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FEEDBACK: STILL THE SIMPLEST AND BEST SOLUTION

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Abstract: Most engineers are (indirectly) trained to be “feedforward thinkers" and they immediately think of “model inversion" when it comes to doing control. Thus, they prefer to rely on models instead of data, although feedback solutions in most cases are much simpler and more robust.

Keywords: Classical control, stabilizing control, fundamental limitations, self-optimizing control, robustness phase

1 INTRODUCTION

In this paper, we will discuss and compare the following two approaches to control
1. Feedback control (output measurement based)
2. Feedforward control (model-based)

Feedback is a very powerful tool, but, maybe because of its simplicity, it often gets overlooked and forgotten, and it seems that its advantages need to be rediscovered every 20 years or so. Simple feedback loops, often using simple PID (proportional-integral-derivative) control algorithms, became the main tools for control engineers in the 1930's or so. The theory behind this is known as „classical control" and is documented in the works of Bode, Nichols and others from the 1940's. The main lesson of classical feedback control is: „Pair close and crank up the gain". More specifically, by „pair close" it is meant that one should use an input-output pair with a small phase lag (or, equivalently, small „efective time delay"). The efective time delay is the sum of the apparent time delay caused by dead time, inverse responses (unstable RHP zeros) and high-order lags. By „crank up the gain" it is meant that the gain around the feedback loop should be large to get good performance and robustness against uncertainty (changes in the system components). However, the loop gain cannot be too large, otherwise we get instability because of the presence of phase lag (efective time delay). About 20 years later, in the era of „optimal control" in the 1960's, this lesson was forgotten. The slogan of optimal control was that anything could be controlled provided one had a model and the states were observable and controllable. It took another 20 years until we reached the 1980's and negative feedback („crank up the gain") was rediscovered with the introduction of „robust control" by John Doyle and others. Bode's stability criterion was replaced by the „small gain theorem" and powerful new robustness results were derived, including the structured singular value. I was lucky enough to be part of this development during my PhD study days at Caltech from 1983 to 1987 and this led to the publication of the book „Multivariable feedback control" in 1996, Skogestad and Postlethwaite (2005). However, now, about 20 years later, it seems that the feedback lesson is again being forgotten. To some extent, this is caused by the extensive use of model predictive control (MPC), which is an improved version of optimal control from the 1960's. MPC is model based and feedback is only introduced indirectly. However, also MPC indirectly uses feedback as its main mean of dealing with uncertainty, and is subject to the same advantages and limitations as derived in classical and robust control. Feedback is sometimes claimed to be outdated, and the argument is: „Feedback is based on what has happened and therefore comes too late. The future is to put focus on getting models and using model-based control". This statement is right in saying that one could use models to improve robustness and performance of feedback control, but it is wrong in saying that feedback is not part of the future. So it is time to rediscover the power of feedback control, and the objective of this paper is to point out the following three fundamental advantages of feedback control:

1. Simplicity. With feedback one can get tight control with only a very crude model.
2. Robustness. Feedback is required for making a system adapt to new conditions.
3. Stabilization. Feedback is the only way to fundamentally change the dynamics of a system.

We here concentrate on man-made systems, but feed back is even more prevalent in nature. Actually, because of the three fundamental advantages of feedback just mentioned and because control systems in nature have to be simple and robust, we can make this bold statement without knowing anything about the subject. The insight about the fundamental importance of feedback was the basis for the field of cybernetics, Wiener (1948). Today, with the great leaps forward in systems biology one is discovering the details of how nature uses (negative) feedback, but the insight that nature must rely on feedback was clear more than 50 years ago, Wiener (1948). (Nature also uses positive feedback, typically, to generate instability and quick changes, but this paper deals with the virtues of negative feedback).

2 SIMPLICITY AND ROBUSTNESS OF FEEDBACK: THE FEEDBACK AMPLIFIER

One important step in the development of feedback control theory was the introduction of Harold Black's feedback amplifier for telephone communication in 1927, Kline (1993). The engineers at the Bell laboratory in New York were trying to make an accurate amplifier, but were facing problems with the variation and uncertainty of the amplifier. The engineers suggested various „ingenious" feedforward ideas to correct for this. Then came Harold Black and proposed to wrap a simple high gain feedback loop around the amplifier, and suddenly there was no need to build an accurate amplifier. The solution was so simple that people found it difficult to believe. To understand the feedback amplifier consider Figure 1. The objective is to amplify the signal $r(t)$ by a factor a such that $y_{ideal}(t) = ar(t)$. The original feedforward approach was to build a very accurate adjustable amplifier (Figure 1).

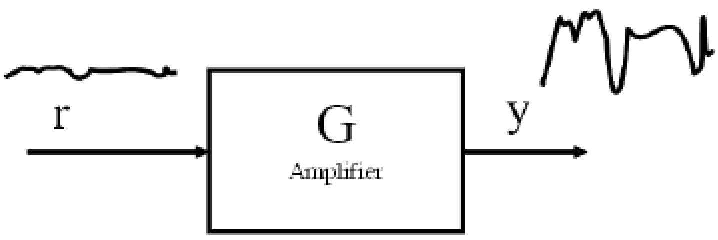

Figure 1: Solution 1 (feedforward): $G = k = a$ (adjustable).

The problem is that this
is very dificult and also that the amplification will vary with the frequency of the signal $r(t)$. The corresponding feedback solution of Black is shown in Figure 2.

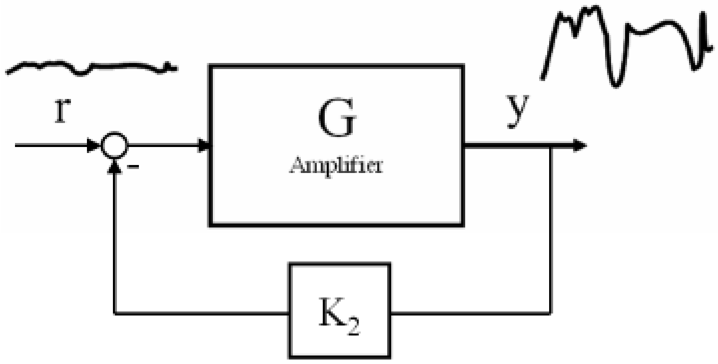

Figure 2: Solution 2 (feedback): $G = k$ (large constant gain $k > a$). $K_2 = 1/a$ (adjustable).

The closed-loop response becomes

$$\frac{y}{r} = \frac{G}{1 + GK_2} \approx \frac{1}{K_2} = a \qquad (1)$$

where the approximation holds provided we have high-gain feedback with $|GK_2| >> 1$. Thus, we have the (seemingly incredible) fact that the overall amplification is independent of the amplifier G. Even a lousy amplifier will work well, provided it has a suficiently high gain and we can measure the result and compare it with the desired signal. Really, the only thing one needs to know is the sign of G. However, except for first- or second-order systems with no effective delay, high-gain feedback has its price, and to avoid instability we know from Bode's stability criterion that the loop gain must be less than 1 at the critical frequency where the phase lag around the loop is -180 degrees (-360 degrees including the negative gain in the feedback loop). Otherwise, signals at this frequency will increase in magnitude for each pass through the loop and we have instability. A comparison of the robustness of feedforward and feedback control is shown in Figures 3 and 4. The plant is $y = Gu + G_d d$ (this is not the amplifier case but the results are similar). The plant is $G = k/(10s+1)$ (s is the Laplace variable) and nominally $k = 10$. The response is shown for a step disturbance d where $G_d = 10/(10s+1)$. Since nominally $G = G_d$, the ideal feedforward control law is $u = -G^{-1}G_d d = -d$ (d is a measured disturbance). In Figure 3 we compare the response with that of a feedback control law $u = -K(s)y$ (y is a measured output) where $K(s)$ is a PI feedback controller with integral time 10 [s] and gain $1/\tau_c = 1$, corresponding to a closed-loop time constant $\tau_c = 1$ [s] (selected according to the IMC tuning rule, Skogestad (2004b)).

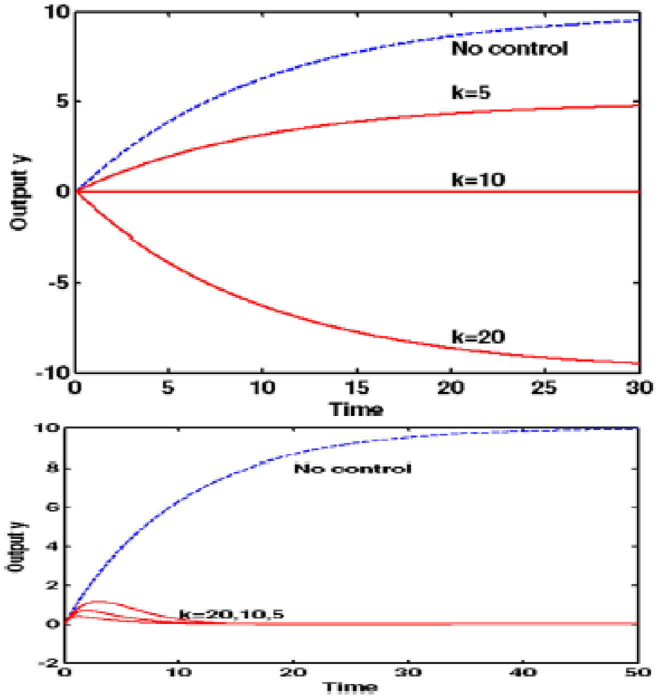

Figure 3: The magic of feedback! ☺ Comparison of feedforward and feedback control with respect to gain error. Nominal gain is $k = 10$. Top: Feedforward control. Bottom: Feedback control.

Nominally, $k = 10$ and the feedforward law gives perfect control. However, if the plant gain is $k = 5$ (which is only half of the disturbance gain) then we get only half of the correction, and if $k = 20$ we overcompensate such that feedforward is as bad as no control, but in the opposite direction. This should be compared with the excellent robustness of feedback control (bottom in Figure 3), which is hardly affected by the variation in the plant gain k.
As mentioned, the main problem with feedback control is its sensitivity to phase lag (effective time delay) in the loop as illustrated in Figure 4.

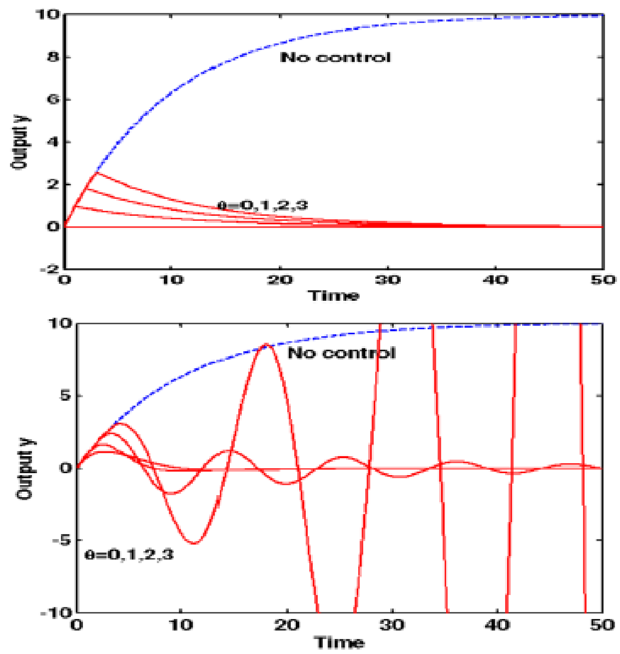

Figure 4: The problem with feedback... ☹ Comparison of feedforward and feedback control with respect to time delay error. Nominal delay $\theta = 0$. Top: Feedforward control. Bottom: Feedback control.

The feedback strategy handles well a time delay increase from $\theta = 0$ to $\theta = 1$ [s]. However, when the time delay increases to $\theta = 2$ [s] (which is twice the closed-loop response time) the system starts oscillating, and for to $\theta = 3$ [s] the system is unstable. On the other hand, feedforward control is only weakly affected by the time delay error. The conclusion is that feedback control is very robust to plant variations as long as the phase lag (effective time delay) is relatively small such that we can use a large feedback gain.

3 SIMPLICITY AND ROBUSTNESS OF FEEDBACK: SELF-OPTIMIZING CONTROL

Let us now look at a quite different issue: How should we link optimal operation and control, or in terms of feedback control: What should we control? The idea of self-optimizing control is to turn open-loop („feedforward") optimization (strategy shown at right in Figure 5) into a setpoint feedback control problem (left strategy in Figure 5) (Morari et al. (1980); Skogestad (2000)). The trick is to find the right „magic" variable c to control. The term „magic" is here used for two reasons. First, finding it may not be easy, and second, if one can find a good variable then a simple feedback scheme may work so well that it almost seems like magic.

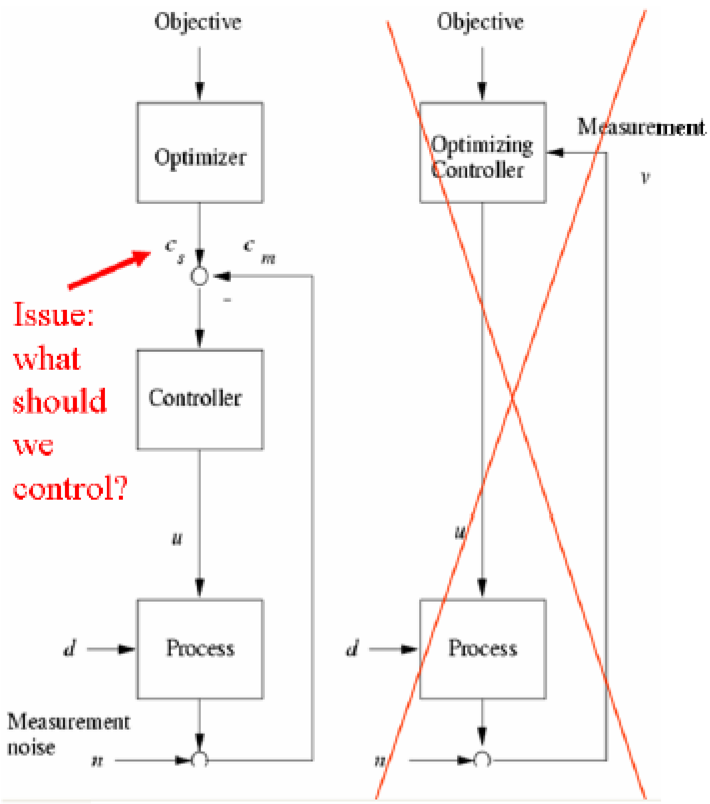

Figure 5: Implementation of optimal operation: We want to replace open-loop „feedforward" optimization (right figure) by a self-optimizing feedback scheme (left figure) with constant setpoint cs (such that the role of the „optimizer" can be minimized).

In terms of selecting controlled variables for feedback control, there are two main cases:
1. Constrained optimization problems. Here the choice is easy: Control the active constraints! (Maarleveld and Rijnsdrop (1970)).

2. Unconstrained optimization problems. Here the choice is not so obvious. If possible, we would like to find some „self-optimizing" variable, which when kept constant indirectly gives optimal operation of the process.

An example of a constrained optimization problem is optimal operation of a 100m runner where the objective function is to minimize time, i.e., the cost is $J = T$. Here, optimal operation is limited by the maximum power (input constraint). Thus, we do not need much thinking to decide on a control policy: Just run as fast as possible (maximum input). Actually, keeping a maximum input does not require any feedback, but it does if there is an active output constraint, for example, if we want to minimize the driving time and are limited by the maximum speed limit. An example of an unconstrained optimization problem is marathon running. Again the objective function is to minimize time, i.e., the cost is $J = T$, but clearly one should not simply just run as fast as possible. Thus, some more thinking is required to find a good control policy. One extreme, which requires a lot of systematic thinking, is to use a „feedforward" strategy where one designs a model-based optimizing controller for the marathon runner. However, this would probably require several PhD theses only to get the model, and it would require a computer and complex control system to implement the on-line optimizing controller.
A feedback solution is far simpler and in practice probably more effective. One candidate „magic" controlled variable (CV) is the speed, $c = v$. Indeed, running at constant speed is probably close to optimal for cases where the track is even and there is little wind.
However, deciding on the appropriate setpoint for the speed may be difficult. An even better „magic" CV is probably the heart rate, $c = hr$. The optimal setpoint of the heart rate is almost constant, independent of the terrain and wind conditions, and one may even use similar optimal heart rates for different persons. Thus, heart rate seems to be a „self-optimizing" variable for marathon running.
Other „applications" of self-optimizing control include process control, biological processes, pizza baking, and running the central bank of a country, Skogestad (2004a).
How does one find self-optimizing variables in a systematic manner? This has been one of my main research interests over the last 10 years, and several methods have been developed. In terms of analysis of a given choice of CVs (c), the crudest and most general approach is the „brute force approach", Skogestad (2000), where one evaluates the cost J when keeping constant CV setpoints for expected disturbances (d) and implementation errors (n). If one is also able to optimize the system and find the optimum J_{opt} then one can evaluate the loss $L = J - J_{opt}$, which gives insight into whether it is worth looking for a better policy. The problems with the „brute force approach" are that it gives no insight into what a good CV might be and that the number of possible CV combinations grows exponentially with the problem size (even worse, if one allows for variable combinations as CVs there are infinitely many possible strategies).
So what is a good self-optimizing variable (c)? To identify good candidates we may use the the following four requirements (Skogestad (2000)):

Requirement 1. Its optimal value is insensitive to disturbances (so that the optimal variation Δc_{opt} is small).

Requirement 2. It is easy to measure and control accurately (so that the implementation error n is small).

Requirement 3. Its value is sensitive to changes in the manipulated variable u; that is, the gain G from u to c is large (so that even a large error in controlled variable c results in only a small error in u). Equivalently, the optimum should be „flat" with respect to the variable c.

Requirement 4. For cases with two or more controlled variables, the selected variables should not be closely correlated.

All four requirements should be satisfied. For example, for the marathon runner, the optimal heart rate is weakly dependent on the disturbances (requirement1) and the heart rate is easy to measure (requirement2). The heart rate is relatively sensitive to changes in power input (requirement 3). Requirement 4 does not apply since this is a problem with only one unconstrained input (the power).
For many problems the cost J depends mainly on the steady-state behavior and the four requirements can be combined into the maximum gain rule. According to Halvorsen et al. (2003), for a given choice of controlled variables (CVs, outputs) c, the worst-case loss for (small) disturbances and implementation errors can be estimated as:

$$L_{wc} = \frac{1}{2}\frac{1}{[\underline{\sigma}(G')]^2} \tag{2}$$

Here $G' = (SGJ'_{uu}{}^{-1/2})$ is the scaled gain matrix, where $G = dc/du$ is the unscaled gain matrix, $S = diag\{1/span(c_i)\}$ is the output scaling, $span(c_i) = \Delta c_{opt,i+n_i}$ is the expected variation in c_i caused by its optimal variation due to disturbances ($\Delta c_{opt,i}$) plus its implementation error (n_i), and finally the input „scaling" Juu is the Hessian matrix (second derivative) for the effect on the cost J of the unconstrained degrees of freedom u. So, we want to select controlled variables c that give the largest value of the minimum singular value $\underline{\sigma}(G')$ of the scaled gain matrix. In the scalar case this is simply the magnitude of the gain matrix, $\underline{\sigma}(G') = |G'|$. Compared to the „brute force method", this method has the advantage of not requiring that one evaluates the cost for each choice of CVs. Instead, one needs to evaluate the gain matrix, G, and the scaling, $span(c)$, which does not depend on the number of candidate CVs.
The use of the maximum gain rule requires a model, and the model may also be obtained experimentally. For example, for the marathon runner one would first need to analyze some optimal runs to find the expected variation $\Delta c_{opt,i}$ in the candidate CVs (speed, heart rate, etc.) with respect to the expect disturbances (wind, inclination). Next, one would need to change the power to find the (unscaled) gain for the same candidate CVs. The scaled gain could be evaluated, and one would prefer a CV with a high scaled gain.
For unconstrained quadratic optimization problems, which provide a local approximation of any real optimization problem, we have developed systematic methods for finding optimal linear measurement combinations. The simplest is the „nullspace method" which gives no loss for the case with no implementation error, provided we have as many measurements y as there are disturbances (d) plus inputs (u). The extension to the case with any number of measurements and to implementation error is given by Alstad et al. (2009).

