KAUNAS UNIVERSITY OF TECHNOLOGY

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METHODS OF COMPUTATIONAL INTELLIGENCE FOR DEFLECTION YOKE TUNING

Summary of Doctoral Dissertation

Technological Sciences, Informatics Engineering (07T)

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Relevance of the problem. Cathode ray tube (CRT) is still the most widely used display device for television and computer monitors. Experts and the largest producers are predicting that CRT will be popular for a long time among customers considering the price and quality of image. 160 mill. television kinescopes were sold last year. Only 5 mill. or 3 % were LCD (*liquid crystal display*) or plasma displays. Following the prognosis, 202.6 mill. TV will be sold in 2007 year and only 41.6 mill. or 21% of them will be novel displays. So Lithuania CRT and deflection yoke (DY) producers have purpose to be the leaders in the market for the next 10-15 years.

The success of CRT in the market is predetermined by two factors – the development of new type CRTs with better optical-constructional parameters and reducing the costs of production. These goals could be reached by the development of new advanced methods for production quality control.

In recent years CRT and DY producers started to pay a big attention to the quality of control systems. While designing such systems some technical - scientific problems occur. Generally those problems are not widely discussed in the scientific studies and demands some original solutions and scientific investigation.

The increase of computer numerical data processing speed, leads in using technical vision and image processing means in CRT industry. One of the largest Europe TV DY producers “Vilniaus Vingis” started to use such systems combined with intelligent decision support systems (DSS) for deflection yoke tuning. The most important attributes of the DSS is DY tuning quality and the speed of decision making. As it was mentioned there is not enough information about designing and implementation of such systems. There are some works about decision support systems, but they were designed for DY which control beams misconvergence only in 9 or 16 measuring points or only between the red (R) and the blue (B) beams. Sometimes no experimental investigation results were presented. So the analysis of proposed methods showed that this area of work demands an exhaustive scientific investigation.

Aim of the work – to propose new methods and algorithms for automated deflection yoke tuning.

Objectives of the work:

1. The analysis of DY quality parameters, their tuning methods.
2. The proposal of mathematical models of the tuning shunt influence on beams misconvergence.
3. The proposal of fast and effective decision search methods.
4. Performing of experiments of effectiveness of the decision support systems proposed.

5. Making recommendations for practical application of these decision support systems.

Scientific novelty of the work. Mathematical models of the shunt influence to the beam misconvergence are proposed. These models evaluate different size shunt influence on beam misconvergence.

New mathematical models of DY tuning influence on balance parameters and DY balance influence on beam misconvergence are proposed. These methods allow improving of DY tuning quality.

Combined numerical decision search methods are designed and proposed.

Practical significance of the work results. The decision support system based on artificial neural networks and a combined decision search method have been successfully implemented in the convergence tuning equipment "Vingelis -2", which was made in cooperation with SC "Vilniaus Vingis" and JSC "Elinta". The material of the dissertation was also published in the reports No. 1-4 of the international project EUREKA EU-2374 HYBTUNE. This project could be an example of cooperation between industry and academic institutions in Lithuania.

Approbation and publications of the research. The main results of the work were presented and discussed at:

1. Annual conferences "Automation and Control Technologies", Kaunas, 2000 to 2004.
2. International symposium "Intelligent Systems – 2002", Bulgaria, 2002.
3. International conferences "Methods and Models in Automation and Control", Poland, 2002 - 2003.

The material of the dissertation was published in 9 scientific articles, among them 2 in Lithuanian Journals certified by the Department of Science and Higher Education of Lithuania.

1 article was prepared and sent for publishing in the ISI journal "Robotics and Automation". It is still under the review.

The material of the disertation also was published in the reports No. 1-4 of the international project EUREKA EU-2374 HYBTUNE.

Structure and size of the dissertation. The dissertation is organized as follows: introduction, four basic chapters, general conclusions, list of references, and list of authors' publications.
The dissertation consists of 102 pages, among them 67 figures and 11 tables.

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I acknowledge to my Parents and my Family for great support during my studies. THANK YOU!

<u>Content of the dissertation</u>

In the introduction, the relevance of the dissertation subject in Lithuania and worldwide is being discussed. The goals and tasks of the work are being formulated and the novelty and practical significance of the work are being described.

In the first chapter, the main DYs characteristics are investigated. The means of tuning, the goal function and existing tuning methods are described.

A high quality DY is one of the most important factors for high quality monitor. The CRT produces visible light by bombardment of a thin layer of phosphor material by an energetic beam of electrons. In the color CRT three electron guns produce three beams: red (R), green (G) and blue (B). The role of the deflection yoke is to deflect electron beams in horizontal and vertical directions. If the magnetic field is formed incorrectly, misconvergence of the beams may occur resulting in blurred image on the screen of the monitor. On DY tuning process usually these parameters are tuned:

- static misconvergence,
- dynamic misconvergence,
- secondary parameters.

Static misconvergence – beams misconvergence measured in the centre of the screen. Usually it is tuned automatically and operator doesn't refer to them.

Dynamic misconvergence – beams misconvergence measured in all measuring points except the centre.

Secondary parameters are calculated from primary parameters. Some equations presented below (LS, FS).

The number of misconvergence measuring points depends on the producible DY type, the monitor size and quality requirements. Usually 9, 17 or 25 measuring points are used (Fig. 1.). Misconvergence is evaluated by x and y direction between red and blue (R-B) or between R-B, R-G, B-G. It is assumed that the beam G is always between R and B.

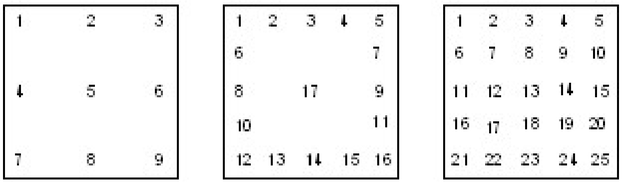

Fig. 1. Location of measuring points on the screen

Small misconvergence can be eliminated by sticking one or several ferroelastic shunts on the inner part of the deflection yoke. This correction is usually done by a human operator. The difference between DY tuning quality performed by an experienced expert and novice is very large. The convergence adjustment is a complex procedure and requires a long time to train an operator to make his job efficiently. Generally, it takes more than one year to become an expert. Therefore, an intelligent decision support system is highly desirable in the industry.

