Dydaktyczna *„Automatyzacja i eksploatacja systemów sterowania*" (VII National Science–Didactics Conference *Automation and Exploitation of Control Systems*), Gdynia 1999, pp. 389÷394.
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10. Grymek Sz., Kiczkowiak T.: *Artificial Neural Networks in calculations of pneumatic driving systems.* III Polsko–Niemieckie Seminarium "Innowacje i postep w hydraulice i pneumatyce" (III Polish–German Seminar *Innovations and Progress in Hydraulics and Pneumatics*), Zakopane 1999, pp. 260÷274.

11. Grymek Sz., Kiczkowiak T.: *Analysis of Feasibility of Artificial Neural Networks in Design of Pneumatic Driving Systems.* III Konferencja Sieci Neuronowe i Ich Zastosowanie (III Conference on Neural Networks and Their Applications). Kule 1997, pp. 444÷449.

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