We are also working on extending the method to nonlinear polynomial systems and to dynamic systems. One approach here is to make use of some property of the solution, such that the gradient with respect to the unconstrained degrees of freedom (u) should be zero at the optimal solution, $J_u = 0$ (e.g., Srinivasan et al. (2003)). Indeed, most of the methods mentioned above can be interpreted as variants of using the measurements for estimating the gradient J_u and then using feedback control to keep J_u close to zero. (However, to include implementation error, which is important for many problems, one may need to go back to the cost J, rather than working with the gradient J_u).

In summary, many real-life optimization problems can be turned into feedback control problems. The key is to find the right „magic" self-optimizing variable to control. The most obvious self-optimizing variable is the gradient J_u, because keeping $c = J_u$ at zero maintains operation optimal, irrespective of disturbances.

4 STABILIZATION USING FEEDBACK: ANTI-SLUG CONTROL OF MULTIPHASE FLOW

Sometimes feedback control can really do magic, meaning that it can do things that could not be done otherwise. In particular, this applies to stabilization, which is only possible with feedback (model-based feedforward inversion will yield an unstable pole-zero cancellation and internal instability which eventually will make the system blow up). One example of stabilization by feedback is for multiphase flow in pipelines with a vertical section (riser). Here, the flow regime can often turn into an undesired sputtering flow regime known as riser-induced slug flow. For example, this happens quite frequently in the production of oil and gas. One can model this system for years and try all kinds of advanced estimation and model-based estimation schemes, and still get only limited improvement. However, as was first shown by Havre et al. (2000) a simple P or PI controller, based on using an exit valve to control the pressure at the bottom of the riser (Figure 6), can „magically" give steady non-slug flow at the same boundary conditions that otherwise gave slug flow (Figure 7).

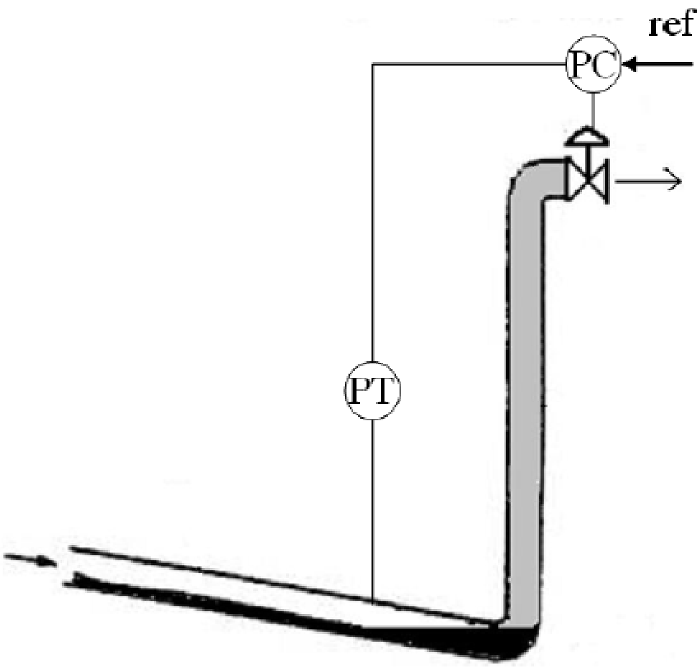

Figure 6: Anti-slug control: Feedback control of pressure at bottom of riser.

What is happening is that by feedback control we are able to stabilize a „naturally" unstable flow regime, that is, we are using feedback to extend the stability boundary of the desired solution. Actually, fluid flow experts find it hard to believe that this is possible. It would be a bit similar to using feedback to extend the stability boundary of laminar flow and thus avoid turbulence (although this is in practice very dificult because of the extremely short time and length scales involved in the switch from laminar to turbulent flow; one the other hand the time and length scales for the transition to slug flow are in the order of minutes and meters, respectively).

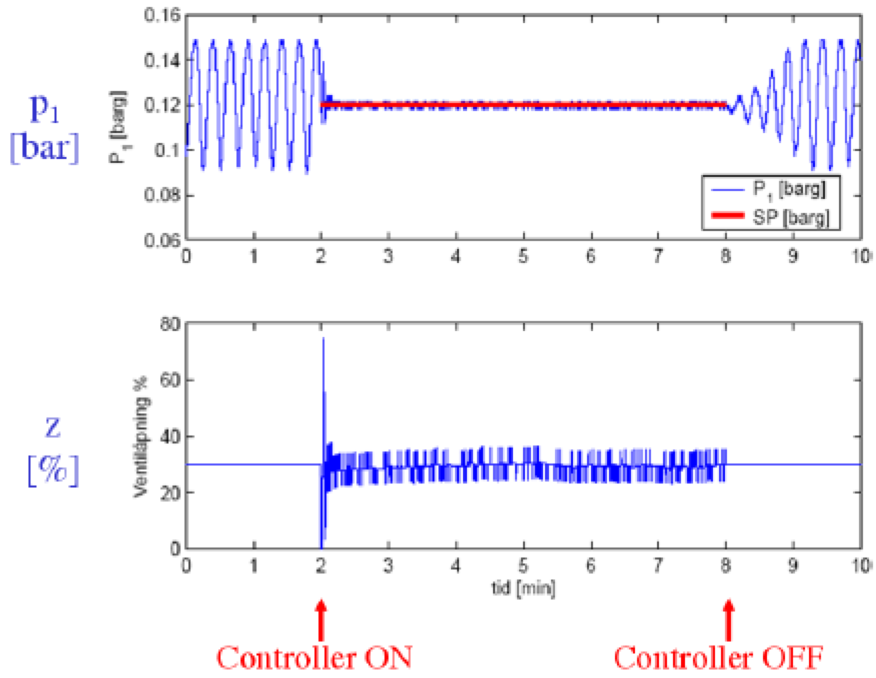

Figure 7: Anti-slug control: Response with feedback strategy in Figure 6.

5 THE ENEMIES OF FEEDBACK: UNSTABLE (RHP) ZEROS AND „EFFECTIVE TIME DELAY"

Let us continue the previous example. Controlling the pressure at the bottom of the riser works great and stabilizes the desired non-slug regime. However, the pressure at the bottom is often not measured, so it is tempting to switch and control the pressure at the top of the riser instead. However, this does not work because of the presence of unstable (RHP) zeros in the response from the valve position (input u) to the top pressure (output y), Storkaas and Skogestad (2007). This is due to the main fundamental limitation of feedback control: High feedback gains cannot be applied in the presence of time delays (Figure 3) and RHP-zeros because it results in closed-loop instability; see also Chapters 5 and 6 in Skogestad and Postlethwaite (2005).

Importantly, these fundamental limitations apply for any controller. Thus, the problem cannot be avoided with sophisticated model-based control. For example, it will not help to use a state estimator to estimate the bottom pressure from a top pressure measurement. When analyzing the estimated bottom pressure it may seem that it works, because the state estimator (Kalman filter) can be tuned to have fast response, but when we couple everything together there will be a hidden RHP pole-zero cancellation between the controller and the plant. The only option is to

„change the system", for example, by introducing additional measurements or additional MVs (inputs).

6 SUMMARY

High-gain feedback control is an extremely powerful tool.

1. For first-or second-order systems the phase lag can never exceed -180 degrees, so we can „crank up the gain" as much as we want. However, more generally the gain must be such that the closed-loop time constant is less than the effective time delay in the system, approximately.

2. Complex systems can be controlled by hierarchies (cascades) of single-input-single-output (SISO) control loops.

3. To achieve optimal operation (economically), it is important to select the right controlled variable (CV). First, any active constraints should be controlled. Second, for remaining unconstrained degrees of freedom one should search for variables that achieve „self-optimizing control".

4. Stabilizing feedback control can make new things possible (for example, anti-slug control).

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DESIGN OF ROBUST GUARANTEED COST CONTROLLER PID FOR NETWORKED CONTROL SYSTEMS (NCSs)

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The paper addresses the problem of output feedback guaranteed cost controller design for NCSs with time-delay and polytopic uncertainties. By constructing a new parameter-dependent Lyapunov functional and applying the free-weighting matrices technique, the parameter-dependent, delay-dependent design method will be obtained to synthesize a PID controllers achieving a guaranteed cost such that the NCSs can be stabilized for all admissible uncertainties and time-delays. Finally, numerical examples are given to illustrate the effectiveness of the proposed method.

Keywords: PID controller, output feedback, Networked Control Systems (NCSs), polytopic system, parameter-dependent quadratic stability, time-delay system.

Feedback control systems wherein the loops are closed through real-time networks are called Networked Control Systems (NCSs). Advantages of using NCSs in the control area include simplicity, cost-effectiveness, ease of system diagnosis and maintenance, increased system agility and testability. However, integration of communication real-time networks into feedback control loops inevitable leads to some problems. As a result, it leads to a network-induced delay in networked control closed-loop system. The existence of such kind of delay in a network-based control loop can induce instability or poor performance of control systems.

In the recent years, the stability analysis and controller synthesis for systems with time-delay are important in theory and practice. In the time domain, there are two approaches for controller design and studying of stability of closed-loop systems: Razumikhin theorem and Lyapunov-Krasovskii functional (LKF) approach. It is well know that the LKF approach can provide less conservative results than Razumikhin theorem and references therein. Existing criteria for asymptotic stability of time-delay systems can be classified into categories: delay-independent criteria and delay-dependent. And it is also know that the delay-dependent criteria make use of information on the length of delays, they are less conservative than the delay-independent ones, even if the time delays are very small. On the other hand, a wide class of uncertainty types studied in the system and control literature fall into the polytopic perturbations. For the time-delay system with polytopic-type uncertainties, the parameter-dependent stability condition is of less conservativeness than quadratic stability condition. Recently, free-weighting matrices method or slack-variable method and cross term bounding method was developed to obtain less conservative condition.

Motivated by the above observation, in this article, the parameter-dependent, delay-dependent design method will be studied to design a robust output feedback PID controller achieving a guaranteed cost such that the NCSs can be stabilized for all admissible polytopic-type uncertainties and time-delays. Sufficient condition for existence of a guaranteed cost output feedback controller is established in term of matrix inequalities.

MULTIVARIATE STATISTICAL METHODS FOR INDUSTRIAL PROCESS PROGNOSTICS

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Abstract: The paper deals with multivariate statistical methods used for failure prognostics in industrial processes. Modern on-line process monitoring system should support classic fault detection, isolation and diagnosis (FDI) sub-systems to avoid process down-time, increase production, optimize parameters of the production line, etc. However faults usually demand immediate intervention by operator, therefore by using reliable prognostic system, risks can be avoided, maintenance intervals can be scheduled, operation and production strategy can be updated, etc. Presented methods are intended for operator's visual detection of process deviation (along with automated FDI systems) while process monitoring, diagnosis and data analysis tasks are running. By understanding nominal process operation, a hardly detectable small faults and drifts can be used to predict failure scenarios in process prognostics.

Keywords: Fault detection and isolation, prognostics, principal component analysis, multivariate statistical analysis.

1 INTRODUCTION

Modern supervisory systems are being developed towards achieving continuous quality production and guarantee system uptime. Since tasks of classic control and process value monitoring are mainly well defined, fault diagnosis and prognostics are expected to become part of the advanced tasks of intelligent supervisory platforms. Fault detection, isolation and diagnosis (FDID) tasks can help reduce process down-time and guide operator to achieve optimal operation of the process. In case of operator's ignorance to alert messages the system is quickly affected by failures and later down-time. Some of these events can be detected and predicted if suitable intelligent methods for process monitoring (prognostics) are considered. Prognostics can be found in many situations e.g. weather, stock market, finance, industry etc. From technical or production point of view a process down-time presents considerable money loss (customer penalty, safety violation, reduced production plan). Additional advantage is in organized maintenance intervals or planned mechanical reconstructions, etc. Prediction approach can be developed using raw measurement data or suitable models of processes, upon which the prognostics is realized. Each of them has their own advantages (transparency, implementation) therefore various methods can be combined. Most of them came from the field of artificial intelligence and soft computing, however in the paper some of the multivariate statistical methods are presented (principal components, nonlinear principal components, etc).

2 MULTIVARIATE STATISTICAL METHOD FOR PROGNOSTICS

Principal component analysis (PCA) is very popular and quite reliable technique for detection of unpredicted process behaviour (FDI) and can be used for prediction task.

Improved nonlinear extension of PCA model is usually made to fit the nonlinear process behaviour. Using on-line data observation in a specific time window data measurements of continuous process can be regarded as batch sequences, where process deviation can be quickly detected. Mainly data driven modelling of the process is presented since this is the basics for later implementation to a real process. Nonlinear characteristics were modelled by nonlinear principal components, realized by auto-associative neural network, extended to recurrent structure to include process dynamics. Algorithms for process prognostics were realized and tested in Matlab/Simulink environment for several case scenarios (real time hydraulic model, offline data measurement analysis for typical industrial process, etc.). Left figure (Fig.1) shows a nominal process model with current batch data comparison; the middle shows added faulty batch where data fall out the requested region (batch unsatisfactory); and the right picture presents nonlinear model trajectory where upon curve deviation any unpredicted behaviour can be used for prognostics. According to the direction (angle) changes also identification and diagnosis of the predicted faults can be achieved.

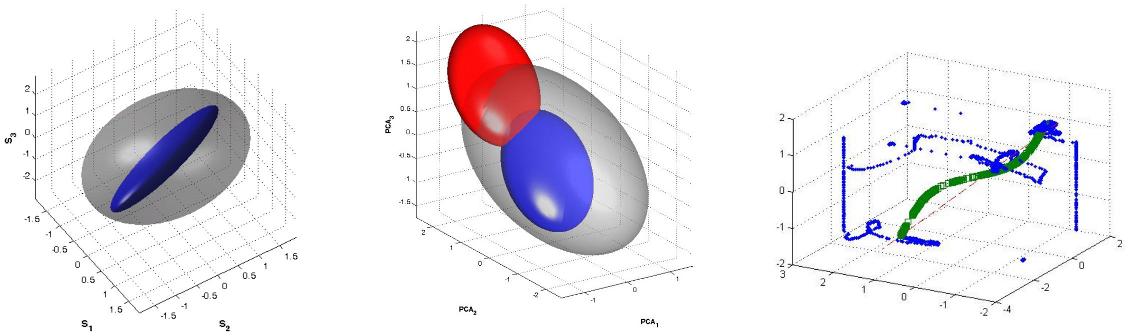

Figure 1: Various (linear, nonlinear, batch, continuous) process prognostics.

3 CONCLUSION

Fault Failure prediction of industrial process contributes to reduced down-time, detection of process deviation, higher productivity, smaller maintenance costs, etc. Beside advanced artificial intelligence and soft computing methods, multivariate statistical methods were tested to obtain results for predicted equipment degradation alert, followed by fault detection and diagnosis. Benefits of multivariate statistics are mainly in easy implementation however the choice of prognostic technique is based on many specific constraints.

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STATE CONTROL OF THE DISCRETE TIME-DELAY SYSTEMS

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The use of Lyapunov method for the stability analysis of time delay system has been ever growing subject of interest starting with the pioneering works of Krasovskii [Krasovskii 1956, 1963]. Usually now for the stability issue of the time delay systems modified Lyapunov-Krasovskii functionals are used [Friedman 2001] to obtain the delay-independent stabilization and results based on this functional are applied to controller synthesis and observer design. This time-delay independent methodology and the bounded inequality techniques are sources of conservatism that can cause higher norm of state feedback gain. Progres review in this research field can be also found in [Zhong 2006], and the references therein. The purpose of this paper is to present an improved version of the time-delay system state feedback control design method. Based on the Lyapunov-Krasovskii functional the delayed-independent stability condition is derived using the linear matrix inequality techniques. The results obtained with a numerical example are presented to compare limitations in the system structure. Since the presented method is based on the convex optimization techniques it is enough efficient.

For a controllable discrete time linear MIMO system model of the form

$$\boldsymbol{q}(i+1) = \boldsymbol{F}\boldsymbol{q}(i) + \boldsymbol{F}_d\boldsymbol{q}(i-h) + \boldsymbol{G}\boldsymbol{u}(i), \qquad \boldsymbol{y}(i) = \boldsymbol{C}\boldsymbol{q}(i)$$

with constant matrices $\boldsymbol{F}$, $\boldsymbol{F_d}$, $\boldsymbol{G}$, $\boldsymbol{C}$ of appropriate dimensions and with the linear state feedback control law $\boldsymbol{u}(i) = -\boldsymbol{K}\boldsymbol{q}(i)$ Lyapunov-Krasovskii inequality, giving sufficient stability condions for the memory-less controller design, is derived as follows:

$$\begin{bmatrix} \boldsymbol{Q}-\boldsymbol{P} & \boldsymbol{0} & (\boldsymbol{F}-\boldsymbol{G}\boldsymbol{K})^T\boldsymbol{P} \\ * & -\boldsymbol{Q} & \boldsymbol{F}_d^T\boldsymbol{P} \\ * & * & -\boldsymbol{P} \end{bmatrix} < 0, \qquad \boldsymbol{P} = \boldsymbol{P}^T > 0, \quad \boldsymbol{Q} = \boldsymbol{Q}^T > 0$$

Design uses the standard LMI numerical optimization procedures to manipulate the system feedback gain matrix as the direct design variable. Finally the design method is illustrated by a nontrivial example.

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PARAMETRIZATION AND CONVEX APPROXIMATION APPROACH TO STABILIZATION VIA OUTPUT FEEDBACK

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Abstract: A parametric description of all static output feedback stabililizing controllers for switching diffusion systems is presented. This description is expressed in terms of coupled linear matrix equations and non-convex quadratic matrix inequalities which depend on parameter matrices similar to weight matrices in LQR theory. A convexifying approximation technique is proposed to obtain the LMI-based.algorithms for computing of the gain matrix. These are non-iterative and used computationally efficient SDP solvers.The results are then applied to simultaneous stabilization of a set of diffusion systems, robust stabilization and stochastic passification problems.

Keywords: Swithching diffusion, parametrization, output feedback, simultaneous stabilization, robust stabilization, passification, linear quadratic regulator, linear matrix inequalities, convex approximation

1 DESCRIPTION OF THE PROBLEM

Consider switching diffusion system described by the following equations

$$dx(t) = [A(r(t))x(t) + B(r(t))u(t)] + \sum_{l=1}^{m} \gamma_l(r(t))[A_l(r(t))x(t) + B_l(r(t))u(t)]dw_l(t), \qquad (1)$$
$$y(t) = C(r(t))x(t), t \ge 0,$$

where $x(t) \in \mathbf{R}^{n_x}$ is the continuous component of the state, $u(t) \in \mathbf{R}^{n_u}$ is the control input vector; $y(t) \in \mathbf{R}^{n_y}$ is the output vector; $r(t)\,(t \ge 0)$ is the discrete component of the state, taking values in a finite set $\mathbf{N} = \{1,\ldots,N\}$; this component is modeled by homogeneous Markov chain; $\gamma_l(\cdot)\,(l = 1,\ldots,m)$ are positive scalars; $w(t) = [w_1(t)\ldots w_m(t)]^{\mathrm{T}}$ is the $\mathbf{R}^m$-valued standard Wiener process defined on the probability space $(\Omega, \mathrm{F}, \mathbf{P})$ with natural filtration $\{\mathrm{F}_t\}$; for $r(t) \in \mathbf{N}$ the system matrices and scalar parameters of the i-th mode are denoted by $A_i, B_i, A_{li}, B_{li}, C_i$ and γ_{li} which are real known with appropriate dimensions; the initial conditions $x(0) = x_0, r(0) = r_0$ are deterministic.