It is clear that the more precaution from allowable misconvergence the better tuning quality. The tuning quality is measured by the coast function $Krit_m$. The $Krit_m$ is a cost function depending on the predicted values of the misconvergence parameters of the DY when the correction shunt is placed.

$$Krit_m = \max\left\{ \max_{j=1,\dots,N}\left(\frac{s_{ij}}{s_j^{A\min}}\right), \max_{j=1,\dots N}\left(\frac{s_{ij}}{s_j^{A\max}}\right)\right\} \tag{1}$$

where s_{ij} is the predicted value of the parameter s_j having a correction shunt placed at the i-th position, s_j^{Amin} is the minimum allowable value of the parameter s_j , s_j^{Amax} is the maximum allowable value of the parameter s_j , N is the number of parameters.

In the cost function formula any secondary parameter can be involved. It is assumed that DY is tuned correctly if the value of the $Krit_m$ is less than unity. The parameter vector of DY with correction shunt placed in the i-th position is calculated as follows:

$$S = s_0 + s_i \quad (2)$$

Metal and ferroelastic shunts placement positions are showed in Fig. 2.

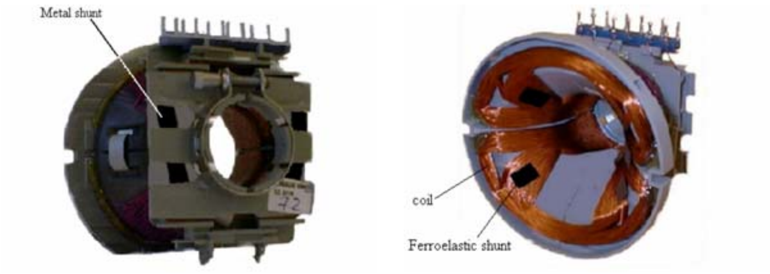

Fig. 2. Metal and ferroelastic shunts placement positions

Metal shunts are used only for secondary parameters tuning, and ferroelastic shunts for secondary and primary parameters both. LS and FS parameters could be calculated by formulas:

$$LS = (x_4 - x_6)/2 \quad (3)$$

$$FS = (x_2 - x_8)/2 \quad (4)$$

As it was mentioned before, primary parameters can be tuned by sticking feroelastic shunts on the inner part of the DY. The shunt could be placed in an angle interval from 0° to 360° and in a distance interval from 0mm to 40mm. Different size shunts can be used for tuning DYs which quality requirements are very high. Experimental investigation showed that the bigger shunt the bigger influence on beam misconvergence. But there are some positions where bigger shunt is making smaller influence. It is happening because in some positions big shunt covers the area with different influence sign. So totally we have smaller influence on beam misconvergence. This information was involved in the shunts influence model.

In Fig. 3-4 shunt (size 8x16mm) influence on beam misconvergence between red and blue beams are presented. Shunt was placed in the angle interval from 0° to 360°. The distance was fixed.

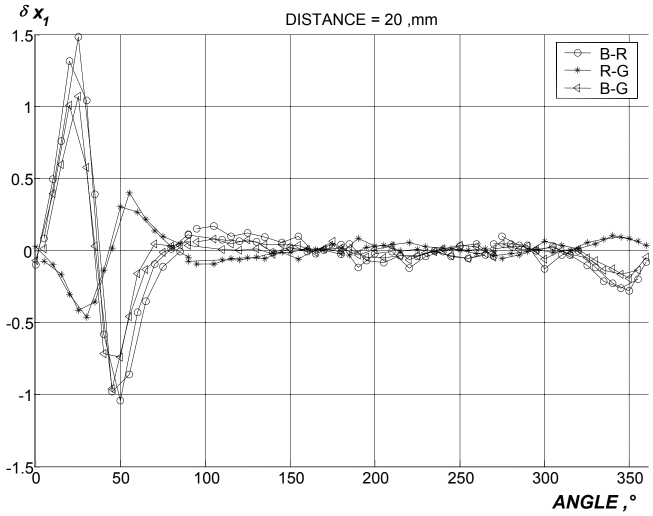

Fig. 3. Shunt influence on beam misconvergence B-R, R-G, B-G in a measuring point 1 according to *x* direction.

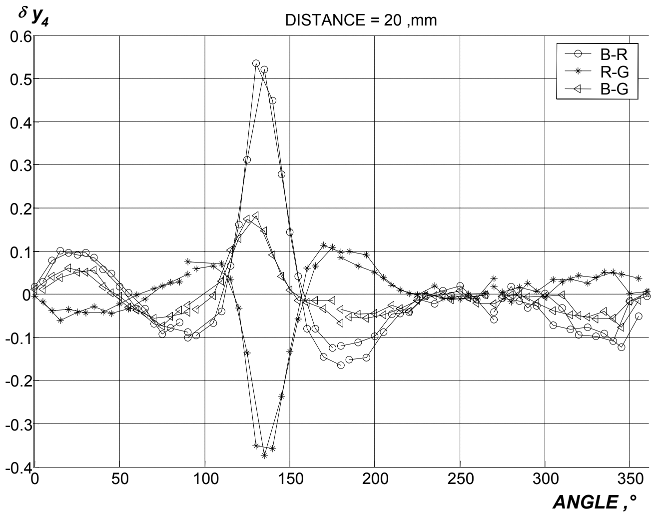

Fig. 4. Shunt influence on beam misconvergence B-R, R-G, B-G in measuring point 4 according to *y* direction

In this chapter also existing tuning methods are presented and discussed.

In the second chapter the mathematical models of tuning shunt influence on beam misconvergence are proposed. These methods are based on:

- artificial neural networks,
- fuzzy logic,
- heuristic experience.

Experimental investigation showed that shunt influence is hardly nonlinear. So for such influence modeling the artificial neural networks as a suitable technique were selected.

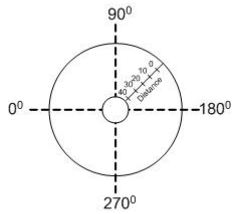

Fig. 5. Description of shunt position on DY

Decision support system (DSS) for the deflection yoke tuning consist of two phases, learning and operating.

- In the learning phase the neural network is trained to perform a mapping: tuning shunt position → changes in misconvergence. As it was mentioned above, the position is given by a distance *d*, as measured from the outermost border of a DY, and an angle Θ, as measured from the horizontal axis. The shunt positioning system is shown in Fig. 5. Thus, we have *M* (*M* – number of measuring points * number of differences between beams) "primary" parameters $\Delta x_1,\ldots,\Delta x_M$ ir $\Delta y_1,\ldots, \Delta y_M$. Hence, the neural network solves the function approximation task by performing a mapping from the shunt position space, defined by a depth and an angle, to the space of misconvergence changes $\delta_{x1},\ldots \delta_{yM}$. The learning phase is executed only once when the system is adapted to correct the misconvergence for deflection yokes of given type.
- In the operating phase, the actual beam misconvergences are measured. If at least one of the measurements is outside the allowable interval, the tuning process is activated. First, employing the trained neural networks, the changes in misconvergence are predicted for different correction shunt positions. Having the

prediction results, the best position to place the tuning shunt is found by executing a search procedure. The best position is that yielding the minimum value of the cost function (1). It is assumed that a DY is tuned correctly if the values of the "primary" and "secondary" parameters fall inside given intervals.

When using more than one shunt to tune a DY, the additivity assumption about the influence of several shunts to the beams misconvergence is made, i.e., the influence of several shunts placed on a DY is equal to the sum of the influences caused by the placement of the same shunts at the same positions one at a time. The structure of neural networks system with two inputs is shown in Fig. 6. When the number of measuring points is 9, we have 18 neural networks.

The multilayer perceptron, with one hidden layer and 10 hidden neurons with sigmoid transfer function (5), was selected.

$$\varphi = \frac{2}{1 + e^{-2a}} - 1 \qquad (5)$$

To train the neural network performing the mapping *z=f(d,Θ)* we have random chosen 8 DYs which does not requires any tuning with correction shunts.

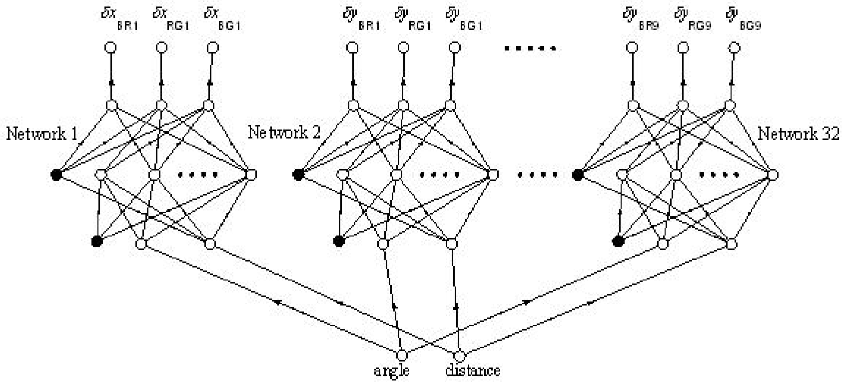

Figure 6. Structure of neural networks system with two inputs.

The data for ANN training were received by sticking correction shunt on a DY and by measuring the change of the misconvergence. Eighty-one measurements were made for each of the deflection yoke. . Measuring points were distributed with 10° and 10mm quantization step in all shunt placement interval. Some neural network functions showed in Fig. 7-8.

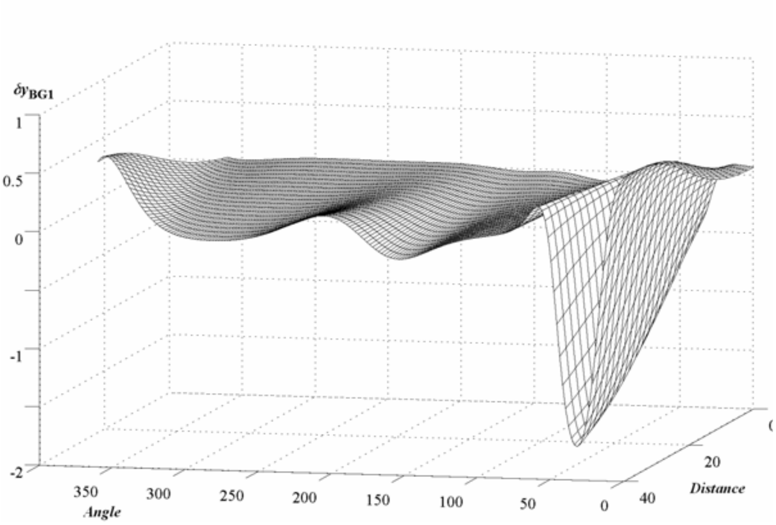

Fig. 7. Shunt (8x16 mm) influence on beam *BG* misconvergence in measuring point 1 according to *Y* direction.

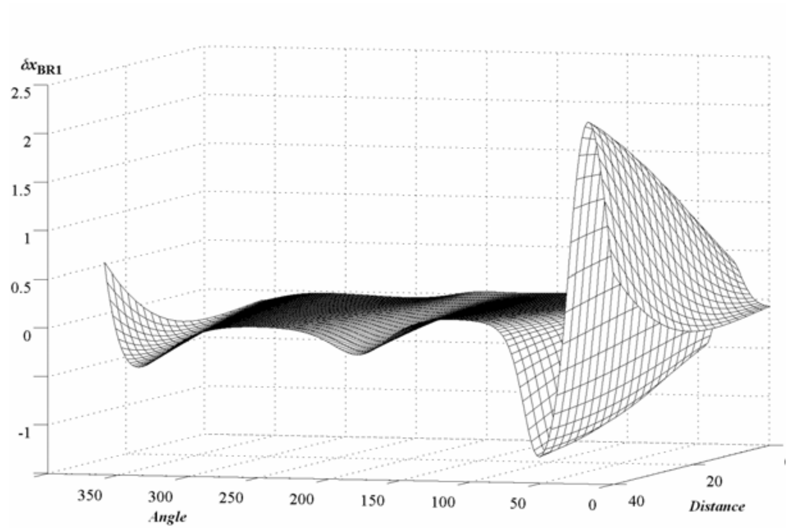

Fig. 8. Shunt (8x16 mm) influence on beams *BR* misconvergence in a measuring point 1 according to *X* direction.

In order to improve the efficiency of decision support system it was decided to use different size shunts. Two mathematical means for shunt size modeling were used:

- Neural networks
- Polynomial function

The proportions for shunts were set as follows: 6x12mm – 0.75, 8x16mm – 1, 10x20mm – 1.25. To evaluate the shunt size influence on beam misconvergence in all angle (0,…,360)° and distance(0,…,40)mm interval, the different size shunts were placed in predetermined angle and distance positions. So we constructed neural network with three inputs (angle, distance and size) and three outputs *δ(B-R)*, *δ(R-G)* and *δ(B-G)* (Fig. 9).