Assume that the switching static output feedback control has the form

$$u(t) = -F_i y(t), \text{ if } r(t) = i, i \in \mathbf{N}. \qquad (2)$$

The purpose of the paper is to describe in terms of the LQR-type parameters all the gain matrices in (2), such that the system (1), is exponentially stable in the mean square and to derive LMI based algorithms for computing these gain matrices. The results are then applied to simultaneous stabilization of a set of diffusion systems, robust stabilization and stochastic passification problems.

METODA NÁSOBNÉHO DOMINANTNÍHO PÓLU PRO REGULÁTORY SE DVĚMA STUPNI VOLNOSTI A PROPORCIONÁLNÍ SOUSTAVY S DOPRAVNÍM ZPOŽDĚNÍM

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Metoda násobného dominantního pólu (MNDP) je jednoduchá analytická metoda, která umožňuje určit hodnoty stavitelných parametrů standardních regulátorů i regulátorů se dvěma stupni volnosti (two degree of freedom - 2DOF) za předpokladu, že regulační pochod má být aperiodický bez překmitu. Je uvažována proporcionální soustava s dopravním zpožděním

$$G_P(s) = \frac{k_1}{T_1 s + 1} e^{-T_d s}$$

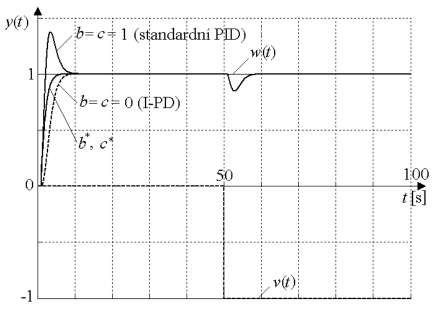
a 2DOF PID regulátor, který může být popsán vztahem

$$U(s) = K_P \left\{ bW(s) - Y(s) + \frac{1}{T_I s}[W(s) - Y(s)] + T_D s[cW(s) - Y(s)] \right\}$$

Vhodnou volbou vah žádané veličiny b a c lze odstranit překmity způsobené skokovou změnou polohy žádané veličiny. Např. pro proporcionální soustavu s přenosem

$$G_P(s) = \frac{1}{8s + 1} e^{-s}$$

jsou na obr. 1 ukázány odezvy regulačního obvodu s 2DOF PID regulátorem seřízeným MNDP. Z průběhů je zřejmé, že pro váhy b^* a c^* určené na základě MNDP se získají rychlejší odezvy než pro běžně používané hodnoty $b = c = 0$.



Obr. 1. Odezvy regulačního obvodu s regulátorem 2DOF PID a proporcionální regulovanou soustavou

Příspěvek vznikl v rámci řešení grantového projektu GAČR č. 102/09/0894

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CONTROL OF DELAY SYSTEMS – A MEROMORPHIC FUNCTION APPROACH

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Abstract: So called hereditary or anisochronic systems with delay terms at the left (and/or the right) side of differential equations are addressed. Analysis and synthesis of such systems can be conveniently studied through a special ring of stable and proper retarded quasipolynomial meromorphic functions (R_{MS}). Stable and unstable first order plants and a stable second order plant are studied. The control methodology is based on the solution of Diophantine equations in this ring. Final controllers result in the Smith predictor like structure and they own a scalar parameter (or parameters) which can be considered as a „tuning knob“ and it allows a controller to be appropriately tuned. Among many possible methods, very simple and intuitive pole-assignment-like tuning idea is utilized. Simulation examples verify and demonstrate the usability of the method presented in this paper.

Keywords: Rings, algebraic tools, Diophantine equation, parameterization, Smith predictor.

$$G(s)=\frac{0.3\exp(-4s)}{(s+0.2\exp(-0.8s))(s+0.5)}=\frac{\dfrac{0.6\exp(-4s)}{(s+m_0)^2}}{\dfrac{(s+0.2\exp(-0.8s))(s+0.5)}{(s+m_0)^2}}$$

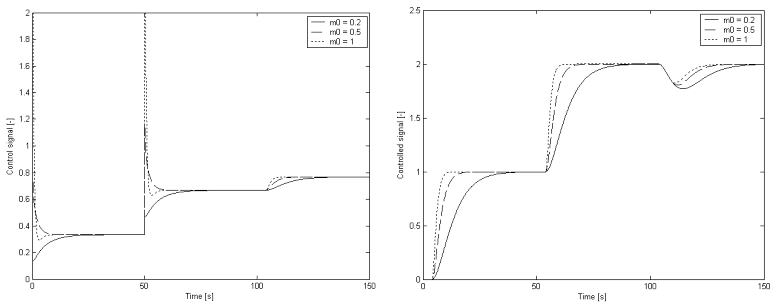

Figure 1: Closed-loop step responses

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COMPARISON OF DIFFERENT METHODS FOR ROBUST CONTROLLER DESIGN

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Abstract: The presented paper deals with simple and practical methods of discrete controller design using conventional approach based on robust stability analysis in frequency domain, and the new approach using the reflection vectors techniques. The control structure consists of feed-forward and feedback part. Proposed algorithms were tested in illustrated examples for stable, unstable and oscillating systems. Simulations were realized in MATLAB-Simulink, Version 7.0. Obtained results show applicability of the theoretical principles for control of processes subject to parametrical model uncertainty.

Keywords: robust control, robust stability, parametrical uncertainty, diofantine equation, pole-placement, time-optimal controller, PID controller, quadratic programming, reflection vectors

CONCLUSION

The paper deals with the development of robust methods based on reflection vectors methodology for computation of control law coefficients guaranteeing stability, robustness and high performance with respect to parameter uncertainties. Theoretical results were verified on the examples for feedback and feedforward control structures. Proposed methods were tested for both stable and unstable processes.

The paper proposes theoretical principles and design methodology of robust discrete-time controllers for systems with parametric uncertainties.

The illustrative example was solved using quadratic programming for suitably defined cost function. Simulation results prove applicability of the proposed robust controller design theory for systems with parametric uncertainty.

ACKNOWLEDGEMENT

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ROBUST PI CONTROLLERS FOR SYSTEMS WITH TRANSPORT DELAY

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Presence of transport delays in the input-output relations is a common property of many technological processes. Plants with transport delays can often not be controlled using usual controllers designed without a consideration of a transport delay. Such controllers tend to destabilize the closed-loop system.

The paper presents robust controller design for systems with uncertain transport delays. Robust PI controllers are designed using approach, which combines the method based on plotting the stability boundary locus in the (k_p, k_i)-plane with the pole-placement method. The pole-placement method was used for the choice of the PI controller from the stability region in such manner that the quality of control was achieved. The approach enables to assure robust stability of the closed loop as well as the quality of the control response prescribed by the choice of the closed loop poles or the relative damping or the natural undamped frequency of the control response.

Designed controllers were tested by simulation experiments. Obtained results confirm that the proposed approach leads to the design of robust controllers that are suitable for control of real processes with transport delay and with uncertainty.

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MODIFICATION OF NEIMARK D-DECOMPOSITION METHOD FOR DESIRED PHASE MARGIN

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Frequency domain techniques for analysis and controller design dominate SISO control system theory. Bode, Nyquist, Nichols, and root locus are the usual tools for SISO system analysis. Frequency methods are often used for controller design because it is easy to ensure performance of closed loop system through phase margin in open loop. To achieve the desired phase margin, controllers are usually designed using Bode characteristics.
In this paper Neimarks method of D-decomposition is used (Neimark, 1992). This method is usually used for controller design which ensures closed loop stability with desired stability degree. In this paper is presented modification of this method aimed on phase margin instead of stability degree.
Proposed controller design approach ensures stability and performance in term of phase margin. If the aim is to design PID controller it is necessary to design the controller in two steps. In first step PD controller can be designed and in second step, PI controller design can by applied on plant with PD controller. Final PID controller is than calculated as

$$PID = (k_1 + k_d s)(k_2 + \frac{k_i}{s}) = k_1 k_2 + k_d k_i + \frac{k_i k_1}{s} + k_d k_2 s \quad (1)$$

In this way controller for unstable plant can be designed, if this plant is possible to stabilize with PD controller.
Theoretical results have been verified on case studies.

ACKNOWLEDGMENTS

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Trakčný pohon s PMSM – návrh riadiacej štruktúry

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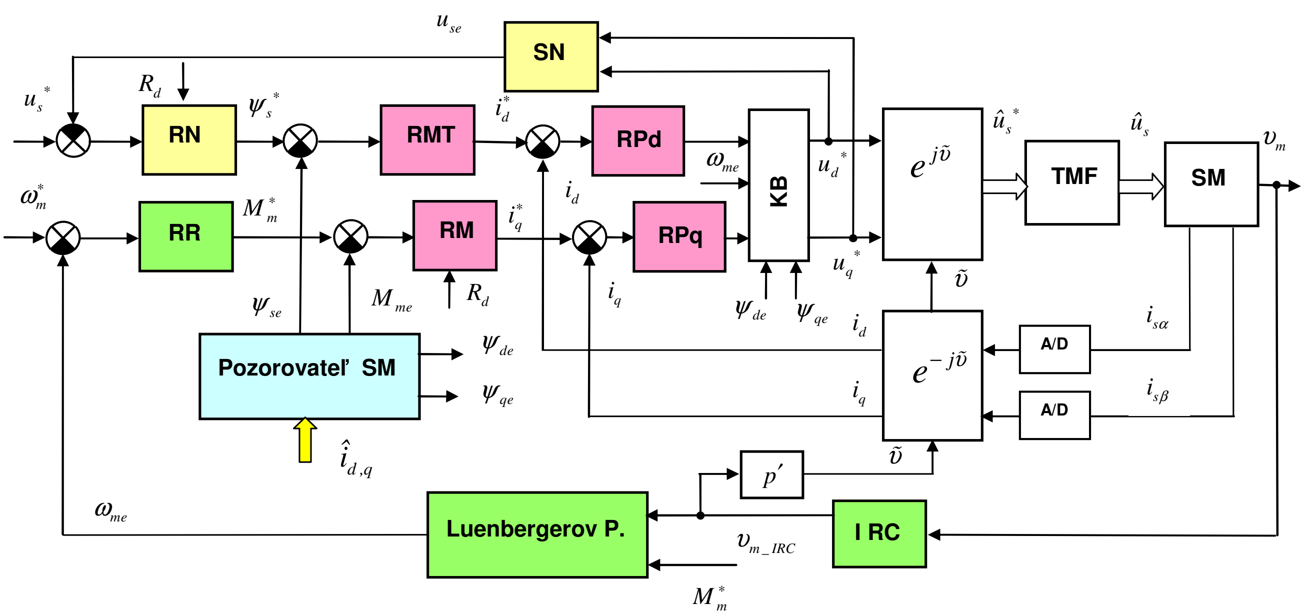
Abstrakt : Príspevok sa zaoberá návrhom riadiacej štruktúry trakčného pohonu so synchrónnym motorom s permanentnými magnetmi (PMSM). Podrobne je opísaný návrh a realizácia rýchlostného servosystému s odbudzvaním. Výsledky návrhu sú overené na hyridnom simulačnom modeli v prostredi Matlab Simulink.

1 ÚVOD

Synchrónny motor s permanentnými magnetmi- PMSM (Permanent Magnet Synchronous Motor) je v oblasti trakčných pohonov relatívne novou jednotkou. Aplikácie PMSM sa začali v trakcii objavovať vo väčšej miere posledných desiatich rokov, najprv prevažne v elektrických a hybridných pohonoch cestných vozidiel. V súčasnosti sa aplikácie PMSM rozširujú aj v oblasti koľajových vozidiel mestskej dopravy, ako aj vozidiel železničnej dopravy s výkonmi do 300 kW 1,3].

2 RÝCHLOSTNÝ TRAKČNÝ SERVOSYSTÉM SO SM PM S ODBUDZOVANÍM

Na *Obr.1* je zobrazená bloková schéma rýchlostného servosystému s PMSM s odbudzovaním magnetického toku.



Obr. 1 ROR SMPM s odbudzovaním magnetického toku

THE ROLE OF INTERDISCIPLINARY SEMINARS IN THE DEVELOPMENT OF CYBERNETICS

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Abstract: Interdisciplinary seminars have promoted the development of cybernetics. The most important of them were held in the USA, the UK and the Soviet Union. In this work we have collected and systematized information about the development of cybernetics.

Keywords: cybernetics, interdisciplinary seminars

Discoveries are known to be made by cross-disciplinary researches. One of perspective forms of research is interdisciplinary approaches. Now a symbol of these interdisciplinary approaches is synergetics. But in the middle of the 20th century it was cybernetics. Cybernetics was defined by Norbert Wiener the father of cybernetic, in his book of that title in 1948. What promotes appearance this science? First of all, these are interdisciplinary seminars. The most important of them were held in the USA, the UK and the Soviet Union.

In initial period of the development of cybernetics many seminars which have played an important role in the development of cybernetics were held in different counties of the world. The purpose of the work is to collect and systematize information about the most important of them. It is acute because information is disconnected.

The first seminar in the USA emerged in Princeton in the early 1940s. The seminar was founded by Arturo Rosenbluth and Norbert Wiener. The meetings were held monthly for 2 years. The early meetings of the second seminar in the USA were held in New York in 1944-1950. This seminar had financial support. The most important and longest seminar in the USA is the seminar financed by Josiah Macy Foundation. Warren McCulloch headed the seminar.

The British seminar Ratio Club was held from 1949 to 1958 mainly in London and is called “a cybernetic dining club”. Information about the Ratio Club is little-known.

Struggle for cybernetics in the Soviet Union was very fierce. Alexey Andreevich Lyapunov led the struggle. The meetings was held from 1954 from 1973. For 19 years there were 141 meetings.

In the process of work we drew following conclusions:
- only a big team of scientists is able to solve serious scientific problems,
- interdisciplinary seminars are one of perspective forms of collective work,
- informal and international communication showed itself to good advantage.

So,

- we have collected and systematized information about the development of cybernetics,
- we used rare information about a 'cybernetic dining club' (the English interdisciplinary seminar) the Ratio Club,
- we have represented studied information in the form of a presentation and an electronic learning book. It can be recommended for use by students and masters in «The History of Cybernetics» and in «Computer Science» courses.

NÁVRHOVO ORIENTOVANÁ IDENTIFIKÁCIA SÍNUSOVÝM EXCITAČNÝM SIGNÁLOM A JEJ VÝHODY PRI SYNTÉZE ROBUSTNÝCH PID REGULÁTOROV

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Abstrakt

Moderné algoritmy inžinierskych metód syntézy PID regulátorov využívajú návrhovo orientovanú identifikáciu riadeného systému. Základná myšlienka návrhovej orientácie spočíva v účelovom zostavení koncepcie identifikácie podporujúcej dosiahnutie stanoveného cieľa regulácie. Správna symbióza voľby metódy identifikácie a následného výberu metódy syntézy PID regulátora môže poskytnúť mnoho výhod projektantovi regulačného obvodu [1]. Cieľom tohto príspevku je poukázať na tieto benefity pri používaní excitácie riadeného systému sínusovým budiacim signálom. Príspevok pojednáva o zostavení a aplikácii navrhnutej inžinierskej metódy syntézy robustného PID regulátora založenej na identifikácii sínusovým excitačným signálom využívanej na riadenie laboratórneho modelu motora s neurčitosťami.

Kľúčové slová: Návrhovo orientovaná identifikácia, sínusový excitačný signál

1 SÍNUSOVÝ SIGNÁL PRI IDENTIFIKÁCII A NÁVRHU PID REGULÁTORA

Ak syntézou PID regulátora je potrebné dosiahnuť *predpísanú dobu regulácie* t_{reg} a/alebo *neprekročenie maximálneho preregulovania* η_{max} prechodovej charakteristiky regulovanej veličiny, potom je výhodné používať predkladanú inžiniersku metódu založenú na *identifikácii riadeného systému sínusovým excitačným signálom. Návrhovo orientovaná identifikácia* využívaná v tejto metóde umožňuje určiť *frekvenciu sínusového budiaceho signálu* ω_n regulovaného systému *zo zadanej doby regulácie* t_{reg} vzťahom

$$\omega_n \doteq \frac{\gamma\pi}{t_{reg}}, \text{ pri obmedzení } \omega_n \in \langle 0.2\omega_c, 0.95\omega_c \rangle, \qquad (1)$$

kde ω_c je kritická frekvencia riadeného systému a $\gamma(\phi_M,\omega_n)$ je dynamický koeficient. Cieľ riadenia je najskôr určiť až potom zabezpečiť takú fázovú bezpečnosť ϕ_M otvoreného regulačného obvodu práve pri excitačnej frekvencii ω_n, aby sa dosiahla predpísaná doba regulácie t_{reg} a/alebo neprekročenie maximálneho preregulovanie η_{max}. Projektantovi regulačného obvodu sú nápomocné vytvorené závislosti $\eta_{max}=f(\phi_M,\omega_n)$ a $t_{reg}=(\phi_M,\omega_n)$, ktoré ponúkajú návrhovo orientovaný výber hodnôt veličín ω_n a ϕ_M k identifikácii a regulácii riadeného systému s neznámym matematickým modelom. Okrem jednoduchosti ďalšou výhodou novej metódy je možnosť jej jednoduchej robustifikácie. *Táto práca je podporovaná Agentúrou pre vedu a výkum Ministerstva školstva Slovenskej republiky, číslo grantu: 1/0544/09.*

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ADAPTIVE CONTROL OF CHEMICAL REACTOR

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This paper deals with the adaptive control of the nonlinear process represented by the continuous stirred tank reactor (CSTR). This chemical equipment is widely used in the chemical industry for production of various chemicals and drugs. Computer simulation which is used in this work has several advantages over the experint on the real model – it saves costs, reduces dangerousity and speed up experiments. The paper presents one approach to the control of the chemical reactor based on the choice of the external linear model (ELM) of the originally nonlinear process parameters of which are identified recursively and parameters of the controller are then adopt to these estimated ones. The polynomial approach together linear quadratic (LQ) approach used for the controller synthesis show good control results although the system has negative control properties.

The chemical reactor under the consideration is Continuous Stirred Tank Reactor (CSTR) – see Figure 1. The reaction inside the reactor is called *van der Vusse* reaction can be described by the following reaction scheme (Chen, *et al*., 1995):

$$\begin{aligned} &A \xrightarrow{k_1} B \xrightarrow{k_2} C \\ &2A \xrightarrow{k_3} D \end{aligned} \qquad (1)$$

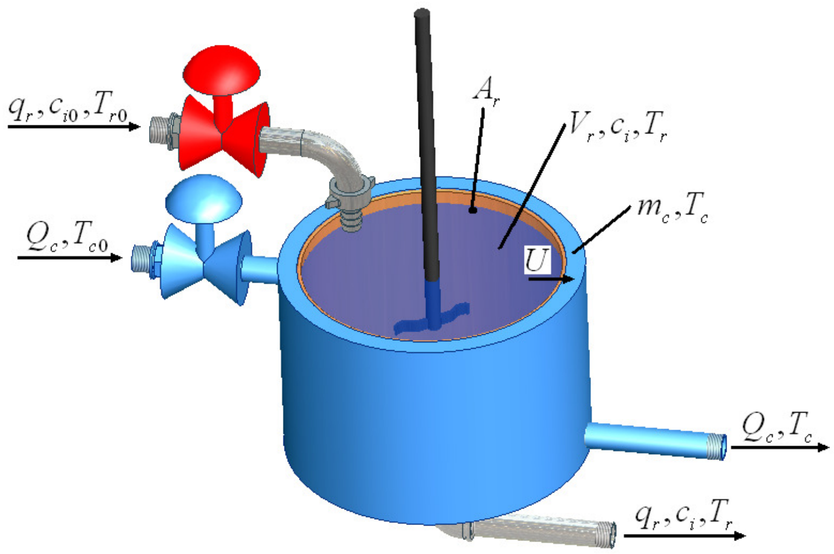

Figure 1: Continuous Stirred Tank Reactor (CSTR)

The adaptive approach used in our case is based on choosing of the External Linear Model (ELM) of the nonlinear process, parameters of which are estimated recursively and the parameters of the controller are then recomputed in every step according to estimated parameters of the ELM. The resulted controller works in continuous-time and in our case its structure corresponds to the structure of the real PID controller.