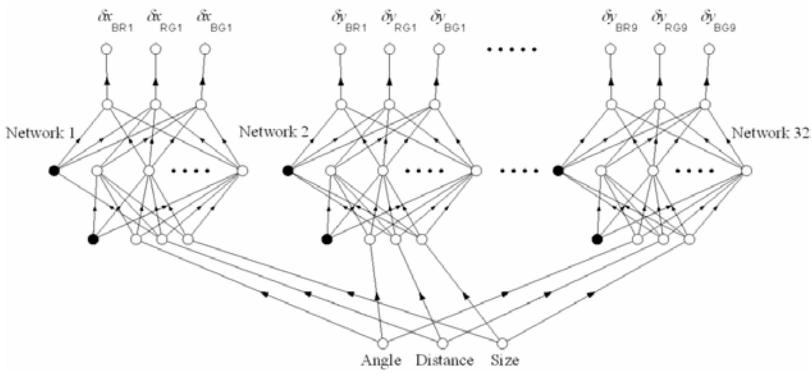

Figure 9. Structure of neural networks system with three inputs.

It has one hidden layer with 15 hidden neurons. The tan-sigmoid transfer function type was selected for hidden layer neurons, and linear for output neurons. Levenberg-Marquardt training algorithm was used for ANN training. Some simulation results are presented in figures 10-11. Neural network function depicted with continuous line.

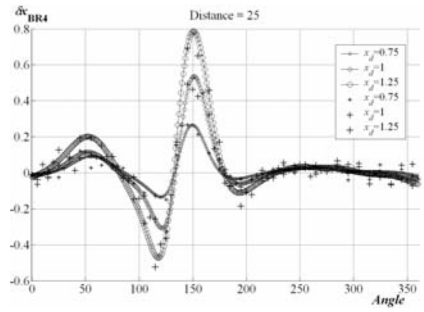

Fig. 10. Different size shunts influences on beam *BR* misconvergence in a measuring point 4 according *X* direction.

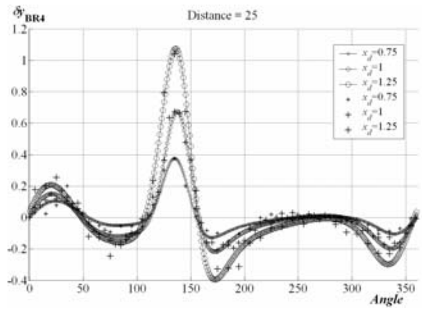

Fig. 11. Different size shunts influences on beam *BR* misconvergence in a measuring point 4 according *Y* direction.

The second strategy was to predict standard shunt size ($x_d=1$) influence on beam misconvergence with neural network (two inputs) and to evaluate a shunt size with second order polynomial equation.

$$P(x_{ds}) = Ax_{ds}^2 + Bx_{ds} + C \qquad (6)$$

Polynomial equation need to satisfy two conditions:

- If shunt size $x_{ds} = 1$, then $P(x_{ds}) = \delta^{net}$,
- If shunt size $x_{ds} < 0.5$, then $P(x_{ds}) = 0$.

After the expression of parameters C and B from equations which were made after the evaluation of conditions mentioned above, we have got the expression (7):

$$p_i\left(x_{ds}\right) = a_i\left(x_{ds}^2 - 1\right) + \frac{a_i\left(1 - x_{0i}^2\right) - \delta_i^{net}}{\left(x_{0i} - 1\right)}\left(x_{ds} - 1\right) + \delta_i^{net} \qquad (7)$$

Coefficients a_i and x_{oi} were evaluated by least square method.

These two modeling strategies were tested with using 140 measurement of different shunt size influence on beam misconvergence. Modeling with neural networks showed better results than modeling with polynomial equations.

For the DYs of given type (Thomson SMZ) tuning the metal shunts could be used. Especially for "secondary" parameters, but also for "primary". The earlier made decision support system was able to execute only the tuning with ferroelastic correction shunts. Metal shunts positions were selected by the operator. Experimental investigation showed that sometimes metal shunts have not enough influence on "secondary" parameters. It means that DSS need to overtake the tuning with ferroelastic and with metal shunts both.

For metal shunts influence on "secondary" parameters modeling the multilayer perceptron with one hidden layer, 3 hidden neurons with sigmoid transfer function were selected. The ANN was trained using Levenberg-Marquardt training algorithm. As experimental investigation showed the involving of metal shunts positions prediction into DSS improved the DYs tuning results.

Before starting the tuning procedure of DYs of type Philips KS2180 the balance parameters (YVB, TBPINB and ROTATION) are tuned. It means that they become close to zero. To do this, the DY is turned so that its symmetrical axis has a little displacement comparing with DY placed in the initial position. The DY is turned by three engines. Each one of them turns DY in one direction: horizontal, vertical and around symmetrical axis. So we have shunt position changes by all three directions (*ΔH, ΔV, ΔR*). Balance parameters are calculated from primary parameters. Because of shunt influence model was made with data gathered from DY in the initial position, at the start of the tuning procedure each of DY was standing in a different position, and we had influence prediction errors. To eliminate this error the deflection yoke misbalance evaluation model was created. It was accepted that the shunt influence to beams misconvergence is changed because of the DY balance parameters tuning and changes of shunts angle and distance from symmetrical axis. It could be written:

$$\Delta\mathbf{SN}\left(\alpha, \text{distance}, size, \Delta YVB, \Delta TBPING, \Delta ROTATION\right) = \Delta\mathbf{SN}\left(\alpha', \text{distance}, size\right)\left(\frac{r}{r'}\right)^{\rho} \quad (8)$$

where α' and r' are recalculated shunt angle and a distance from the symmetrical axis. ρ is a degree selected by minimization of sum square error and equal to four.

It was identified that changes of balance parameters *ΔYVB, ΔTBPINB, ΔROTATION* and measured changes *ΔH, ΔV, ΔR* have a linear dependences.

If *ΔH, ΔV, ΔR* are known, changes of shunt placement angle and the distance from symmetrical axis can be easily calculated from simple geometrical formulas. *ΔH, ΔV, ΔR* from parameters changes *ΔYVB, ΔTBPINB, ΔROTATION* are calculated by such formulas:

$$\Delta H = k_h * \Delta YVB \quad (9)$$
$$\Delta V = k_v * \Delta TBPINB \quad (10)$$
$$\Delta R = k_r * \Delta ROTATION \quad (11)$$

Coefficients k_h, k_v, k_r were identified by using a sum square error minimization method.

Experimental testing of the model showed that the DY misbalance evaluation model improves the shunt influence prediction results.

After tuning shunts are placed the "primary" parameters are changed. Balance parameters are changed also, and they will be tuned automatically again. So it is clear that if we want to have a correct prediction result, we need to evaluate shunt influence on the balance parameters and balance parameters tuning influence on beams misconvergence.

For a shunt influence on the balance parameters modeling the multilayer perceptron with one hidden layer and 10 hidden neurons with sigmoid transfer function was selected. Output layer neurons have a linear transfer function. The neural networks system for modeling of shunts influence on the balance parameters is shown in Fig. 12.

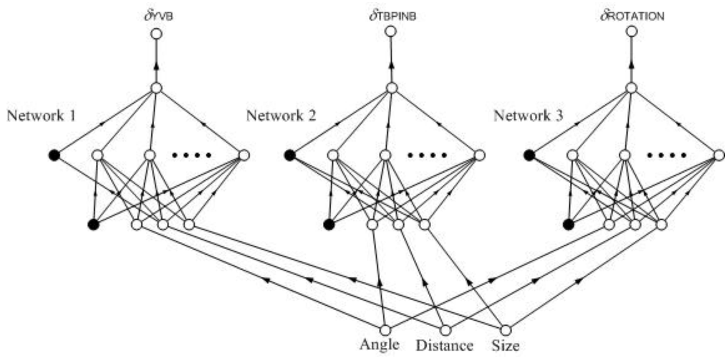

Fig. 12. The neural networks system for modeling of shunts influence to balance parameters

The balance parameters *YVB* and *ROTATION* neural network function depending on the shunt placement angle and distance is shown in Fig. 13-14.

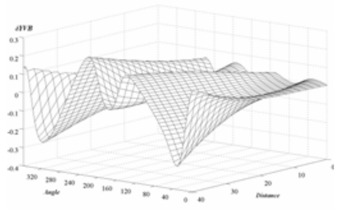

Fig. 13. Ferroelastic shunt influence on balance parameter *YVB*.

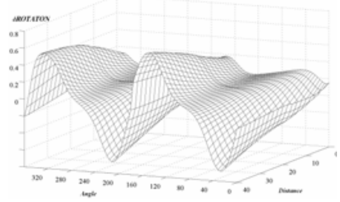

Fig. 14. Ferroelastic shunt influence on balance parameter *ROTATION*.

As it was mentioned, the DY could be turned according to three axis directions. We need to know how the beams misconvergence depends on the balance parameters changes. In other words, we need to design a mathematical model for the prediction of balance parameters tuning to the beams misconvergence. The model was designed using the second order polynomial equation (11)

$$\Delta SN_k = b_{0k} + \sum_{i=1}^{3} b_{ik} v_i + \sum_{i=1}^{3} b_{ik} v_i^2 \qquad (11)$$

Fuzzy logic for the shunt influence on beams misconvergence modeling was used after interview with human – operators. They said that if beam misconvergence is evaluated only in 9 measuring points, it is possible to find such shunt positions where the shunt makes influence on misconvergence only in one measuring point without influence on misconvergence in other measuring points. In that situation is convenient to use fuzzy logic. These shunt influence models are human – operator work imitation and can eliminate misconvergence in one measuring point without influence on misconvergence in other measuring points.

Fuzzy model was designed for the DY of type Thomson SMZ. A separate model was created for each of measuring points and for misconvergence according to *x* and *y* directions between red and blue beams (R-B). Structure of the model is presented in Fig.14.

Fig. 14. Structure of the fuzzy logic model.

Each model has one input (beams misconvergence) and two outputs (shunt placement angle and distance).

The made fuzzy rules have a form:

IF *misconvergence* THEN *angle* and *distance* is.

For the fuzziness of the input and output variables the Gaussian transfer functions were selected.

$$\mu_{Fi}^{l}\left(x_i\right)=\exp\frac{-\left(x_i-r_{xi}^{l}\right)^2}{2\left(\delta_{xi}^{l}\right)^2},\ \mu_{G}^{l}\left(y\right)=\exp\frac{-\left(y-r_{y}^{l}\right)^2}{2\left(\delta_{y}^{l}\right)^2}. \quad (12)$$

where r_{xi}^{l}, r_y^{l} – the averages of membership functions, δ_{xi}^{l}, δ_{xi}^{l} – the width of the membership functions.

The output of the model is produced by the centroid of area defuzzification method. The centroid of area method finds the center of mass to yield the output.

The Heuristic - tuning by effects model is based on the heuristic human-operator knowledge. It is known where to place a correction shunt if particular beams misconvergence in some measuring points appears. It was suggested to combine this model with DSS based on the neural networks. It was expected that the heuristic – tuning by effects model can help to reduce the number of possible shunt placement positions to tune the DY and time for search procedure likewise.

In the third chapter the decision search methods are described. If we have the shunt influence on beams misconvergence mathematical model we can predict the beam misconvergence changes depending on the shunt placement position. When the misconvergence changes are known the optimal shunt positions are found by executing a search procedure. The best position is that one which yields the minimum value of a cost function. The cost function is a function of beam misconvergences (1).

The search methods used for the DY tuning:

- Sequential search,
- Exhaustive search,
- Stochastic simulated annealing (SA) search,
- Combined SA + gradient descent search,
- Combined SA + quasi-newton search.

The sequential search is when positions for shunts placement are found one by one and all positions found before are fixed and frozen. It is a very fast method but not effective in respect of cost function $Krit_m$.

The exhaustive search is when all possible shunts placement positions are checked. It is the best method in respect of cost function, but not of search time. If five or six shunts needs for DY tuning, the exhaustive search become impossible because of crucial increase of possible shunts placement positions.