SYNTÉZA REGULÁTORA POLOHY POMOCOU ZOVŠEOBECNEJ METÓDY ŽELANEJ DYNAMIKY

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Abstrakt: V článku je prezentovaná jednoduchá metóda syntézy regulátora s dvoma stupňami voľnosti (2DOF) pomocou zovšeobecnenej metodiky želaného prenosu. Metóda navrhuje len jeden regulátor.

Kľúčové slová: PID regulátor, 2DOF, IMC štruktúry, robustnosť, stabilné a nestabilné systémy

1 ÚVOD

Staršie metódy syntézy PID regulátora SISO obvodu (STREJC) predpokladali navrhnúť regulátor buď pre riadenie alebo pre poruchu. Moderné metódy riadenia SISO obvodov predpokladajú súčasne dobrý regulátor pre riadenie aj pre poruchu. Dnes sa vyprofilovalo niekoľko metód (VRANČIĆ), ktoré dokážu navrhnúť regulátor s vyhovujúcimi vlastnosťami aj pre riadenie aj pre poruchu. Podstatou týchto metód je: Navrhne sa nezávisle dobrý regulátor pre riadenie a pre poruchu. Dobrý regulátor poruchy má dosť veľké preregulovanie pri skoku riadenia. Preregulovanie sa potlačí tak, že sa do riadenia zapojí filter s takými vlastnosťami, aby sa regulačný obvod správal rovnako - podobne, ako regulačný obvod s regulátorom riadenia. Prax uprednostňuje tie metódy, ktoré využívajú štruktúru regulátora PID daného ISA normou.

$$G_c(s): \quad U(s)=K_R\left(\left(bW(s)-Y(s)\right)+\frac{1}{T_I s}E(s)+\left(cW(s)-Y(s)\right)\frac{sT_D}{1+sT_f}\right) \tag{1}$$

Cieľom príspevku je popísanie fungovania systémov s dvoma stupňami voľnosti, a zapísanie vzorca, ktorý uľahčí syntézu regulátora. Výsledkom analýzy náhodne vybraných článkov venovaných syntéze regulátora vhodného aj pre riadenie aj pre poruchu je: Ak má regulátor súčasne dobré vlastnosti pre poruchu aj pre riadenie, potom sa dá podstata konkrétnej metódy zredukovať na návrh metódou inverznej dynamiky („Vykráť všetko čo sa dá“). Rozdiel je len v tom, že klasická metóda inverznej dynamiky „kráti“ prenos pôvodného regulovaného systému. Ak sa niečo nedá vykrátiť – niečo je nestabilné, tak to stabilizuj, a potom vykráť. Toto je podstata napr. dobre navrhnutých IMC štruktúr.

Tu prezentovaná metóda predpokladá „krátenie“ modifikovaného prenosu regulovaného systému (nemeníme štruktúru a parametre regulovaného systému, ale len jeho správanie sa). Výsledkom analýzy je pochopenie akým spôsobom treba priradiť k (1) regulátor poruchy (2) vypočítaný podľa metodiky zovšeobecnenej želanej dynamiky tak, aby sa súčasne splnili aj požiadavky na riadenie aj na poruchu. $M(s)$ a λ vyjadrujú želanú dynamiku riadenia a poruchy regulovanej sústavy $G_P(s)$. Koeficient β zabezpečuje stabilitu regulátora

$$G_c(s)=\frac{\beta}{\lambda s M(s)}+\frac{\beta}{M(s)}-\frac{1}{G_P(s)} \tag{2}$$

. Vzorec (2) možno priamo použiť pre syntézu regulátora nestabilných sústav.

PRACTICAL STRATEGIES OF CREATING OF E-LEARNING TOOLS

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Abstract: The paper considers application of some basic principles in creating computer tutorials with the example of authoring of e-learning tools package to illustrate informatics studies. The package includes presentations, electronic laboratory operations manual, and also computer tests.

Keywords: E-learning tools, didactic principles and recommendations, informatics, computer science.

1 INTRODUCTION AND PRELIMINARIES

If we mechanically renew traditional paper textbooks with the use of new technologies we will not considerably improve quality of training. It makes sense to analyze classical didactic principles and if possible to apply some of them in the new field of creating e-learning tools.

2 BASIC PRINCIPLES AND RECOMMENDATIONS

E-learning tools should be created, using the following basic principles and recommendations: visualisation, structural precision, edge, historicism, giving the user option of training speed, adapted interface. The first and the most important is principle of visualization. This principle was the basic in the textbook of outstanding teacher J.A. Komensky «The World of Sensual Things in Pictures» written as early as 1650-1654! The principle of structural precision is very important to form information block. The main thing is that all materials presented in the textbook or presentation should be interconnected. "Father of Russian physiology" I.M. Setchenov, speaking about mnemonics, confirmed that it was important «to stick together previous things with subsequent ones». Edge principle assumes that information beginning or information end is better remembered. The authors also took into consideration edge principle while making questions bank. There was a problem to focus attention to the material located in the middle of information block. Including historical references is not an end in itself. They are to intensify interest and motivation to study the subject. Except these principles, we will examine some recommendations, following which it is possible to make tutorials more effective.

3 THE RESULTS OF WORK

The executed work has allowed to reveal factors of intensification and optimization cognitive activity of students. The e-learning tools package on "Microsoft Office Excel 2003" has been created.

4 CONCLUSION

Observation of all requirements and recommendations undoubtedly promotes learning efficiency and information perception processes.

DIAGNOSTICS OF THE PROFIBUS INDUSTRIAL BUS

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Modern control of factory and process automation is jointed with industrial communication. PROFIBUS is worldwide fieldbus with dominant impact in Europe. All bus components succumb of ambient impact like vibration, accidental deformation or particular damage, temperature cycles, ageing, EMI, etc. There are sources of failures in hardware, including conections.

The detectable common problems on Profibus cable: signal line is broken, terminator power is insufficient, a termination is missing at the end station, an extra terminator at a station, high line resistance between two stations, high capacity between bus lines, PROFIBUS drivers output low voltage, baudrate too high for installed cable length, too much stations.

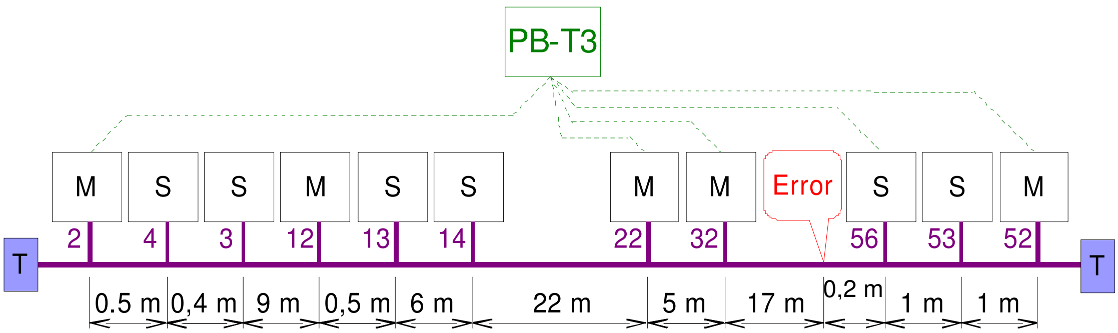

Figure 1: The testing PROFIBUS DP network

A testing communication network is shown in Fig.1. The network consists of five PROFIBUS DP Masters Class I (the „M“ stations – five programmable logic controllers), five PROFIBUS DP Slaves (the „S“ stations – one DP/PA link, two remote I/O systems ET 200M, two electrical drives) and hardware error generator (Error).

Detection type of the fault and localisation of an error is task for diagnostic expert and good diagnostic methods and tools. The paper deals with elimination of transmission problems using a fieldbus tester for physical layer of PROFIBUS DP. For experiments was used Softing's diagnostic tool PB-T3 and Profibus network with 11 stations in one segment. The special device, conection and method were prepared for simulation of transmission troubles. Results and experiences of this diagnostic method can be used for training of diagnostic experts.

TRAFFIC FLOW VIDEODETECTION

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Keywords: Traffic monitoring, image processing, segmentation, differential images

ABSTRACT

This paper deals with a traffic flow video detector. Main idea to create this type of detector is that is no need to mount aditiitional hardware components like induction loops. The traffic control center can be equipped with this type of detection software and can affect length of green phases and cycles in crossings. Another field of application is in road tunnels where can be counted the number of cars in tube and affect the ventilation controllers. Data set presented in this paper has been recorded on the bridge in Bernolákova ulica in Žilina.

The analysis is based on fact that moving objects are causing differential image in image matrix subtraction. Formula for this operation is:

$$D_{(t)} = \left| I_{(t-1)} - I_{(t)} \right| \tag{1}$$

where:

- I(t) is image matrix
- D(t) is differential matrix

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SECURITY AND SAFETY FEATURES OF INDUSTRIAL COMMUNICATIONS SYSTEM

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Modern industrial communications networks are increasingly based on the open protocols and platforms that are also used in IT (*Information and Telecommunications*) technologies. Industrial automation systems are used in wide variety of application, e. g. process manufacturing, electric power generation and distribution, gas and water supply, transportation and others. Communication networks and facilities are an important element within distributed control systems. In many cases communication systems is component part of the system which partook in control of SRCP (*Safety-Related Critical Processes*). Undetected corruption of data transmission (e.g. control commands) can cause considerable substantially damages within equipment, environments or demands on human health and this is reason why system have to be designed so that guarantee required SIL (*Safety Integrity Level*). Safety-related industrial communication systems must be resistant against hazardous faults and this is way we must elliminate all attacks which can occur in HW, SW and communication part of global industrial automation system (see Figure 1).

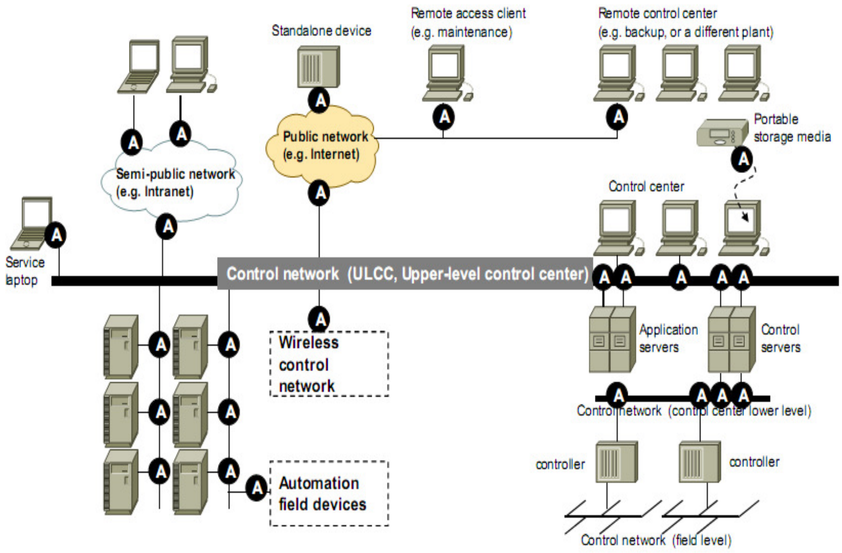

Figure 1: Attacks to industrial automation systems

The paper deals with the problems of safety and security communication systems witch are used in the safety critical applications. The summarisation of attacks to industrial automation systems and security issues and recommendations applicable to the industrial networks based on cryptographic techniques is mentioned. The mainly part is oriented to identification of risks and summarisation of the defensive methods of wireless communication. Practical part the cryptoanalytic's attacks to standard wireless communications basen on IEEE 802.11 communication protocols are mentioned.

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FAULT-TOLERANT EMBEDDED SYSTEMS WITH MULTIPLE FPGA IMPLEMENTED WATCHDOGS

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Abstract: The paper deals with the problem of fault-tolerant embedded systems. Embedded computer systems are defined as systems that are an inseparable part of the devices, which they control. Generally, they work in real time and they use special input/output devices for an external communication. To ensure the tolerance of the faults in the program flow of a concurrent process, we often use a watchdog timer. When starting new process, the watchdog timer that has been assigned to the process is initialized. The initialization value is, with a small reserve, equal to the maximum execution time of the process. If a fault occurs in the process and changes the program flow in such way that it lets the watchdog timer overflow, it automatically signalizes that an error occurred in the program flow or that the program didn't meet the response time deadline. Principal disadvantage of this approach is that the system is by standard equipped only with one or several few hardware timers. Each hardware timer is then used for the implementation of orders of tens to hundreds of software watchdog timers for the concurrent processes. An individual fault in a process can possibly manipulate the hardware timer in such way that it is no longer usable and thus blocks the control for all the processes assigned to this hardware timer. Nowadays, the programmable hardware devices give to embedded designers much more flexibility and customizability of their products. The programmable hardware provides us with the possibility of implementing a hardware watchdog timer for each of the concurrent processes in the system. In our proposed solution, we use the multiple watchdogs system that assigns a dedicated hardware watchdog timer to each of the concurrent processes. The creation and assignment of the own hardware watchdog timer for each of the system's processes eliminates the possibility of disabling the watchdog timer for another process. In the paper, the advantages of such implementations are summarized and various implementation architectures are presented. One of the presented implementation architectures – the multiple watchdog timer circuit with serial commmunication interface is presented and described in detail. The paper also deals with the results of the experimental circuit synthesis. In the conclusion, we state that an implementation of our proposed solution is feasible and we propose and discuss more complex architectures and the future work.

Keywords: embedded systems, concurrent processes, fault-tolerant systems, watchdog, reconfigurable circuits, FPGA

SYSTÉM PRE AUTOMATICKÚ KOMPOZÍCIU WEBOVÝCH SLUŽIEB

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Abstrakt: Článok pojednáva o možnosti kompozície webových služieb (WS) pomocou metód plánovania používaných v umelej inteligencii. Webové služby sú distribuované programy, ktoré sú umiestnené na sieti a používané pomocou štandardných sieťových protokolov. Každá služba má určitú funkčnosť, a v prípade, že nie je možné splniť cieľ pomocou jednej služby, prichádza na rad ich kompozícia. Ako najvhodnejší spôsob kompozície webových služieb sa ukázalo byť použitie metód plánovania používaných v oblasti umelej inteligencie (UI). Je to dané hlavne priamou podobnosťou definície plánovacieho problému s problémom kompozície WS. V článku, popri stručnom úvode do problematiky WS a ich kompozície, predstavujeme vlastný návrh systému pre kompozíciu WS a jeho implementáciu.

Kľúčové slová: kompozícia, plánovanie, plánovač, webová služba, WSDL, OWL, OWL-S

1 ÚVOD

Webové služby sú distribuované programy umiestnené na sieti, najčastejšie na internete, a používané pomocou štandardných sieťových protokolov, najčastejšie pomocou HTTP. V prípade ak nie je možné dosiahnuť požadovaný cieľ pomocou jednej WS, je tu možnosť, že ho bude možné dosiahnuť pomocou kompozície viacerých služieb do tzv. pracovného a dátového toku. Pre prácu s WS je potrebné oboznámiť sa s hlavnými štandardami a protokolmi, ktoré používajú:

- **WSDL** (Web Service Description language) – jazyk pre abstraktné definície dát a operácií, ktoré sú potom viazané na konkrétne štandardy a protokoly.
- **OWL-S** (Semantic Markup for Web Service) - umožňuje detailnejšie popísanie webovej služby, napr. z pohľadu dát, kde je možné priraďovať dátam rôzne koncepty z importovaných ontológií.
- **SOAP** (Simple Object Access Protokol) - slúži pre štrukturalizovanú komunikáciu medzi službami cez sieťový protokol (napr. HTTP). Vznikol z potreby zabezpečiť komunikáciu medzi službami vytvorenými v rôznych programovacích jazykoch.

2 PLÁNOVACÍ PROBLÉM A KOMPOZÍCIA WS

Plánovací problém je možné reprezentovať ako model sveta a môžeme ho zapísať ako päticu $\mathbf{<S, S_0, S_G, A, \Gamma>}$ (Peer, 2005), kde **S** reprezentuje množinu všetkých stavov v danom modeli, $\mathbf{S_0}$ je počiatočný stav, $\mathbf{S_G}$ je stav cieľový, **A** je množina dostupných akcií, z ktorých každá mení stav sveta prechodom z jedného stavu do druhého a **Γ**, ktorá je podmnožinou S x A x S, definuje predpoklady a závery (efekty) pre každú akciu. Súvislosť plánovania a kompozície WS je nasledovná: stavy $\mathbf{S_0}$ a $\mathbf{S_G}$ možno reprezentovať ontológiami OWL, akcie **A** ako atomické WS, predpoklady a efekty pre akcie **Γ** možno priamo zistiť z OWL-S popisu služieb

OPTIMALIZÁCIA SYSTÉMOV POUŽITÍM METÓDY KONEČNÝCH PRVKOV A EVOLUČNÝCH ALGORITMOV

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Predkladaná práca opisuje optimalizačný prístup vhodný na riešenie úloh z rôznych aplikačných domén, kde model systému je opísateľný parciálnymi diferenciálnymi rovnicami. Na modelovanie problému je využitá metóda konečných prvkov (FEM - Finite Element Method) a na hľadanie optimálneho riešenia problému sú využité evolučné algoritmy. Medzi úlohy riešiteľné pomocou FEM prístupu môžeme zahrnúť rôzne typy polí, ako elektromagnetické, elektrické, magnetické, silové, tepelné a iné. Hovoríme tu o úlohách z mechaniky (mechanické namáhanie, pružnosť, pevnosť), z aerodynamiky alebo hydrodynamiky, o úlohách z oblasti šírenia tepla alebo chémie, ale aj o iných oblastiach. Okrem toho tento prístup dovoľuje navrhovať a optimalizovať tiež regulačné obvody v uvedených aplikačných doménach.

Základná myšlienka riešenia pomocou FEM je vo vytvorení geometrie daného objektu a v definovaní plošnej alebo priestorovej siete bodov, ktorú nazývame konečné prvky. V nich budeme počítať reálnu hodnotu funkcie. V ostatnom priestore hodnoty hunkcie vhodne aproximujeme. FEM umožňuje modelovať problém. Evolučný algoritmus, v našom prípade genetický algoritmus, plní úlohu nástroja, ktorý je v definovanom priestore schopný nájsť optimálne (suboptimálne) hodnoty množiny zvolených parametrov, ktoré minimalizujú určenú účelovú funkciu. V ďalšom sú demonštrované výsledky optimalizácie vybraných úloh z oblasti regulácie teploty, z hydrauliky a šírenia tepla. Tieto úlohy boli riešené spojením FEM metódy v prostredí Comsol a genetického algoritmu bežiaceho v prostredí Matlab/Simulink. Riadený objekt nie je reprezentovaný zjednodušeným lineárnym alebo nelineárnym modelom použitím niektorej formy reprezentácie diferenciálnych resp. diferenčných rovníc (napr. prenosová f.), prípadne ani umelou neurónovou sieťou, ako je to obvyklé. Fyzikálne deje sú modelované pomocou FEM v celom definovanom priestore.

Prvá demonštrovaná úloha predstavuje návrh optimálnych parametrov PID regulátora teploty v bode plošného objektu tvaru obdĺžnika. Tri hrany sú tepelne izolované a ľavá izolovaná nie je. Ovládaný zdroj tepla sa nachádza vpravo od bodu A. Šírenie tepla je modelované pomocou FEM. Cieľom úlohy je návrh PID regulátora (resp. akéhokoľvek iného typu regulátora, ktorého model vieme vytvoriť v simulačnom prostredí Simulink) tak, aby bola minimalizovaná zvolená účelová funkcia. V ďalšej úlohe ide o optimalizáciu hydrodynamického tvaru prekážky v potrubí, ktorým preteká kvapalina. Do tohoto potrubia sa má umiestniť objekt obdĺžnikového tvaru, ohraničený ďalšou stenou, ktorá má klásť čo najmenší odpor pretekajúcej kavapaline. Cieľom je teda nájsť tvar krivky steny, ktorá má minimalizovať tvorbu turbulencií v potrubí. Posledná aplikácia je riešená v 3D priestore. Cieľom je nájsť optimálne rozmery a optimálnu polohu dvoch vykurovacích telies v budove s jednou miestnosťou. Budova je zvonka obtekaná studeným vzduchom. Požiadavkou je, aby sa teplota v miestnosti rozložila čo najviac rovnomerne a čím bližšie k požadovanej teplote.