The simulated annealing procedure is a random search process and it is fast and effective for a globally optimal point search. The proposed SA algorithm can be realized as follows:

1. Randomly select the initial parameter vector x_0 (shunt position). Choose "Temperature" T value such that exp(-ΔKrit/T) ≥0.999 for all error E changes ΔE.
2. Select a component x_i of x uniformly at random.
3. Change vector w to vector x' such that $x'i=\xi_i$, where ξ_i – the value chosen uniformly at random from the search area X_i.
4. Set

$$x^{new} = \begin{cases} \mathbf{w}' & \text{with probability } \exp\left[\dfrac{-\left[Krit(x^{'}) - Krit(x)\right]}{T}\right]; \\ \mathbf{w} & \text{else.} \end{cases} \quad (13)$$

5. If it was made M successful changes of vector x (changes for which the value of E dropped) or N total changes in w have occurred since the last change in temperature, then set the value T to β*T. M is typically an order of magnitude smaller than N and β is typically between 0.8 and 0.9999.
6. If the minimum value of E has not decreased more than ε (a small constant) in last S (S>>N) iteration then stop the search. Otherwise go to step 2.

The Gradient descent was selected for the local optimization. After the increase of requirements for the deflection yoke tuning the quality of SA search becomes not enough. For the search improvement the SA search method was combined with gradient descent. Gradient descent could be realized as follows:

1. At the moment t=0 the actual beam misconvergences SN_{act} are measured and the initial shunts positions $angle^t$, distance^t , $size^t$ are selected.
2. The beam misconvergences of DY with shunt placed in initial positions:

3. $SN_{predict} = SN_{act} + \delta^{net}(angle^t, \text{distance}^t, size^t)$
4. Let's mark $E=Krit_s$. Calculate the system error $E^t(SN^t_{predict})$.
5. If E^t value is less than unit, then stop the search.
6. Calculate new shunts sizes and placement positions by formulas:

$$\begin{aligned} angle^{t+1} &= angle^t - \eta\, \partial E^t \big/ \partial angle^t \\ distance^{t+1} &= distance^t - \eta\, \partial E^t \big/ \partial distance^t \\ size^{t+1} &= size^t - \eta\, \partial E^t \big/ \partial size^t\ , \end{aligned} \tag{14}$$

In order to accelerate the shunts positions search the RPROP ("resilient backpropagation") algorithm [14] for changing of each one of the input vector component was used. The partial derivative of the cost function with respect to input was used only to define the descent direction. The coefficient η_i was changed depending on whether successful or not the last step was.

$$\Delta x_i = -\eta_i \operatorname{sgn}\left|\frac{\partial E}{\partial x_i}\right| \tag{15}$$

where Δx_i – the change of input vector ith component, η_i – the learning rate for the ith input vector component.

It should be noted that the DY tuning quality was evaluated by the cost function $Krit_m$, but the cost function used for the gradient descent search procedure was $Krit_s$.

$$Krit_s = \sum_i^9 \sum_j^3 \sum_k^2 \left(\frac{sn_{ijk}}{sn_{ijk}^{\max}}, \frac{sn_{ijk}}{sn_{ijk}^{\min}} \right)^n \tag{15}$$

where i – the number of measuring points, j – the number of differences between beams, k – the number of axis (x and y), n – the cost function degree.

Quasi-newton search method was used in purpose to reduce search time. Quasi-newton method let as to evaluate Hessian matrix without calculating the second order derivatives and don't need the inverse of the Hessian. Two the most popular Hessian matrix inverse evaluation formulas are *Davidson-Fletcher-Powell* (DFP) and *Broyden-Fletcher-Goldfarb-Shanno* (BFGS). In this case the BFGS formula was selected, since it is generally regarded as being superior:

$$G^{\tau+1} = G^{\tau} + \frac{pp^T}{p^T v} - \frac{\left(G^{\tau} v\right) v^T G^{\tau}}{v^{\tau} G^{\tau} v} + \left(v^T G^{\tau} v\right) uu^T; \qquad (16)$$

$$p = In^{\tau+1} - In^{\tau}; \qquad (17)$$

$$v = g^{\tau+1} - g^{\tau}; \qquad (18)$$

$$u = \frac{p}{p^T v} - \frac{G^{\tau} v}{v^T G^{\tau} v}; \qquad (19)$$

where *In* – the input (shunts positions) vector, *g* – the first order derivatives vector.

The problems arising from Hessian matrices which are not positive defined were solved by starting from a positive-definite matrix (such as a identity matrix). Initializing the procedure using the identity matrix corresponds to taking the first step in the direction of the negative gradient. At each step of the algorithm the direction is guaranteed to be a descent direction, since the matrix G is positive defined. The shunt position vector is updated using

$$In^{\tau+1} = In^{\tau} + \alpha^{\tau} G^{\tau} g^{\tau}; \qquad (20)$$

The coefficient α was defined experimentally, and equal to 0.3.

The coefficient α was changed depending on if successful or not the last step was by RPROP algorithm.

The number of shunts required for the DY tuning was defined by the proposed tree-branch algorithm. The search is started with three shunts and later depending on the cost function found, the number reduced or increased by the algorithm. The structure of the algorithm proposed is presented in Fig. 16.

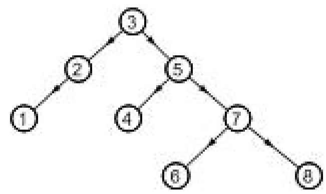

Fig. 16 . Structure of the tree-branch algorithm.

The Heuristic fuzzy-ANN search algorithm was created for the DY tuning by DSS based on the fuzzy logic. This DSS consists of two parts:

- ANN shunt influence model (shunt influence matrix)
- Fuzzy logic shunt influence model

The search algorithm could be expressed by four steps:

1. At first step the position for shunt is found by the fuzzy model.
2. Check if $Krit_m$ is less than unity. If not, then find in which measuring point the ratio between beams misconvergence and maximum allowable value is the biggest.
3. Then find the shunt position by the fuzzy model for that measuring point.
4. Change all shunts positions (angle and distance) in predetermined range -8:2:8 predetermined number of iterations and calculate $Krit_m$. The best position is that, which yield the minimum value of the cost function. If $Krit_m$ is less than unity then stop, else back to step 2.

In the fourth chapter, the experimental investigation of the methods for the deflection yoke tuning is presented.

Experimental investigation started from simple decision support system wich consists of neural networks shunt influence model and simulated annealing search method. This DSS was tested with 100 DYs type of Thomson SMZ. 98 of them were tuned successfully and only 2 declined.

Next experiment was executed with DSS which consists of neural network shunt influence on beam misconvergence and the balance parameters model, the DY balance influence to beams misconvergence model and the SA search method combined with the gradient descent. During this experiment the tuning parameters were defined and recommended to use. Also the degree of the criterion was defined.

Then DSS which can evaluate shunt size was tested with 100 DYs of type Philips 2180. The system with different shunt size produces better results but increases the search time. One more disadvantage, that operators need to cut shunts if they want to have the same influence on beams misconvergence.

The SC "Vilniaus Vingis" engineers suggested combining the DSS based on neural networks with heuristic – tuning by the effect method. Experimental investigation showed that tuning by the effect method didn't reduce the search time, but also increased the cost function $Krit_m$ found.

The attempt to change the gradient descent search method by quasi-newton method was investigated. Some problems arise with practice of the quasi-newton method. QN method used less iteration to reach the minimum of the cost function, but it was not clear when to stop the search. Because of the difference between the degree of the criterion, used by the gradient descent and by the quasi-newton methods, the influence of the measuring points, where ratio between actual and allowable misconvergence was small, on the criterion wasn't eliminated. So sometimes when the cost function $Krit_s$ is descending the $Krit_m$ is growing. The quasi-newton search method was cast-off.

After DSS based on the fuzzy logic experimental investigation some conclusions were made. This DSS is suitable for the deflection yoke tuning only when the beam misconvergence is evaluated in 9 measuring points and between red and blue beams.

Conclusions

1. The exhaustive review of the methods for the DY tuning was made. It was estimated that there are not methods published to tune the DY when beam misconvergence is evaluated in 16 or 25 points on the screen, between R-B, R-G, B-G beams.
2. The mathematical models of shunt influence to beam misconvergences are proposed. The misconvergence is evaluated in 9, 17 or 25 measuring points on the screen, between R-B or R-B, R-G, B-G beams and shunt could be placed in all angle (0…360)° and distance (0…40)mm intervals.
3. The proposed mathematical model of DY misbalance evaluation enables to evaluate changes of shunt influence depending on the DY misbalance.
4. New methods of shunt influence to the balance parameters and the balance parameters tuning influence on the beam misconvergence were proposed.
5. The new combined search method *simulated annealing* + *gradient descent* was proposed and investigated. This method is effective for global and for local cost function minimization.
6. In order to improve the search quality and reduce the search time the cost function with high degree was proposed and investigated.
7. On the basis of the neural network shunt influence on beam misconvergence mathematical model and combined *simulated-annealing* + *gradient descent* search method the software for deflection yoke tuning was designed and implemented into DY tuning equipment "Vingelis-2".

Author's publications on the subject of dissertation

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3. **Vaitkus V., Gelžinis A., Simutis R.** Decision Support System for Deflection Yoke Tuning. – ISSN 1392-124X. Kaunas: Technologija. 2003. – Nr. 3(28). – P. 21-26.

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7. **Vaitkus V.** Spalvinių kineskopų kreipiamųjų sistemų balansavimo įtakos liktinei spindulių nesuvesčiai tyrimas ir prognozavimas. // Konferencijos *Automatika ir valdymo technologijos – 2002* medžiaga. –ISBN 9955-09-183-5. Kaunas: Technologija. 2002. –P. 65-69.

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9. **Vaitkus V., Gelžinis A., Simutis R.** SPS kreipiamųjų sistemų derinimui kūrimo procedūros ir paieškos metodai. // Konferencijos *Automatika ir valdymo technologijos – 2004* medžiaga. –ISBN 9955-09-644-6. Kaunas: Technologija. 2003. –P. 87-92.

About the author

Vygandas VAITKUS

Born in 1976, Mažeikiai, Lithuania. Received his bachelor diploma from Kaunas University of Technology in 1998 and M.Sc. diploma in 2000. Since 2000 Ph.D. student at the Department of Process Control, Kaunas University of Technology.

Basic research area – mathematical modeling and optimization techniques. Have interest on financial process control.

Reziumė

Nors į rinka aktyviai veržiasi skystųjų kristalų ir plazminiai kineskopai, vakuuminiai televiziniai kineskopai vis dar yra populiariausia vizualinės informacijos atvaizdavimo priemonė pasaulyje. Ekspertai ir stambiausi pasaulio kineskopų gamintojai prognozuoja, kad vakuuminiai kineskopai dar negreit užleis pozicijas rinkoje kitų rūšių atvaizdavimo priemonėms. Nuo gamybos pradžios vakuuminis kineskopas buvo nuolat tobulinamas, atsirado įvairių jo modifikacijų, išgaubto ekrano kineskopus pakeitė visiškai plokšti, gerėjo vaizdo kokybinės charakteristikos. Tai buvo pasiekta daug dėmesio skiriant kineskopo ir jo komponentų gamybos proceso kontrolei.

Viso pasaulio kineskopų gamintojai ypač daug dėmesio ėmė skirti intelektinėms kokybės kontrolės ir valdymo sistemoms. Siekiama pakeisti žmogų tuose gamybos etapuose, kur reikia didžiulių žmogiškųjų resursų. Juk mašinos gali dirbti ištisą parą, be pietų pertraukos, be poilsio dienų ir jų darbo rezultatų neveikia nuovargis.

Televizinių kineskopų pramonėje sparčiai populiarėja vizualinės informacijos nuskaitymu ir apdorojimu pagrįstos kokybės kontrolės ir valdymo sistemos. Kelis kartus padidėjusi kompiuterinės technikos duomenų apdorojimo sparta leido pradėti tokias sistemas taikyti ir vienai didžiausių Lietuvos elektronikos pramonės įmonių – AB „Vilniaus Vingis“ , gaminančiai spalvotųjų kineskopų elektromagnetinio kreipimo sistemas (KS). Kompiuterinės regos sistemos yra kombinuojamos su intelektualiomis sprendimo priėmimo sistemomis (SPS) ir naudojamos KS derinti. Sprendimo priėmimo sistemos nusipelno nemažesnio dėmesio nei kompiuterinės regos sistemos, todėl AB „Vilniaus Vingis“ didelę reikšmę teikia šių sistemų parametrams – greitaveikai ir tikslumui gerinti.