CLUSTERING ALGORITHM IN MULTIDIMENSIONAL DATA SETS USING PART NEURAL NETWORK

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Keywords: PART neural network, clustering algorithm, multidimensional data space.

Abstract

For the purpose to increase the accuracy information retrieval the research of the semantic web has been developed. Traditional clustering methods don't work efficiently for data sets because of the inherent sparsity of data. This motivated the concept of subspaces clustering whose advantage is to find cluster formed in subspaces of the original high dimensional space. Nowadays the research of information retrieval utilizes neural networks where it is possible to generate clusters from input samples.

The paper deals with utilization of neural networks for clustering of multidimensional data sets. First chapter is concerned with the problematics of Projective ART neural network (PART NN) and their use in the area of non-controlled learning for creation of cluster. As well describes a principle of Projective Adaptive Resonance Theory in the process of learning of neural network and presents its individual phases.

In the next part the article focuses on use of PART NN for processing of multidimensional data. At first describes proposed and testified them through experiments, automatic generated domain ontology based on PART NN and Bayesian network. The major contribution PART with buffers is introducing a buffer management mechanism that allows data sets not to be immediately clustered into one cluster and partly achieve an independent purpose order without very correct parameters. Neural networks enforce in various domains of medicine and in gene analysis also. However in most gene expression datasets, the number of samples is less than that of gene. Was invented a new filtering method BagPART, based on PART theory, which is more effective than traditional filtering methods when sample size is small. In order to correctly select genes, BagPART method applies an idea modifying PART NN introducing idea of Bagging.

Examples from various areas suggest that with daily increase of information, as well as kinds of methods of storing and data processing with huge data sets on multidimensional spaces, PART NN and modifications of PART NN find increasing application.

Acknowledgement

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RIADENIE NELINEÁRNYCH SYSTÉMOV POMOCOU NEURÓNOVÝCH SIETÍ OPTIMALIZOVANÝCH GENETICKÝMI ALGORITMAMI

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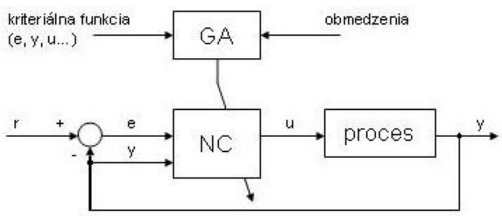
Riadenie nelineárnych procesov nie je jednoduchou úlohou. Jedným zo spôsobov riadenia takýchto procesov je riadenie pomocou neurónovej siete, ktorá predstavuje inteligentný regulátor. V tomto článku je predstavená metóda návrhu neurónového regulátora použitím genetických algoritmov. Táto metóda umožňuje nájsť optimálne nastavenie váh neurónovej siete tak, aby bola zabezpečená požadovaná kvalita riadenia v celom pracovnom rozsahu procesu. Navrhnutá metóda riadenia je overená v prostredí Matlab-Simulink na príklade izotermického reaktora, ktorý reprezentuje reálny nelineárny proces.

Pri riadení niektorých tried nelineárnych dynamických systémov sa s výhodou využívajú neurónové regulátory (neural controllers, NC). Neurónová sieť sa môže použiť pre riadenie nelineárnych procesoch v rôznych typoch riadenia, ako sú priame inverzné riadenie, neuro-prediktívnym riadenie, riadenie s referenčným modelom alebo ako neurónový regulátor optimalizovaný pomocou genetických algoritmov (GA). Tento článok sa zaoberá posledným spomenutým prípadom, t.j. neurónovými regulátormi optimalizovanými pomocou genetických algoritmov. Na obrázku 1 je zobrazený riadiaci systém s NC optimalizovaný pomocou GA (Sekaj, 2003).



Obrázok 1: Bloková schéma riadiaceho systému s NC optimalizovaným pomocou GA

Neurónový regulátor je reprezentovaný viacvrstvovou perceptrónovou (multi-layer perceptron, MLP) sieťou s jednou skrytou vrstvou. Tento typ neurónovej siete je schopný aproximovať ľubovoľnú spojitú nelineárnu funkciu, čo jej umožňuje pri dobrom nastavení parametrov sledovať zmenu dynamiky procesu v závislosti od pracovného bodu. Správne nastavenie parametrov NS zabezpečuje GA optimalizáciou kriteriálnej funkcie vyjadrujúcej kritérium kvality riadenia.

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COMPARISON OF USING SIMPLE GENETIC ALGORITHM AND PARALLEL GENETIC ALGORITM IN HEAT TRANSFER MODEL OPTIMIZATION

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Genetic algorithms (GA) are effective stochastic optimisation approaches imitating the natural evolution process. Despite progress in the area of GA, the premature convergence (finding of local optimum) sometimes occurred and also the large computing effort to find the slotution is needed. Especially when more complex system is to be optimised or the model simulation takes lot of time. In such cases it's necessary to reduce the number of fitness evaluations (model simulations).

A possible way is to use parallelism. Parallel genetic algorithms (PGA) are able to improve the performance of simple genetic algorithms with a single population. In parallel genetic algorithms (PGA) the evolution is distributed into many more or less isolated subpopulations, where the transfer of genetic information among these subpopulations has an important influence on the evolution process. In our comparison a GA with 50 individuals in the single population and a PGA with 5 nodes with 10 individuals in each subpopulation are experimentally compared. The architecture of the considered PGA is depicted in Fig.1.

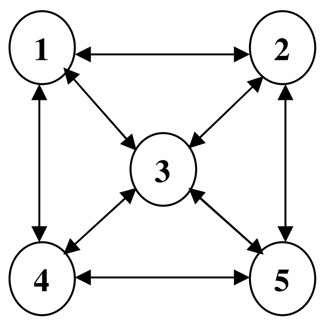

Figure 1: Considered coarse-grained PGA architecture

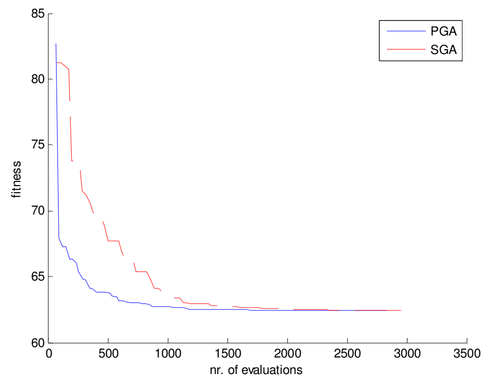

Figure 2: Convergence of buildins's model calibration

In our experiment the heat transfer problem and a heat transfer model of a building calibration were optimised. Simulations were implemented in Comsol Multiphysics. Genetic algorithm and its parallelisation were implemented in Matlab. A comparison of cost function convergence (vs. generation number) of the PGA (blue) and SGA (red) is depicted in Fig. 2.

Due to apropriate information migration between nodes, the PGA configuration may bring decrease of computation time in comparison with using simple GA with a single population. It also may avoid the premature convergence and find a better solution.

RIADENIE CHEMICKÉHO REAKTORA V PRÍTOMNOSTI PORÚCH POMOCOU NEURO-FUZZY SYSTÉMU RIADENIA

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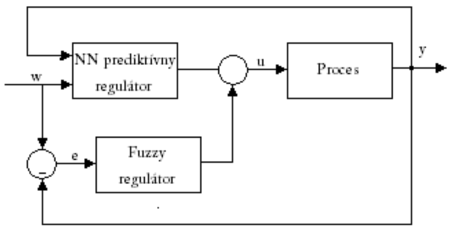
Abstract: V príspevku je popísaný inteligentný systém riadenia tvorený kombináciou neurónového prediktívneho regulátora a neuro-fuzzy regulátora typu ANFIS. ANFIS je zapojený paralelne a upravuje výstup získaný z prediktívneho regulátora, čím zlepšuje riadiace vlastnosti. Kvalita riadenia je overená na riadení prietokového chemického reaktora v nominálnom stave a v prítomnosti porúch. Experimentálne výsledky potvrdili zlepšenie kvality riadenia v porovnaní so samostatným neurónovým prediktívnym regulátorom a zároveň navrhnutý systém riadenia preukázal dobré zvládnutie poruchy.

Keywords: Neuro-fuzzy regulátor, Neurónová sieť, Prediktívne riadenie, Chemický reaktor.

1 NEURO-FUZZY RIADENIE

Neurónové prediktívne riadenie (Vasičkaninová, 2008) je rozšírené o neuro-fuzzy regulátor typu ANFIS. tento regulátor je zapojený paralelne s neurónovým prediktívnym regulátorom, tak ako je vidieť na obrázku 1 a upravuje jeho výstup tak, aby zlepšoval akčný zásah.



Obrázok 1: Schéma neuro-fuzzy riadenia

2 ZÁVER

V príspevku popísaný inteligentný systém riadenia CSTR, tvorený paralelným zapojením neurónového prediktívneho regulátora a neuro-fuzzy regulátora typu ANFIS, kombinuje výhody prediktívneho riadenia s neuro-fuzzy systémami, čím sa zlepšuje kvalita riadenia.

Zlepšenie riadenia potvrdzujú aj získané simulačné výsledky, z ktorých je tiež vidieť, že navrhnutý systém riadenia dobre zvláda náhodný výskyt poruchy vstupnej teploty reakčnej zmesi a vstupnej koncentrácie látky A. Získané výsledky ukazujú robustnosť a užitočnosť navrhnutého inteligentného systému riadenia a poukazujú na vhodnosť využitia tejto techniky pri riadení procesov.

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COOPERATION OF SUBSYSTEMS IN DISCRETE EVENT SYSTEMS

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Discrete event systems (DES) represent a wide class of systems used in human practice – e.g. flexible manufacturing systems, communication systems, transport systems, etc. They are discrete in nature, i.e. driven by discrete events. Petri nets (PN) are widely used at DES modelling and control as well as at the synthesis of the DES structure. The place/transition Petri nets (P/T PN) are used in this paper.

A modular approach to the synthesis and control of DES is proposed and tested. Namely, the DES subsystems are understood to be the modules of a more complex structure – like a group of subsystems and/or a global system. They are modelled by P/T PN and assembled in order to cooperate. The goal-directed cooperation of the PN modules is achieved by means of the PN-based supervisor synthesis. Supervisor synthesis methods are utilized in order to ensure the prescribed (desirable) cooperation of the modules. Two approaches to the synthesis of the supervisor are presented – the approach based on the PN place invariants (P-invariants) and the approach utilizing the state vector, control vector and the Parikh's vector of the PN models.

Moreover, the synthesis of the manufacturing system structure, based on the goal-directed cooperation of PN modules, is introduced too. The transit from the initial structure represented by the autonomouos agents to the final structure satisfying all prescribed conditions for the agents cooperation can be realized in several steps. The step-by-step procedure of the structure synthesis is more suitable than the procedure realized in one step. It has two main reasons: (i) it is practically impossible to form the whole set of conditions simultaneously or to expect that a chosen (apparently complete) set will be absolutely satisfied without any problem; (ii) forming a simpler set of conditions in any step, finding the corresponding structure, evaluating its quality and forming a new set of conditions seems to be more convenient and more credible procedure. Namely, in any step unexpected problems can appear. They have to be considered and solved by means of additional conditions.

Both the author's previous results and existing knowledge in the area of supervisory control are utilized in this paper. The applicability of the presented approaches is demonstrated on illustrative examples.

The procedure of the cooperation synthesis is given in analytical terms. It utilizes linear algebra. Consequently, it is lightly applicable in commercial modelling and simulation tools like Matlab, Dymola, Mathematica, etc., as well as in the free-downloadable tools like Scilab.

SIMULATION-BASED OPTIMISATION OF A REAL WORLD MANUFACTURING PROBLEM

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Keywords: simulation-based optimization, discrete-event simulation, real-world manufacturing problem

1 INTRODUCTION

Simulation historically was not an optimization technique. Based on the improvement of heuristic optimization techniques and development of computational hardware, simulation of a very large number of production systems configuration can be performed in order to find optimal, or near optimal solution.

2 PROBLEM STATEMENT

The real production system is represented by a set of unreliable machines and workstations. Let r - is a capacity of the production line, let d represents average demands, and q_1, q_0 – duration of up and down periods. We can express capacity and demand gap by the following formula:

$$\delta = \frac{rq_0}{q_1 + q_0} - d$$

The aim is to minimize the operational cost by minimizing the production and demands gap over the infinite horizon. There are two types of customers orders – long term and short term orders. The simulation helps to find an optimal strategy for a ratio of short and long term orders to be accepted to increase a profit.

3 CONCLUSION

The example presented in the paper is based on a real world problem, however the data presented are fictitious. The proposed solution will be tested within the project APVV VSMP 0216-09 OptiMAT.

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AGENTOVÝ SYSTÉM NA BÁZE KLONÁLNEJ SELEKCIE

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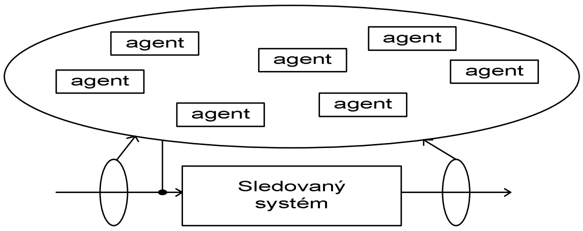
1 ÚVOD

Od počiatku vytvárania prvých riadených strojov a neskoršie aj pri vzniku prvých počítačov bol počas návrhu kladený zreteľ na čo možno najmenej poruchový chod. S nárastom autonómnych systémov narastá aj požiadavka vytvoriť také zariadenia, ktoré sú schopné samoopravy, prípadne čiastočného fungovania pri zásahu chyby. Táto práca ponúka riešenie motivovane algoritmami umelej imunitnej odozvy DE CASTRO (2001).

2 NAVRHOVANÝ SYSTÉM

Agentový systém je založený na reaktívnych agentoch (BROOKS R. 1991),(KUBÍK, A.2001), ktoré simulujú funkciu buniek imunitného systému. Komunikácia prebieha nepriamo skrze prostredie, kde každý agent dostáva všetky správy od všetkých.



Obrázok 1: Navrhovaný systém

3 ZHODNOTENIE

Navrhovaný systém je veľmi odolný voči poruchám vďaka reaktívnej povahe agentov a vďaka spôsobu komunikácie. Pri zlyhaní, ktoréhokoľvek agenta systém naďalej pokračuje vo svojej činnosti. Riešenia, ktoré MAS hľadá nemusia byť vždy nájdené. Súvisí to s povahou poruchy, ktorá vyvolala zlyhanie, ale aj s princípom proliferacie, ktorý je základom pri generovaní nových riešení. Napriek tomu je tento systém schopný nachádzať riešenia vopred nedefinovaných problémov, a tak pomôcť udržať v chode autonómne zariadenie.

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APLIKÁCIA TEÓRIE DISKRÉTNYCH UDALOSTNÝCH SYSTÉMOV NA ANALÝZU A MODELOVANIE REÁLNEHO VÝROBNÉHO SYSTÉMU

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Predmetom riešenia projektu je výskum a vývoj nových prístupov pre optimalizáciu riadenia a plánovania výrobného procesu recyklácie aplikovaním výskumu v oblasti nekonvenčných metód riadenia so zameraním na špecifiká výrobných liniek na recykláciu na báze polymerizácie. Cieľom optimalizácie výrobného procesu je nastavenie parametrov výrobného procesu tak, aby sa zabezpečilo zvýšenie flexibility, zníženie výrobných nákladov a zvýšenie kvality výrobkov.

Úlohou článku je poukázať na možnosť využitia modelovania výrobného systému poňatého ako diskrétny udalostný systém pri optimalizácii rozvrhovania výroby. Výrobný systém pozostávajúci z regranulačnej linky, štyroch vyfukovacích a dvoch rolovacích liniek sa zaoberá recykláciou tzv. mäkkých plastov na báze polymerizácie a následnou výrobou odpadových vriec z LDPE fólie. V súčasnosti je plánovanie výroby založené na intuitívnom rozhodovaní človeka, pričom je možné vytvoriť len krátkodobé plánovanie cca. 5 – 7 dní (nie je možné mať rozplánovanú výrobu v celom rozsahu prijatých objednávok), ktoré je veľmi náročné. Preto je nutné zmapovanie všetkých prestojov a vlastností výrobných liniek, na základe ktorých bude vytvorený model. Vytvorenie modelu výrobného systému je nutnou podmienkou pre simuláciu a následnú optimalizáciu výrobného procesu. Pri optimalizácii výrobného procesu je potrebné navrhnúť vhodnú kriteriálnu funkciu a zvoliť vhodnú metódu pre optimalizáciu (napr. hill climbing, tabu search, genetické algoritmy, ...). V článku je model výrobného systému vytvorený ako diskrétny udalostný systém. Aby sme mohli výrobný systém so spojitým procesom poňať ako diskrétny udalostný systém je nutné upresniť, čo bude reprezentovať stav a čo udalosť. V tomto prípade sa udalosťou rozumie vyrobenie resp. spracovanie výrobku na danej výrobnej linke a stav, bude reprezentovať výrobnú linku na ktorej sa vyrába resp. spracováva daný výrobok. Pre vytvorenie modelu je použitá knižnica SimEvents softvérového nástroja Matlab. Z výsledku simulácie dvoch prístupov spracovania výrobkov rolovacou linkou vyplýva, že aplikáciou jedného z nich je možné minimalizovať prestoj na rolovacej linke až o 44%. Taktiež výrobu jednotlivých LDPE fólií jednej objednávky je možné rozložiť na viaceré vyfukovacie linky, resp. vyrobené LDPE fólie sa môžu spracovávať na oboch rolovacích linkách naraz, čím sa skráti čas výroby. Avšak, nie vždy rozvrh s najkratším časom výroby je optimálnym riešením po finančnej stránke. Preto je nutné nájsť optimálne riešenie rozvrhovania výroby aby vyhovovalo viacerých kritériám.

Kľúčové slová: diskrétny udalostný systém, SimEvents, Matlab

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A SIMULATION APPROACH TO PRODUCTION LINE BOTTLENECK ANALYSIS

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Abstract: The paper presents a comparison of several methods for production line bottleneck analysis using discrete event simulation approach and simulation software Witness. An experimental environment has been built for processing and comparison of results obtained from Witness simulation experiments. The advantages and constraints of the cited methods are discussed.

Keywords: production system, bottleneck detection, simulation, Witness

Both theory and practice of production system management take interest in detection and reduction of bottlenecks, because the identification and reduction of them allows optimization of production resources, minimization of production costs and increase of flow fluency.

This paper deals with four data driven methods for bottleneck detection, developed in the last decades: method based on measuring the average active periods of machines (Roser et al., 2001), turning point method (Li et al., 2007), method using the emanation arrows (Biller et al., 2008), method using the synchronization indicator (Králová, Bielak, 2004). An experimental environment consisting of the simulation model and MS Excel user interface allows the setup of input data for the model of production line and view the analysis results for each of the methods. The analysis is based on simulation statistics about resource utilization, starvation, blocking, waiting for labor, setup and breakdown for each workplace and on the evaluation of relationships between the downstream and upstream activities.

ACKNOWLEDGEMENT

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PERSISTENTLY EXCITING MODEL PREDICTIVE CONTROL USING FIR MODELS

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Abstract: Model Predictive Control (MPC) is a well known and widely used advanced optimal control technique. It is a common practice to use a process model to predict the future behavior of the plant. The model/plant mismatch may have direct consequences on the quality of the prediction, causing potential controller performance degradation. An approach to tackle this problem may be to use closed loop system identification such that the model parameters are estimated and updated online, while the feedback controller is running. This adaptation requires that the plant input is persistently exciting, however a standard MPC controller is not able to provide sufficient input frequency content to obtain reliable parameter estimates. In this article a Persistently Exciting Model Predictive Control (PE-MPC) formulation is given. A Finite Impulse Response (FIR) model is adopted for prediction, and Recursive Least Square (RLS) is used for parameter estimation. Moreover, it is shown how to derive a persistently exciting constraint, suitable for implementation with MPC. Finally, it is explained how to implement the optimization problem such that, every sample time, only two Quadratic Programming (QP) problems are solved, and the optimal solution is applied in a receding horizon fashion. In the final part of the work, a simulation based example is given to show the effectiveness of the approach.

Keywords: Model Predictive Control, FIR model, Persistent Excitation Condition, Recursive Least Square.

DYNAMIC OPTIMIZATION OF A HYBRID SYSTEM: EMULSION POLYMERIZATION REACTION

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This work deals with the problem of dynamic optimization of hybrid systems. Hybrid systems are dynamic systems which keep both continuous and discrete character. Hybrid models provide better dynamic information of physical phenomena occurring in processes in real world. As an example of hybrid system we treat polymerization reaction in batch reactor. More precisely, emulsion copolymerization reaction of styrene and α–methylstyrene is in our scope. Overall process model involves kinetic model, molecular weight distribution model and reactor temperature dynamics model. It is described by seven first–order non–linear ordinary differential equations (ODEs) which right hand sides are varying according to one of the three stages of the process. Our goal is to produce polymer of prescribed terminal quantity and quality in minimum time. Quantity condition is presented by final conversion of monomer (styrene and α–methylstyrene) and quality condition is described by the final value of number–average molecular weight, weight–average molecular weight or polydispersity index of polymer. Control variable is reactor jacket inlet temperature. We obtain optimal trajectories of control variable using control vector parameterization (CVP) method. This method translates infinite dynamic optimization problem into finite non–linear programming (NLP) problem. The NLP computation requires gradient information which we attach using method of adjoint variables. Finally dynamic optimization results as well as process simulation results are provided.

Keywords: Dynamic Optimization, Hybrid Systems, Emulsion Polymerization

MODELING AND CONTROL OF COMPLEX SYSTEMS (ABSTRACT)

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Many controlled processes consist of continuous dynamics governed by logic rules, such as for instance on/off switches or valves, gears or speed selectors. Often, the control of these systems is left to schemes based on heuristic rules inferred from practical plant operation. In this paper, as an example of hybrid control, is studied simple thermal process of Air-handling unit (AHU). AHU model contains discrete parts like bypass damper, cooling water pump and fan speed switcher. Objective of control problem is to design a control law that optimally selects discrete inputs (damper, fan speed) and continuous inputs (cooling coil valve openning). For this purpose we need hybrid model that includes continuous dynamics and discrete logic. Mixed logical dynamical (MLD) structure is defined in the following form:

$$x(t+1) = A_t x(t) + B_{1t} u(t) + B_{2t} \delta(t) + B_{3t} z(t) \quad (1.3a)$$

$$y(t) = C_t x(t) + D_{1t} u(t) + D_{2t} \delta(t) + D_{3t} z(t) \quad (1.3b)$$

$$E_{2t} \delta(t) + E_{3t} z(t) \le E_{1t} u(t) + E_{4t} x(t) + E_{5t} \quad (1.3c)$$

where $t \in Z$, $x = [x_c, x_l]^T$, $x_c \in \mathbf{R}^{n_c}, x_l \in \{0,1\}^{n_l}, n = n_c + n_l$ is system state, whose components are devided into continuous x_c and $0-1$ x_l ;
$y = [y_c, y_l]^T$, $y_c \in \mathbf{R}^{p_c}, y_l \in \{0,1\}^{p_l}, p = p_c + p_l$ is output vector,
$u = [u_c, u_l]^T$, $u_c \in \mathbf{R}^{m_c}, u_l \in \{0,1\}^{m_l}, m = m_c + m_l$ is control input which includes analog u_c and binary (On/Off) inputs u_l; $\delta \in \{0,1\}^{n}$ and $z \in \mathbf{R}^{r_c}$ represents auxiliary variables.
The class of MLD systems includes the following important classes of systems:

- Linear hybrid systems.
- Sequential logical systems (Finite State Machines, Automata) ($n_c = m_c = p_c = 0$).
- Nonlinear dynamic systems, where the nonlinearity can be expressed through combinational logic ($n_l = 0$).
- Some classes of discrete event systems ($n_c = p_c = 0$).
- Constrained linear systems ($n_l = m_l = p_l = r_l = r_c = 0$).
- Linear systems ($n_l = m_l = p_l = r_l = r_c = 0, \quad E_{it} = 0, i = 1,4,5$).

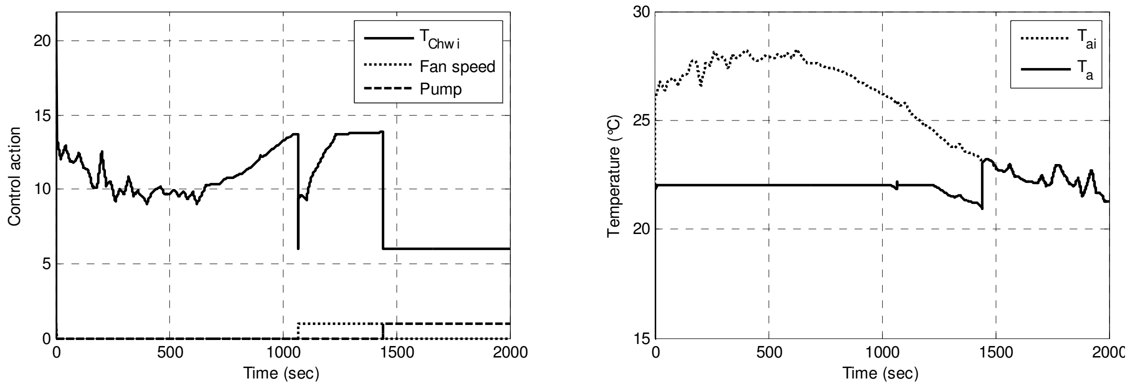

Fig. 3 Time response of control action and output temperature under explicit RHC of AHU

FURNANCES CONTROL USING MPC HYBRID

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Abstract: The paper deals with design of explicit hybrid predictive control. To design the controller we do not use usually used method which solves multi-parametric MILP or MIQP programming problem. The problem is solved by searching through tree of evolution and reachability analysis. Resulting control is restricted to systems with discrete inputs.

Keywords: explicit hybrid control, model predictive control, reachability analysis

1 INTRODUCTION AND PRELIMINARIES

Since the MPC control method is computationally intensive and therefore not useful for rapid and complex systems several authors in their articles devoted to the creation of an explicit control law. The advantage of this approach is that all the calculations that would otherwise had to be done on-line are done in advance and on-line computation is reduced to selecting the optimal control action based on the current state.

One of the solutions (proposed by Bemporad) uses combination of reachability analysis and multi-parametric linear programming. Resulting control law is expressed in PWA form.

This article addresses extension of Potočkin work who proposed the calculation of control law by reachability analysis. Control input of the system was a binary variable. Control inputs used in this article are discrete variables which can have more than 2 values. Next improvement is more accurate control achieved by refining of input variable values around steady state.

2 PROBLEM STATEMENT

The first task is to create an algorithm that determines the optimal control input for a given system state and selected performance function by searching through tree of evolution (Figure 1.). The second step is to identify areas that have the same optimal input. To implement control law it is necessary to train neural network so that it is able to identify in which area the current state is entered. Finally we improve system control to desired accuracy.

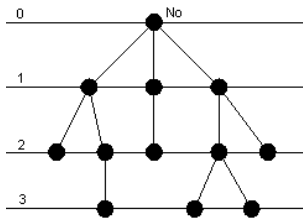

Figure 1.: Tree of evolution

3 CONCLUSION

The advantage of examining approach to system control is that to determine an explicit control law it is not necessary to address the complex problem of multi-parametric programming. For discrete inputs is less time-consuming to search through the tree of evolution and on-line implementation of controller is also quick.

BILEVEL PROGRAMMING FOR ANALYSIS OF REDUCED MODELS FOR USE IN MODEL PREDICTIVE CONTROL

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In this paper we use bilevel programming to find the maximum difference between a model predictive controller (MPC) using a full model and an MPC using a reduced model. The results apply to MPC with quadratic cost function and linear model with linear constraints.

Traditional method addresses the quality of a reduced model either in open or closed loop, but not in the presence of constraints. Our main contribution is therefore to asses the performance of reduced order models for use in MPC with constraints.

To achieve this we first set up a bilevel program on the form

$$\begin{aligned}&\max_{x\in X} d(u_{\text{red}},u)\\ &\text{subject to } u = \arg\min \ \{\text{MPC formulation with full model}\}\\ &\qquad\qquad u_{\text{red}} = \arg\min \ \{\text{MPC formulation with reduced model}\}\end{aligned} \tag{1}$$

We show that for a well-posed MPC problem, the optimization problem (1) can be reformulated as a mixed-integer linear program (MILP). This is done by writing up the Karush-Kuhn-Tucker (KKT) conditions for both MPC formulations and representing the complementarily conditions with binary variables.

To calculate the difference in the controllers we use the infinity norm of the input difference (through the B-matrix), i.e.

$$d(u_{\text{red}},u) = \left\| B(u - u_{\text{red}}) \right\|_\infty \tag{2}$$

Here we could also have used differences in outputs y using the framework presented in the paper. This measure renderes problem (1) non-convex, however it may be rendered into a MILP using standard techniques.

The method is demonstrated on a 16-state linear model, where we compare the full model with reduced models ranging from 1 to 15 states.

Planned further work in this project is to test the method on more realistic examples. In addition we will let the physical disturbances define the search-space in problem (1), rather than the intial states. Letting the initial states represent the disturbances can be very conservative as in the worst case we get combinations of disturbances that can never occur in practise.

PREDICTIVE PID CONTROL

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Keywords: predictive control, PID controller, PLC

Model predictive control (MPC) refers to a family of advanced control methods which make explicit use of a process model to predict the future process behavior and to calculate a future control sequence minimizing an objective function. The objective function is formulated as a combination of the set-point tracking performance and control effort. As predictive control belongs to the category of the open-loop optimization techniques, its implementation is based on the receding horizon strategy, i.e. only the first control signal of the future sequence is used at each sampling instant and the calculation is repeated in the next sampling time.

MPC technology can now be found in a wide variety of application areas including petrochemical, chemical, food processing, automotive and aerospace industries. Their popularity is mainly due to the fact, that they can be used to control a great variety of processes including time-delayed systems or non minimum phase or the unstable ones. The multivariable case can easily be dealt with as well. Another important feature is that the constraints can be systematically incorporated into the design procedure. Predictive algorithms take part of several commercial control packages.

Despite the wide development of advanced control methods, the PID controllers are still commonly used in industry for its structural simplicity and design rules of thumb. The PID control function can be found in many medium-size programmable logical controllers (PLC) and all large PLC. Such functions can be used directly by entering the parameters for given PID controller structure.

The aim of this paper is to employ the classical PID algorithm on industrial computers to do advanced control without the necessity of the specialized software. More specifically, the PID control structure implemented on Simatic S7-200 programmable logical controller has been considered. The PID controller parameters are obtained by equating the discrete PID control law with the classical pole-placement control structure of GPC given some conditions on the orders of the polynomials involved in the GPC control structure. As these orders depend on the process model, the process model order is restricted to a maximum of two, the first order model results in a PI controller while a second order plant yields a PID structure. On the other hand, there is no restriction on the choice of GPC tuning parameters so that the advantages of model predictive control can fully be exploited.

Performance of the PID control loop is shown to be equivalent to GPC scheme by means of simulation. An application of predictive PID algorithm for the control of a laboratory plant is also presented.

Acknowledgement

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MODELOVANIE A RIADENIE VÝUKOVÉHO MODELU GULIČKA NA PLOCHE S VYUŽITÍM MPT TOOLBOXU

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Abstrakt: Autori v tomto článku poukazujú na možnosti aplikačného využitia laboratórneho modelu gulička na ploche a MPT Toolboxu ako voľne dostupné rozšírenie funkcií programového balíka Matlab/Simulink pre modelovanie a riadenie dynamických systémov s cieľom vytvorenia modelu a návrhu stavového optimálneho algoritmu riadenia pre sledovanie zvolenej referenčnej trajektórie.

Gulička na ploche je laboratórny model firmy Humusoft pod označením CE 151, ktorý sa skladá z guličky pohybujúcej sa po ploche, ktorá sa môže nakláňať v smere osi x a y.

Plocha je riadená dvojicou krokových motorov (servosystém) a poloha guličky je snímaná kamerou, ktorá je umiestnená nad plochou. Obraz z kamery je spracovávaný počítačom, výsledkom čoho je aktuálna poloha guličky na ploche.

Keďže neexistuje žiadna spätná väzba medzi guličkou a nakláňajúcou sa plochou je možné model rozdeliť na dve nezávisle časti – servosystém a guličku voľne sa pohybujúcu po ploche.

Na základe nelineárnych Euler-Lagrangeových diferenciálnych rovníc popisujúcich dynamiku pohybu guličky po ploche a zjednodušujúcich predpokladov pre servosystém je možné vytvoriť nelineárny dynamický model pomocou funkcií MPT Toolboxu a ďalej s týmto modelom pracovať.

MPT Toolbox umožňuje návrh tzv. multiparametrických regulátorov, jedná sa o triedu optimálnych a prediktívnych regulátor, ktoré transformujú problém riadenia (optimalizačný problém) na matematickú úlohu lineárneho, kvadratického či multimaprametrického programovania. Cieľom je teda návrh takého stavového regulátora pre nelineárny dynamický systém gulička na ploche (vytvorený takisto s podporou funkcií MPT Toolboxu), ktorý bude schopný sledovať zvolenú referenčnú trajektóriu napr. tvaru štvorca, elipsy, hviezdy.

MPT Toolbox poskytuje široké možnosti návrhu, či už MPC (Model predictive control) regulátorov, alebo klasických stavových optimálnych regulátorov. Ako vhodný sa ukázal optimálny regulátor, ktorý minimalizuje funkcionál v tvare:

$$J = x(N)^T P_N x(N) + \sum_{k=0}^{N-1} x(k)^T Q x(k) + u(k)^T R u(k) + \left(y(k) - y_{ref}(k) \right)^T Q_y \left(y(k) - y_{ref}(k) \right),$$

pričom objekt riadenia a fyzikálne obmedzenia vstupov a výstupov sú definované v tvare:

$$x(k+1) = f_{dyn}\left(x(k), u(k) \right)$$

$$u_{\min} \le u(k) \le u_{\max}$$

$$y_{\min} \le g_{dyn}\left(x(k), u(k) \right) \le y_{\max}$$

V prípade, že je problém optimalizácie formulovaný pre konečný počet krokov N, v literatúre ho možno nájsť pod skratkou CFTOC (Constrained Finite Time Optimal Control), čiže optimálne riadenie s ohraničeniami na konečnom časovom intervale. Úlohou tejto optimalizácie je určiť také riadenie (akčné zásahy), ktoré bude minimalizovať daný funcionál, samozrejme pri dodržaní obmedzujúcich podmienok, ktoré vyplývajú s fyzikálnej podstaty riadeného objektu v diskrétnej oblasti.

CONTROL OF LABORATORY MODEL OF PENDUBOT

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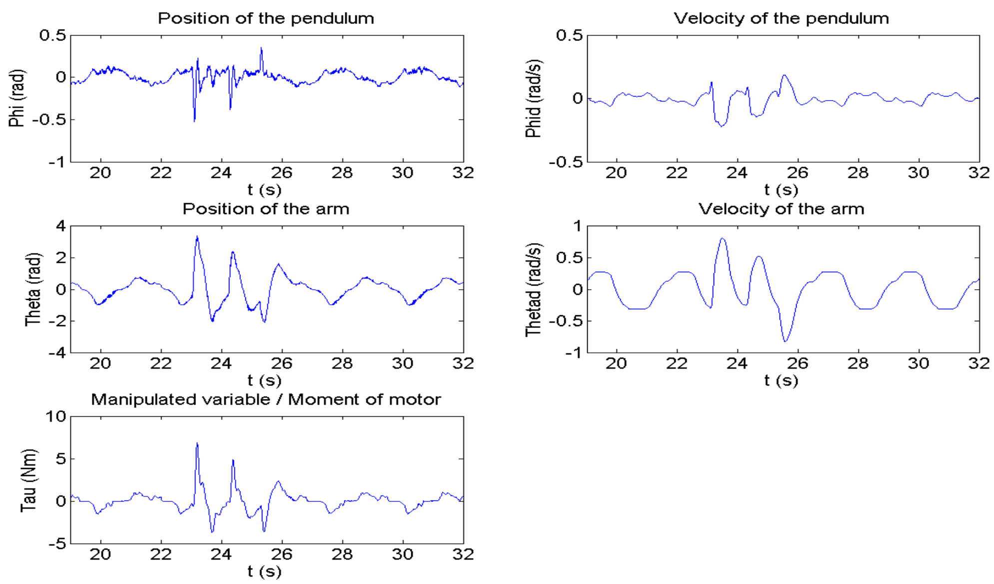
Abstract: This paper presents a concept of control of laboratory model of pendubot, which is a two-link under actuated robotic mechanism. Method of obtaining a mathematical model for pendubot is presented. Further this mathematical model is used for synthesis of LQ control. The inverted pendulum problem is well suited for education in control theory as well as for research in control of nonlinear mechatronic systems with quick dynamics.

Keywords: Inverted pendulum, Pendubot, LQ control, state space model

The pendulum is mechatronical system which is one of the most important examples in dynamics and control and has been studied. Many important engineering systems can be approximately modelled as pendulum in order to gain insight into their dynamic behaviour and for control systems design e.g. trajectory of rocket or segway. Pendubot (Fig.1) is a two-link planar robot with an actuator at the first shoulder and no actuator at the elbow. The second arm moves freely around the first link which is driven by a motor (Mates, 2009). The control objective is to bring the mechanism to one of the unstable equilibrium positions. This paper deals with deriving of a mathematical model of the pendubot. Further the gain matrix of LQ control is obtained and the results are verified on a physical model.

MATHEMATICAL MODEL AND LQ CONTROL

The corresponding equations of motion are derived using Lagrange's equations. The resulting equations can be written in closed form to allow an appropriate system analysis. State space representation is created using linearization in chosen operating point (in our case in the upper position of both arms). Matlab was used to obtain the LQ control. The resulting system is slightly oscillating around the chosen equilibrium position. Approximately at the time instants 23 s and 24,5 s two disturbances have been introduced successfully handled by the controller.



PID CONTROLLER DESIGN FOR MAGNETIC LEVITATION MODEL

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Abstract: The paper deals with design of PID controller for unstable SISO systems in the frequency domain. The method is accomplished with performance specification in terms of phase margin and the modification of Neimark D-partition method which ensures desired phase margin. The practical application is illustrated by the PID controller design for the Magnetic Levitation Model.

Keywords: PID controller, unstable system, D-partition, phase margin, Magnetic Levitation (maglev)

1 INTRODUCTION

Maglev technology has a wide range of applications, for instance, high-speed transportation systems, seismic attenuators for gravitational wave antennas, self-bearing blood pumps for use in artificial hearts, photolithography devices for semiconductor manufacturing and microrobots.

The design method presented in this paper is a graphical approach based on the D-partition method (Neimark, 1992). To achieve the desired phase margin, controllers are usually designed using Bode characteristics. The modification consists in ensuring the desired phase margin.

2 DESIGN OF PID CONTROLLER FOR MAGNETIC LEVITATION MODEL

A small modification of characteristic equation yields

$$1 + G_R(s)G_P(s)e^{-j\varphi} = 0 \tag{1}$$

It is possible to rotate the frequency characteristics of a system, where φ is the angle of desired rotation in radians. The PID controller design consists of two steps: in the first step, PD controller can be designed and in the second step, PI controller design can by applied for the plant with the PD controller. In this way controller for unstable plant can be designed, if this plant stabilizable with a PD controller. Hence in the first step, a PD controller is used for stabilization and a PI controller ensures desired phase margin and eliminates steady state offset. The developed frequency domain design technique is graphical, interactive and it is useful for unstable systems.