Kuriant ir projektuojant tokias sistemas, susiduriama su problemomis, kurios dažnai būna nepakankamai aprašytos literatūroje arba reikalauja priimti originalius mokslinius techninius sprendimus. Vieno tipo kreipimo sistemai parengta sprendimų priėmimo sistema visiškai netinka kito tipo KS. Parengti SPS paprastai galėdavo tik derintojai-ekspertai, turintys didelę derinimo patirtį. Netgi jiems „išmokti“ derinti kurio nors naujo tipo KS ir surašyti jų derinimo taisykles reikėdavo gana daug laiko (apie vienerius metus). Atsižvelgiant į tai, šiame darbe yra tiriami derinimo šunto poveikio spindulių nesuvesčiai matematiniai modeliai ir greitaeigiai sprendimo paieškos metodai, leidžiantys spręsti įvairaus tipo kreipiamųjų sistemų derinimo užduotis.

Darbo tikslas

Darbo tikslas – sukurti ir pasiūlyti naujus KS derinimo metodus ir algoritmus, skirtus automatizuotam KS derinimui.

Darbo uždaviniai

- Atlikti kreipiamųjų sistemų, jų kokybės parametrų, derinimo būdų ir priemonių analizę.
- Pasiūlyti šunto poveikio spalvų nesuvesčiai matematinio modelio sudarymo priemones ir metodus.
- Pasiūlyti ir ištirti greitaeigiškus ir tikslius sprendimo paieškos metodus.
- Atlikti eksperimentinius tyrimus, įvertinančius pasiūlytos sprendimo paieškos sistemos efektyvumą.
- Pateikti siūlomų metodų praktinio pritaikymo rekomendacijas.

Disertacijos struktūra ir apimtis

Disertaciją sudaro: įvadas, keturi pagrindiniai skyriai, išvados, literatūros sąrašas, autoriaus publikacijų sąrašas ir priedai.

Įvade trumpai aptariama tiriamos problematikos svarba pasaulio ir Lietuvos elektronikos pramonei.

Pirmajame skyriuje analizuojami svarbiausi KS derinimo kokybės parametrai, jų derinimo būdai ir priemonės, pateikta literatūros analizė. Antrajame skyriuje pateikiami autoriaus sukurti derinimo šuntų (feroelastinių ir metalinių) įtakos spindulių nesuvesčiai modeliai. Modeliai sukurti remiantis dirbtiniais neuroniniais tinklais (DNT), neraiškių aibių (NA) logika. Taip pat pateikiamas euristinis „Vilniaus Vingio“ inžinierių pasiūlytas derinimo pagal efektus modelis, DNT modeliu paremtos sprendimo priėmimo sistemos greitaveikai didinti. Trečiajame skyriuje pateikiami autoriaus siūlomi sprendimo paieškos metodai. Pateikiami detalūs paieškos algoritmų aprašymai jų kombinavimo ir realizavimo ypatumai. Ketvirtajame skyriuje pateikti eksperimentiniai sprendimo priėmimo sistemų tyrimai ir jų rezultatai.

Išvadose pateikiamos trumpai suformuluotos tyrimų išvados ir rekomendacijos. Moksliniame darbe taip pat pateikiamas naudotos literatūros sąrašas ir autoriaus publikacijų disertacijos tema sąrašas.

Disertacijos apimtis – 102 puslapiai, kuriuose yra 67 paveikslai, 11 lentelių

Mokslinis darbo naujumas

- Sudaryti ir ištirti elastinio šunto poveikio spindulių nesuvesčiai matematiniai modeliai, leidžiantys įvertinti įvairaus dydžio šunto, klijuojamo visame kampo ir gylio intervale ant vidinės KS dalies, poveikį spindulių nesuvesčiai.
- Sudarytas ir ištirtas KS balansavimo derinimo metu poveikio spindulių nesuvesčiai matematinis modelis.
- Sudaryti ir ištirti kombinuoti skaitiniai sprendimo paieškos metodai.

Darbo rezultatų praktinė reikšmė

Darbe pateikta ir išanalizuota skaitiniais paieškos metodais ir dirbtiniais neuroniniais tinklais paremta KS derinimo sistema, bendradarbiaujant su Lietuvos elektronikos pramonės įmonėmis AB“Vilniaus Vingis“ ir UAB „Elinta“, buvo sėkmingai realizuota KS derinti skirtame įrenginyje „Vingelis-2“. Disertacinio darbo medžiaga publikuota tarptautinio EUREKA projekto EU – 2374 HYBTUNE ataskaitose.

Darbo aprobavimas ir publikacijos

Disertacinio darbo tema buvo skaityti pranešimai šiose konferencijose ir seminaruose:

1. Respublikinėse konferencijose „Automatika ir valdymo technologijos“(Kaunas, 2000-2004 m).
2. Tarptautiniame simpoziume „Intelligent Systems – 2002“ (Bulgarijoje, 2002 m.), kurio straipsniai įtraukti į „ISI proceedings” sąrašą.
3. Tarptautinėse konferencijose „Methods and Models in Automation and Robotics“ (Lenkijoje, 2002 -2003 m.)

Disertacinio darbo medžiaga paskelbta devyniuose moksliniuose straipsniuose, iš kurių du yra išspausdinti Lietuvos leidiniuose, įrašytuose į Mokslo ir studijų departamento patvirtintą sąrašą.

Vienas straipsnis parengtas ir atiduotas į ISI sąrašo žurnalą „Robotics and Automation“.

Disertacinio darbo medžiaga paskelbta tarptautinio EUREKA projekto EU – 2374 HYBTUNE dalies ataskaitose Nr. 1 – 4.

Apie disertacijos autorių

Vygandas VAITKUS gimė 1976 m. Mažeikiuose. 1998 m. Kauno technologijos universitete, Elektrotechnikos ir automatikos fakultete įgijo elektros inžinerijos mokslo bakalauro kvalifikacinį laipsnį. 2000 m. ten pat įgijo procesų valdymo mokslo magistro kvalifikacinį laipsnį. Nuo 2000 m. studijuoja Kauno technologijos universitete informatikos inžinerijos mokslo krypties doktorantūroje. Pagrindinės tyrimų sritys yra matematinis modeliavimas ir optimizavimas. Domisi finansinių procesų valdymu.

Nuo 2000 m. dalyvauja tarptautiniame EUREKA projekte *EU - 2374 Hybtune: Hybrid Intelligent Methods for Modeling and Tuning of CRT Deflection Yoke Systems.*

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