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Acknowledgments

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VÝVOJ AUTOMATIZOVANÝCH SYSTÉMOV RIADENIA PROCESOV

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Hospodárnosť podnikania vo výrobnom odvetví je hodnotená podľa produkcie, obratu a schopnosťou reagovať na požiadavky trhu a zákazníka. Zabezpečenie uvedených kritérií je možné dosiahnuť zvyšovaním úrovne riadenia procesov na báze technických a programových prostriedkov lokálnych sietí.

V predkladanom článku je popísaný súčasný vývoj automatizovaných systémov riadenia (SKR) s orientáciou na technologické procesy.

Z metodického dôvodu sú v úvode príspevku definované ciele a úlohy riadenia, ktoré sú zabezpečované príslušným SKR :

- Všeobecne je možné ciele riadenia špecifikovať ako organizačné, prevádzkové a bezpečnostné
- Úlohy riadenia zabezpečujú bilančné vyhodnocovanie priebehu procesu,kontrolu prevádzkových stavov procesu a ochranu procesu

Vývoj a implementácia systémov riadenia sú determinované implementáciou uvedených úloh riadenia a podmienené rozvojom informačnej techniky (IT). Do tejto oblasti patrí rozvoj meracej techniky, techniky ovládania a regulácie, techniky monitorovania a obsluhy a techniky prenosu informácie.

Vývoj IT je v ďalšom uvedený pre procesnú úroveň (snímače a akčné členy), dozorne (lokálne a globálne) a pracovné stanice. Pri popise je uvažovaná štruktúra hierarchického systému riadenia.

V záverečnej časti príspevku sú uvedené trendy vývoja. Okrem tradičných komponentov (snímače, akčné členy a kontrolery), integrálnou zložkou hierarchického systému riadenia sú komunikačné moduly na prenos informácie. V tejto oblasti sa presadzuje Industry Ethernet (s TCP/IP).

OPTIMALIZACE PROVOZU VENTILACE V SILNIČNÍCH TUNELECH

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ABSTRAKT

Řízení větrání v tunelu je složitý problém, který nelze řešit jedním samostatným klasickým regulátorem, protože se jedná o nelineární systém s dopravním zpožděním. Při snaze o efektivní řízení je potřebné tuto soustavu optimalizovat. Optimalizací se míní řízení ventilace dle měřených dopravních parametrů, což s sebou nese řadu výhod, jako dobrá predikovatelnost dopravních parametrů ve srovnání s predikovatelností škodlivin. Tím se šetří zbytečná spínání ventilátorů a prodlužuje se jejich životnost. To by mělo vést ke snížení provozních nákladů, neboť ventilace patří k největším spotřebičům energie.

Pro řízení ventilace se dosud používá v zásadě jednoduchý princip řízení v uzavřené smyčce. Při tomto principu vznikají zásadní problémy, jako je získat co nejvěrohodnější hodnoty koncentrace škodlivin, které jsou v tunelu časo-prostorově rozloženy, druhým zásadním problémem je nelinearita celého procesu, a dále je to setrvačnost vzduchové hmoty v tunelu, která čííní z řížení ventilace složitý problém.

Tyto nevýhody odstraňuje řízení ventilace vycházející z dopravních parametrů, neboť ty jsou velmi dobře predikovatelné na řadu minut a jejichž stochastická složka je omezena danou fyzikální realitou dopravního proudu.

Článek předkládá nový pohled na ventilaci tunelových systémů, která odstraňuje nevýhody řízení dle měření koncentrací CO a viditelnosti situovaných pouze v několika místech tunelu. Senzory pro měření těchto fyzikálních veličin jsou navíc velmi drahé a náročné na údržbu. Optimalizace ventilace má v tunelech zásadní význam, neboť ventilace je významně nejvyšším spotřebičem elektrické energie.

Výzkum byl zaměřen na korelaci dopravních a fyzikálních dat. Zvláště metoda rozhodovacích stromů poskytovala velmi dobré výsledky a umožňovala předpovídat škodliviny pouze z měřených dopravních parametrů ve velkém předstihu.

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CONTROL OF ELECTRONIC THROTTLE VALVE POSITION OF SI ENGINE

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Abstract: The paper deals with a electronic throttle control problem. The proposed method applies a discrete PI controller with parameters scheduling and feedforward controller working together.

Keywords: electronic throttle, PI controller with parameters scheduling, feedforward controller, SI combustion engine, dSpace

1 INTRODUCTION AND PRELIMINARIES

The electronic throttle (ETC) is a valve used in vehicles to regulate air flow into the engine combustion system. The ETC consists of a DC drive, a gearbox, a valve plate, a dual return spring and a position sensor (potentiometer). The heart of this system is a plate swung by the use of the DC motor. There is also the spring provides a torque working against the throttle DC motor. All this construction is a source of nonlinearity, and it is addressed to the use of non-linear control theory as well. In this case experimental researches allow to choose and apply PI controller with scheduling of parameters and feedforward controller. For implementation of control algorithm Real Time Windows target have been used.

2 PROBLEM STATEMENT

We consider the following structure of control system:

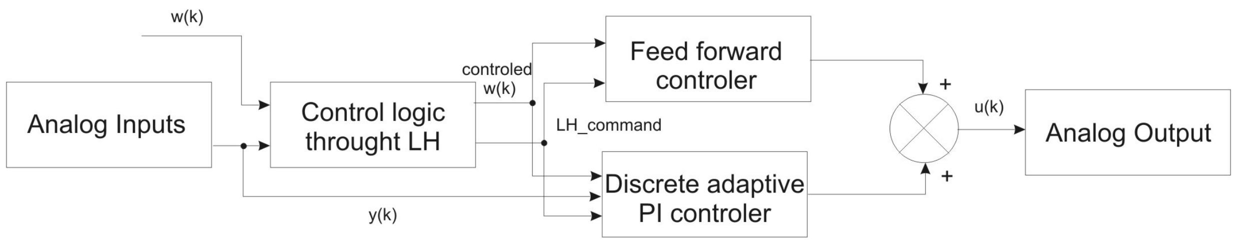

Figure 2.1: Structure of control system

Control system structure which is designed depends on practical experiences and analysis of some articles. Control of electronic throttle using only feedback discrete PI controller show that action value have three main levels, which is used as a knowledge base for feedforward controller designing. K_p and , K_i parameters of discrete adaptive PI controller are changeable depend on: throttle measured position (over or under LH) and movement direction (throttle opening or closing). There is four areas in which K_p and K_i change its values according to linear function (specific in each of this 4 areas).

Independent variable for this functions is absolute value of actual error with boundaries in error maximum (depend on being over or under LH position). There is also implemented nonsensitivity area for K_p, K_i in error equal to zero area.

MICROKERNEL SYSTEM AS BASIS FOR SYSTEM LIBRARY BASED ON GENERIC COMPONENTS

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Abstract: In this paper we present an idea of system library, based on generic components within microkernel system in the area of embedded systems. The paper describes basic Exokernel structure and functionality with focus on Exokernel ability to separate high level abstraction from kernel itself. Equally class hierarchy based Choices framework is briefly described. A Choices divides parts of operating system into class hierarchies. We meditate on weaknesses of both approaches, with respect to performance, configuration at the level of design and reimplementation in a case of hardware architecture changing that is common in embedded systems. Our system library is based on techniques of generic programming in combination with policy based design and design patterns. Generic component library allows one to combine advantages and suppress disadvantages for both Exokernel and Choices. Using library it's possible to build fully specialized operating system in embedded systems.

NÁVRH DISTRIBUOVANÉHO SYSTÉMU RIADENIA PRUŽNEJ VÝROBNEJ LINKY

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Abstrakt: Tento článok popisuje distribuovaný systém riadenia implementovaný na model pružnej výrobnej linky, ktorá sa realizuje na Katedre kybernetiky a umelej inteligencie. Hlavným cieľom je vytvoriť riadiaci systém daného modelu, realizovať jednotlivé úrovne distribúcie (technologickú, dispečerskú a informačnú) a komunikačné väzby medzi nimi. Model výrobnej linky reprezentuje technologický proces pre zostavovanie výrobkov a monitorovanie toku materiálu medzi vstupným a výstupným skladom. Zostavovanie výrobkov je realizované pomocou trojosých manipulátorov a verifikované kamerovým systémom. Vyššie úrovne riadenia poskytujú možnosti monitorovania, priameho operatívneho riadenia a plánovania výroby na základe požiadaviek zákazníka zadávaných pomocou vytvoreného informačného systému.

Použitie distribuovaného systému riadenia prináša so sebou množstvo výhod ako flexibilná hardvérová architektúra, robustné komunikačné technológie medzi hardvérovými komponentmi akými sú pracovné a riadiace stanice, inteligentné snímače a akčné členy, schopnosť správy alarmov a abnormálnych udalostí, integrované diagnostické funkcie, správa aktuálnych a historických dát, užívateľsky prístupné grafické rozhrania a bezpečnosť realizovaná nastavením rôznych prístupových práv pre používateľov. Vďaka týmto vlastnostiam je práve distribuovaný systém najvhodnejším spôsobom ako riadiť daný model pružnej výrobnej linky, ktorý bude použitý vo vyučovacom procese, kde sa budú môcť študenti oboznámiť s rôznymi oblasťami ako programovanie logických automatov, tvorba vizualizačných aplikácií, rozpoznávanie obrazov, správa databázových systémov, realizácia informačných systémov a komunikačných protokolov v objektovo orientovaných programovacích jazykoch a mnoho ďalších.

Kľúčové slová: Distribuovaný Systém Riadenia, Pružná Výrobná Linka

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PREDICTIVE CONTROL OF NONLINEAR PROCESS

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In this paper two predictive control approaches are addressed, proposed and tested. The first method described in this paper is Generalized Predictive Control (GPC). The second one is Dynamic Matrix Control (DMC). The proposed algorithms are tested in model based predictive control of the concentration control in the chemical reactor, manipulating its flow rate.

Model Predictive Control Design

Two of the first proposed model based predictive control methods and still commercially the most successful are DMC and GPC.
The process output in DMC at sample instant t is given as

$$\hat{y}(t) = \sum_{i=1}^{\infty} g_i \Delta u(t-i)$$

where g_i – mean the step response coefficients.

The CARIMA model, representing the plant model in GPC design, is defined as:

$$A(z^{-1})y(t) = B(z^{-1})u(t-1) + C(z^{-1})\xi(t)/\Delta$$

where Δ – is the differencing operator 1-z^{-1},
$\xi(t)$ – denotes white noise sequence,
A, B, C – are polynomials in the backward shift operator z^{-1}.

The sequence of future control signals is computed by optimizing a given (cost) function

$$J = \sum_{i=1}^{p}[r(k+1\,|\,k) - \hat{y}(k+i\,|\,k)]^2\Gamma_y + \sum_{i=1}^{m}\Delta u(k+i-1\,|\,k)^2\Gamma_u$$

Here, r is desired set point, Γ_u and Γ_y are weight parameters, determine the relative importance of the different terms in the cost function, u and Δu are the control signal and its increment, respectively. Parameter p is the length of the prediction horizon, m is the length of the control horizon. Output predicted by the nonlinear fuzzy model is $\hat{y}(k)$.
Application considered involves an isothermal reactor in which the Van Vusse reaction kinetic scheme is carried out.

Acknowledgments

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HYBRID PREDICTIVE CONTROL OF NONLINEAR PROCESS

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In this paper hybrid fuzzy model based predictive control (HFMBPC) is addressed, proposed and tested. The proposed model is tested in model based predictive control of the concentration control in the chemical reactor, manipulating its flow rate.

THE HYBRID FUZZY CONVOLUTION MODEL

The output of the model can be formulated as (Abonyi *et al.* 2000)

$$y_m(k+1) = y_s + K(u_s, x_2, \ldots, x_n).\sum_{i=1}^{N} g_i(x_2, \ldots, x_n).(u(k-i+1) - u_s)$$

where $y_s + K(u_s, x_2, \ldots, x_n)$ is steady-state part, which is described by Takagi-Sugeno fuzzy model and $\sum_{i=1}^{N} g_i(x_2, \ldots, x_n).(u(k-i+1) - u_s)$ is dynamic part of model (the impulse response model). The gain independent impulse response model is $g_i(x_2,...,x_n)$, the previous input values are $u(k-i-1)$ over N horizon, K is steady-state gain, u_s and y_s are steady-state input and output.

THE HYBRID FUZZY MODEL BASED PREDICTIVE CONTROLLER

In most cases, the difference between system outputs and reference trajectory is used with combination of a cost function on the control effort. A general objective function is the following quadratic form

$$J = \sum_{i=1}^{p}[r(k+1\,|\,k) - \hat{y}(k+i\,|\,k)]^2\Gamma_y + \sum_{i=1}^{m}\Delta u(k+i-1\,|\,k)^2\Gamma_u$$

Here, r is desired set point, Γ_u ($\Gamma_u = \gamma.K^2$) and Γ_y are weight parameters, determine the relative importance of the different terms in the cost function, u and Δu are the control signal and its increment, respectively. Parameter p is the length of the prediction horizon, m is the length of the control horizon. Output predicted by the nonlinear fuzzy model is $\hat{y}(k)$.
Optimal solution Δu is then given by minimizing the objective function.

Application considered involves an isothermal reactor in which the Van Vusse reaction kinetic scheme is carried out.

Acknowledgments

This paper has been supported by the Slovak Scientific Grant Agency, Grant No. 1/0544/09.

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NÁVRH ROBUSTNÝCH REGULÁTOROV PRE SIEŤOVÉ RIADIACE SYSTÉMY

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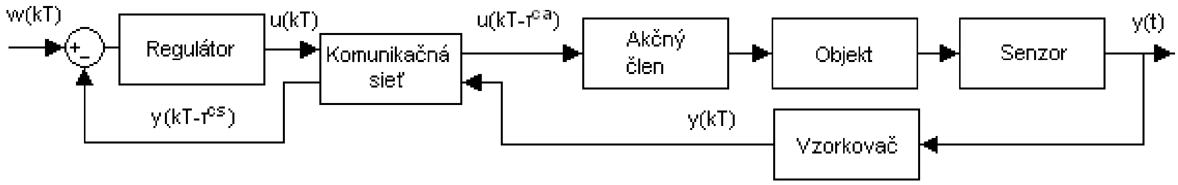
V príspevku je uvedený krátky prehľad o možnostiach návrhu robustných regulátorov pre sieťové riadiace systémy. Neurčitý objekt riadenia uvažujeme v tvare polytopického systému. Pre návrh robustného regulátora sú uvedené postačujúce podmienky parametrický závislej kvadratickej stability s garantovanou kvalitou regulácie.

Keywords: PI controller, time-delay systems, robust control, Lyapunov function

V súčasnostií sa veľká pozornosť venuje návrhu robustných regulátorov pre sieťové riadiace systémy (NCS – Network Control System), v ktorých vznikaju problémy so zabezpečením stability a kvality riadenia v dôsledku vzniku časovo premenlivého dopravného oneskorenia v komunikačnom systéme (KS) na obr. 1



Obr. 1 Sieťový riadiaci systém

Dynamický model objektu riadeného cez komunikačnú sieť je možné opísať týmto systémom diferenciálnych rovníc

$$\dot{x}(t) = [A + \Delta A]x(t) + [A_d + \Delta A_d]x(t - \tau(t)) \qquad (1)$$
$$x(t) = \phi(t), t \in <-\tau(t), 0>; 0 \le \tau(t) \le \tau_M$$

kde $x(t) \in R^n$ je stavový vektor objektu, A, A_d sú známe matice vhodných rozmerov, $\Delta A, \Delta A_d$ sú neznáme matice, ktoré reprezentujú časovo premenlivú ale ohraničenú neurčitosť a $\tau(t)$ je časovo závislé dopravné oneskorenie stavu objektu. Predpokladajme, že dopravné oneskorenia sú ohraničené

$$0 \le \tau(t) \le \tau_M; \dot{\tau}(t) \le d$$

Model neurčitostí objektu riadeného cez komunikačnú sieť vyberieme v tvare polytopického systému. Predpokladáme, že v (1) platí $\Delta A = \Delta A_d = 0$ a model neurčitostí je v tvare

$$[A, A_d] = \sum_{i=1}^{N} \lambda_i [A_i, A_{di}], \sum_{i=1}^{N} \lambda_i = 1, 0 \le \lambda_i \le 1, i = 1,2,...N \qquad (5)$$

Analýzu robustnej stability a návrh robustného regulátora pre model (4) a (5) uskutočníme pomocou Lyapunovovej teórie stability a Lyapunovovu funkciu vyberieme v tvare Lyapunov-Krasovského funkcionálu (LKF).

ACTIVE FAULT TOLERANT CONTROL OF THE CONTINUOS-TIME SYSTEMS

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The main contribution of the paper is present the reformulated design method for the state estimator based reconfiguration control in the continuous-time linear MIMO systems. In contradiction to the adaptive systems there didn't exist much structures to solve this problem [Blanke at all 2003], [Krokavec, Filasová 2008], especially using Linear Matrix Inequality (LMI) approach. To make formalism simpler, Lyapunov inequality is used as the design starting point to demonstrate the application suitability of the unified algebraic approach in these design tasks. Two LMIs are outlined to posse sufficient conditions for a solution and the others LMI can be introduced to adapt these for the control constrain parameters in given estimator and controller structure. An additional control law with the fault estimation is used in this structure to compensate the fault effect. The used structure is motivated by the standard structure [Dong at all 2009], and in this presented form enables to design systems with the modified controller structure.

Considering the controllable continuous-time linear MIMO system

$$\dot{\boldsymbol{q}}(t) = \boldsymbol{A}\boldsymbol{q}(t) + \boldsymbol{B}_u\boldsymbol{u}(t) + \boldsymbol{B}_f\boldsymbol{f}(t), \quad \boldsymbol{y}(t) = \boldsymbol{C}\boldsymbol{q}(t) + \boldsymbol{D}_u\boldsymbol{u}(t) + \boldsymbol{D}_f\boldsymbol{f}(t)$$

with constant matrices $\boldsymbol{A}$, $\boldsymbol{B}_u$, $\boldsymbol{B}_f$, $\boldsymbol{C}$, $\boldsymbol{D}_u$, and $\boldsymbol{D}_f$ of appropriate dimensions and the linear state feedback control law defined as $\boldsymbol{u}(t) = -\boldsymbol{K}\boldsymbol{q}(t) - \boldsymbol{L}\boldsymbol{f}_e(t)$ the observer-based estimators are used

$$\dot{\boldsymbol{q}}_e(t) = \boldsymbol{A}\boldsymbol{q}_e(t) + \boldsymbol{B}_u\boldsymbol{u}(t) + \boldsymbol{B}_f\boldsymbol{f}_e(t) + \boldsymbol{J}(\boldsymbol{y}(t) - \boldsymbol{y}_e(t)), \quad \boldsymbol{y}_e(t) = \boldsymbol{C}\boldsymbol{q}_e(t) + \boldsymbol{D}_u\boldsymbol{u}(t) + \boldsymbol{D}\boldsymbol{f}_e(t)$$

$$\dot{\boldsymbol{f}}_e(t) = \boldsymbol{M}\boldsymbol{f}_e(t) + \boldsymbol{N}(\boldsymbol{y}(t) - \boldsymbol{y}_e(t))$$

The main task of this fault reconfiguration structure was to design fault estimator gain matrices $\boldsymbol{J}$, $\boldsymbol{M}$, $\boldsymbol{N}$, as well as control law matrix parameters $\boldsymbol{K}$, $\boldsymbol{L}$ such that the estimation error with $\boldsymbol{f} = \boldsymbol{0}$ is asymptotically stable. To obtain these parameters Lyapunov inequality is used and this principle gives the sufficient condition for design. Sufient conditions on the existence of such a system and a solution to both controller and fault estimator matrix parameters are derived in term of LMIs. Finally, a numerical example is given to show the effectiveness of the method.

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MODE DECOUPLING AND STATIC SYSTEM CROSS-DECOUPLING IN CONTINUOUS-TIME MIMO SYSTEM CONTROL DESIGN

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The general problem of assigning the system matrix eigenstructure using the state feedback control combining with the static decoupling is considered. Using algorithms for the pole assignment based on the Singular Value Decomposition (SVD), [Krokavec, Filasová 2008] the exposition of the problem is generalized here to handle the specified structure of the right eigenvector set in state feedback control design for linear systems and the static decoupling techniques to obtain cross-decoupling [Wang 2003]. Extra freedom, which makes dependent the closed-loop eigenvalue spectrum, is used only for closed-loop state variables mode decoupling. The integrated procedure provides methodology usable in the linear control system design techniques when designing state controller for the state-space control structures is defined by [Sobel, Lallman, 1989].

A controllable linear MIMO system given by the state-space model

$$\dot{\boldsymbol{q}}(t) = \boldsymbol{A}_0\boldsymbol{q}(t) + \boldsymbol{B}_0\boldsymbol{u}(t), \quad \boldsymbol{y}(t) = \boldsymbol{C}_0\boldsymbol{q}(t) + \boldsymbol{D}_0\boldsymbol{u}(t)$$

and is parameterized by constant matrices $\boldsymbol{A}_0$, $\boldsymbol{B}_0$, $\boldsymbol{C}_0$, $\boldsymbol{D}_0$ of appropriate dimensions. The control policy of the form $\boldsymbol{u}(t) = -\boldsymbol{K}_0\boldsymbol{q}(t) + \boldsymbol{L}_0(t)$ is considered such that the closed-loop transfer function at $s = 0$ has diagonal and non-singular structure and the control system is stable. To make design simple there is derived the canonical form of the system state space description as

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{A}_{11} & \boldsymbol{A}_{12} \\ \boldsymbol{A}_{21} & \boldsymbol{A}_{22} \end{bmatrix}, \quad \boldsymbol{B} = \begin{bmatrix} \boldsymbol{B}_1 \\ \boldsymbol{0} \end{bmatrix}, \quad \boldsymbol{C} = \begin{bmatrix} \boldsymbol{C}_1 & \boldsymbol{0} \end{bmatrix}$$

where $\boldsymbol{A}_{11} \in \mathbb{R}^{m\times m}$, $\boldsymbol{B}_1 \in \mathbb{R}^{m\times m}$ is regular and $\boldsymbol{C}_1 \in \mathbb{R}^{m\times m}$ is orthogonal. This handles naturally optimized structure of the right eigenvectors set for the eigenvalues spectrum and the decoupling conditions to make use of freedom in the state feedback control design. Presented method exploits standard SVD numerical optimization procedures to manipulate the system feedback gain matrix $\boldsymbol{K}$ and to obtain the control signal gain matrix $\boldsymbol{L}$. Then the feedback control law is formed using the backward state transform.

The work presented in this paper was supported by VEGA, Grant Agency of Ministry of Education and Academy of Science of Slovak Republic, under Grant No. 1/0328/08.

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ALGORITHMS FOR FINDING PSEUDOPRIMES

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Abstract: The paper extends the current known tables of Fermat's pseudoprimes to base 3 with the bound of 10^{13}. The paper is motivated by works of C. Pomerance (1980), G. E. Pinch (2000), William Galway (2002) and Jan Feitsma (2009) who provided tables of pseudoprimes with base 2 up to 10^{13} (Pinch), 10^{15} (Galway) and 10^{17} (Feitsma).

Keywords: Fermat pseudoprimes, GRID computation, distributed computation.

1 INTRODUCTION AND PRELIMINARIES

Many public key cryptosystems (RSA, ElGamal, etc.) require a fast generation of prime numbers. The common algorithms generate odd integers and test them for primality. Because the deterministic testing algorithms are slow in practice, faster (non-deterministic) algorithms with some non-zero (but arbitrary low) error probability are used instead.

One of the fastest algorithms is the Fermat primality test; Fermat pseudoprimes being defined as such composite numbers that pass this test. More formally, we call an integer number N a Fermat pseudoprime with respect to base B, if

$$B^{N-1} \equiv 1 \pmod{N}$$

2 ALGORITHM ANALYSIS

Other current research in this topic is devoted to extending the known tables of pseusoprimes with base 2, without any new known of the development of the algorithm proposed by R. Pinch (Pinch 2000). In our work, we improve the original algorithm and use it to compute the pseudoprimes with base 3.

The search is divided into three (distinct) parts:

1. pseudoprimes with repeated factor
2. pseudoprimes with distinct factors
   a) pseudoprimes with large factor (large factor search)
   b) pseudoprimes with small factors (main search)

The search of pseudoprimes with distinct factors is determined by a bound between large and small factors. The analysis of main search (2a) shows that lowering the bound from 10^9 to 10^7 will decrease the time complexity for main search and increase time needed for large factor search. However, this will decrease time for whole search.

ZBER A UKLADANIE DÁT PRI RIADENÍ TECHNOLOGICKÉHO PROCESU

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Abstrakt: Článok pojednáva o spôsobe zberu a ukladania dát na databázovom serveri pri riadení technologických procesov. Zameriava sa na štandardy komunikačných väzieb využívaných pri riešení danej problematiky. Upozorňuje, na čo je potrebné sa zamerať pri tvorbe databáz slúžiacich na ukladanie dát aj z pohľadu ich ďalšieho využívania vo vyšších úrovniach riadenia podniku. Prezentovaná aplikácia je príkladom realizácie zberu a ukladania dát pre konkrétny laboratórny technologický model predstavujúci linku na triedenie výrobkov.

Pri riešení tohto príkladu sa vykonával zber dát z PLC (Programmable Logic Controller) ktorý riadila aplikácia RSSql. Pomocou protokolu DDE (Dynamic Data Exchange) bola realizovaná komunikácia smerom k technologickej úrovni riadenia a pomocou protokolu ODBC (Open Database Connectivity) bola realizovaná komunikácia smerom k databáze vytvorenej na platforme Oracle 10g. Rozhranie ODBC umožňuje prístup k dátam na rôznych SQL (Structuder Query Language) serveroch. Zaručuje nezávislý prístup na databázovom systéme, operačnom systéme a programovacom jazyku.

Na databázovom serveri Oracle bola vytvorená transakčná databáza do ktorej sa sledované dáta ukladali. Pri zbere dát je dôležité zachovať dátové typy a veľkosť údajov, ktoré sa budú do databázy ukladať, aby nedošlo k prípadným kolíziám. Je potrebné zamerať sa na to, aby mali údaje zmysluplný charakter. V opačnom prípade sa budú len veľmi ťažko analyzovať a ich význam bude tým pádom sporný.

Aplikačný Server Oracle 10g tieto dáta sprístupňoval, aby bolo možné ich ďalšie využitie v riadiacom procese. Ukladané dáta sa týkali času a dátumu, aktivitách a polohách jednotlivých súčastí technologického procesu atď.

Sledované dáta mali významnú úlohu pri riadení celkového systému. Na základe týchto informácii riadiace algoritmy rozhodovali o tom, čo bude následne technologický proces vykonávať a generovali akčné zásahy.

Keywords: DDE, ODBC, databázový systém, zber dát, transakčná databáza, riadiaci systém

Poďakovanie: Prezentovaná práca bola zrealizovaná za podpory slovenského grantu VEGA - 1/0617/08.

APPLICATION OF HYBRID CONTROL METHOD FOR TRAFFIC SYSTEMS

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Abstract: The paper deals with control of traffic lights. The crossroads is composed of 2 two-way streets and not all of theoretic ways to pass through crossroads are allowed. We constract the model that describes the evolution of the queue based on number of incoming and outgoing cars and traffic lights. We try to achieve otimal crossroads control which as we believe does not have to be the case when number of cars passing through the crossroads is maximal.

Keywords: predictive crossroads control, transport system

1 INTRODUCTION AND PRELIMINARIES

Generally traffic lights control is not easy job and it is not clear which criterion of performance is right. One criterion is to set traffic lights so that number of passing cars is maximal but we believe this on the best solution.

In this article we try to find trade-off between number of cars passing through crossroads and number of cars facing red light.

2 PROBLEM STATEMENT

At first we have created real model of crossroads. Since such model is not suitable for mathematical analysis it was simplified according to our requests. We have obtained simple model in which queue lenght is increasing if the light is red and decreasing if the light is green. Amber light was missed out.

Next step was optimization of input signals. Instead of using 6 control input signals (1 for each traffic light) we rather use just 4. Optimization was done using discrete logic and Karnaugh map.

The aim of traffic control is to minimize nuber of cars, that are faced to red light. That meas minimization of performance function

$$J = \sum_{k=1}^{N} \left\| Q_x x(k) \right\|_1 - \sum_{k=1}^{N} \left\| Q_L LU \right\|_1 + \sum_{k+1}^{N} \left\| Q_U \left(U(k-1) - U(k)\right) \right\|_1$$

3 CONCLUSION

As a result of the article is proposal of crossroad control based on hybrid predictive control. The main objective for setting traffic lights is number of cars faced to red light. This is a „fair" approach because we let pass through cars which are in longest queue.

Advantage of proposed control is that we do not need to predict crossroad state lots of steps ahead instead we make just one step prediction.

ROBUST CONTROLLER DESIGN TECHNIQUES FOR UNSTABLE SYSTEMS

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Abstract: The presented paper deals with simple and practical methods of discrete controller design using conventional approach based on robust stability analysis in frequency domain, and the new approach using the reflection vectors techniques. We assume that the control structure consists of feed-forward and feedback part. Proposed algorithms were tested in illustrated examples for stable, unstable and oscillating systems. Simulations were realized in MATLAB-Simulink, Version 7.0. Obtained results show applicability of the theoretical principles for control of processes subject to parametrical model uncertainty.

Keywords: robust control, robust stability, parametrical uncertainty, diofantine equation, pole-placement, quadratic programming, reflection vectors

CONCLUSION

The paper deals with the development of robust methods based on reflection vectors methodology for computation of control law coefficients guaranteeing stability, robustness and high performance with respect to parameter uncertainties. Theoretical results were verified on the examples for feedback and feedforward control structures. Proposed methods were tested for both stable and unstable processes.

The paper proposes theoretical principles and design methodology of robust discrete-time controllers for systems with parametric uncertainties.

The illustrative example was solved using quadratic programming for suitably defined cost function. Simulation results prove applicability of the proposed robust controller design theory for systems with parametric uncertainty.

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DECENTRALIZED CONTROL: SOME ASPECTS OF STABILITY AND PERFORMANCE

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Keywords: control system design, decentralized control, robust stability

The paper discusses some basic aspects of decentralized control design concerning stability and performance. Decentralized control design comprises several stages and tasks; we concentrate on control structure selection with appropriate input-output pairing and resulting single loops design so that it guarantees stability as well as required performance of the overall system including interactions. Standard interaction measure used for control structure selection is the relative gain array (RGA), nevertheless, performance relative gain array PRGA (closely related to RGA) is used in this paper, since besides input-output pairing it enables to evaluate the achievable performance (Hovd, Skogestad, 1992). Robust stability condition based on small gain theorem is considered as basic design tool to guarantee overall system stability. The main interest is focused on relationship between stability and performance. On the one hand, stability condition for overall system under decentralized control determines upper bound on modulus of single loops. On the other hand, performance evaluated through PRGA provides lower bounds on the individual loop gains to achieve the required performance, which is determined by bounds on offset (control error) respective to setpoint changes. The use of these design tools is illustrated and analysed on example (decentralized control design for quadruple tank model). The interesting part of simulation experiments is connected with nonminimum phase case, where the single loops are minimum phase, however, the interconnected system includes transmission unstable zero, which inherently limits the required performance. The obtained results show the limitations following from overall stability condition and the influence of interconnections on overall system stability and performance. Presented material provides simple illustration of stability versus performance relationship in decentralized control design and can be used in teaching complex systems control.

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UNIFIED APPROACH TO INPUT-TO-STATE LINEARIZATION OF NONLINEAR CONTROL SYSTEMS

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Abstract: Input-to-state linearization of a system is necessary to consider whenever input-to-output linearization of the system yields an unstable cloosed-loop system. In this work a unified approach to the input-to-state linearization of nonlinear systems, both continuous- and discrete-time, is suggested. From that point of view methods and tools of the so-called pseudo-linear algebra play a key role.

Keywords: nonlinear control systems, input-to-state linearization, unification, algebraic approach

1 INTRODUCTION

Many solutions to control problems of continuous- and discrete-time nonlinear systems show significant similarities. Usually, behind the similarities lies a mathematical abstraction that accommodates both cases. In this paper such an abstraction, called pseudo-linear algebra (Bronstein and Petkovšek, 1996), is introduced to unify the algebraic formalism of differential one-forms of Conte, Moog and Perdon (2007) with an application to input-to-state linearization of nonlinear control systems, both continuous- and discrete-time. Though the differential and shift operators have remarkably different properties and calculations with differential and shift operators are based on different rules, they both accommodate into pseudo-linear algebra as special cases. Note that pseudo-linear algebra covers also q-shift and q-difference operators, where the state at time t determines the state at time qt with $q \in \mathbf{R}$. The q-shift operator can be in some cases used to model discrete-time systems with the varying sampling period.

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RIADENIE TEPELNÉHO PROCESU VNORENÝM SYSTÉMOM

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Príspevok pojednáva tak o identifikácii skúmaného procesu, ako aj o návrhu algoritmov riadenia tepelného procesu konvenčnými a pokročilými vnorenými regulátormi. Na základe identifikovaného modelu laboratórneho tepelno-optického systému, boli návrhnuté parametre konvenčných PI regulátorov pre optický a tepelný kanál systému a fuzzy PI regulátor pre optický kanál.

V úvode práce sú uvedené charakteristické vlastnosti systémov pre lepšiu orientáciu v danej problematike. Ako vnorený systém bola použitá vývojová doska spoločnosti Freescale s 8-bit. mikrokontrolérom.

V prvej časti ďalšej kapitoly je opísaná identifikácia optického kanálu systému, ktorý je tvorený zdrojom svetla halogénová žiarovka a fotosnímačom. Na základe vyhodnotenia prechodových charakteristík bola určená štruktúra a koeficienty modelu optického kanála.

Jadrom práce je návrh fuzzy PI regulátora pre riadenie optického kanála systému a jeho konfrontácia s konvenčným PI regulátorom. Ako fuzzy PI regulátor bol zvolený polohový regulátor. Ďalším krokom bolo vygenerovanie prvotnej FIS štruktúry, ktorú sme neskôr trénovali. Pri procese trénovania bola zvolená hybridná optimalizačná metóda.

V poslednej kapitole je návrh konvenčného PI regulátora na identifikovanom modely tepelného kanála systému. Tepelný kanál je tvorený zdrojom tepla halogénová žiarovka a odporovým teplotným snímačom. Identifikáciu tepelného kanála tepelno-optickej sústavy sme vykonali rovnako ako v prípade optického kanála.

Verifikácia navrhnutých regulátorov bola z pohľadu kvality regulácie v prípade modelu optického kanála veľmi dobrá. Navrhnuté regulátory boli implementované vo vnorenom systéme Freescale prepisom do jazyka C. Výsledky tejto práce budú ďalej použité v edukačnom procese a vo výskumných úlohách v predmetnej oblasti na FEI STU.

Poďakovanie

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TIME OPTIMAL CONTROL USING GRÖBNER BASES

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ABSTRACT

The time optimal control belongs to one of the most important control strategies. It was heavily studied in 50-ties and 60-ties of the previous century but due to its high sensitivity to unmodelled dynamics, noise and disturbances it was later supressed by the pole assignement control. Nowadays there exist several approaches how to cope with this problem and so the time optimal control plays an important role in the modern control theory.

Generally, the time optimal problem can be solved by computation of switching surfaces. These can be derived by using the Pontryagin's maximum principle. A different approach is offered by the dynamic programming based on the Bellman's optimality principle. Another way was represented by Pavlov who solved switching surfaces from phase trajectories (Pavlov, 1966). But switching surfaces can be also expressed by the set of algebraic equations (Walther et al., 2001) that result from time solutions in the phase space. For higher order systems these can be rather complicated to find the exact solution. In this paper we will apply the Gröbner bases theory to thelp us to solve such a set of polynomial equations.

Gröbner bases generalize the usual Gauss reduction from linear algebra, the Euclidean algorithm for computation of univariate greatest common divisors and the simplex algorithm from linear programming. Using them it is possible to transform one set of equations to another one that can be solved more easily. We will apply this technique for the triple integrator system where it is possible to get symbolic solutions but it can be also applied for higher order systems when solving the resulted sets of equations numerically.

KEYWORDS: time optimal control, Gröbner bases, triple integrator system

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RELAY IDENTIFICATION BY ANALYZING NONSYMMETRICAL OSCILLATIONS FOR SINGLE INTEGRATOR WITH TIME DELAY

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Abstract: The paper deals with approximation of systems with dominant first order dynamics and nonsymmetrical input by the Integrator Plus Dead Time (IPDT) model by means of analysis of the nonsymmetrical oscillations arising under relay control. The results achieved by identification of optical plant are then experimentally verified by Disturbance Observer (DOB) based controllers.

Keywords: relay, disturbance observer, integrator plant, nonsymmetrical oscillations

1 INTRODUCTION

Relay identification of plants to be controlled is usually based on the describing functions method. This remains sufficiently simple and precise in the case of nearly symmetrical oscillations. In order to achieve symmetrical oscillations in systems with input disturbance, one should compensate its influence by a counteracting signal added to the relay output. The problem of such approach is given by the usually not known disturbance values. For a noncompensated disturbance, the deformation of oscillations leads to increased influence of higher harmonics and to decreased precision of the identification both by using the describing functions method and the Fast Fourier Transform (FFT). However, when constraining the approximation to Integrator Plus Dead Time (IPDT) model

$$S(s) = K_s e^{-T_d s} / s \qquad (1)$$

it is possible to use relatively simple formulas describing the arising nonsymmetrical oscillations.

2 ACKNOWLEDGEMENTS

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DATA ACQUISITION FROM EDUCATIONAL PLANTS OVER USB IN GNU/LINUX

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Abstract: The paper describes possibilities of implemantation of USB communication in GNU/Linux. It proposes use of USB as data acquisition bus with use of FTDI chip as a serial to USB converter for communication with educational plants. It deals with implementation of communication methods using open source libraries libFTDI, OpenUSB and libUSB.

Keywords: USB, GNU, Linux, Open Source, FOSS, FTDI, libFTDI, OpenUSB, libUSB

1 INTRODUCTION

On site experiments as well as remote experiments are used frequently used in automation education. Real experiments makes students more aware of difficulties that come with implementation of control methods. On the other hand, educational plants are expensive. Answer to the cost could be virtual experiments, but simulation is bounded with models and can not fully substitute contact with real experiment. Eminent part of educational system is data acquisition boards, which are required for connection of educational plant with PC. USB DAQ can cost only a fraction of PCI DAQ [1][2] and are able to save resources[3].

2 PROBLEM STATEMENT

USB communication is not constructed for real-time access. We would like to show that it is able to sample fast enough for general use with educational plants where is 1kHz sampling frequency satisfactory. USB have more communication modes. In paper is presented bulk communication mode mostly used by memory devices [4].

3 EXPERIMENTS AND CONCLUSIONS

For simulation of DAQ we have used uDAQ24/T and Arduino board as USB data acquisition device. Both these devices are communicating over USB with serial to USB converter based on FTDI chip. We have created created applications over most used USB communication libraries libftdi, OpenUSB and libUSB 1.0. We have made benchmarks that have shown that USB can be used for real time control with sampling times higher than 10ms.

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ROBUST CONSTRAINED PID CONTROL

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Abstract: The paper gives overview of the new aspects of the course on Robust Constrained PID Control that is being developed and tought at the Faculty of Electrical Engineering and Information Technology of the STU in Bratislava for more than two decades. Within these, as a central point, new method for robust tuning of constrained controllers based on the performance portrait will be introduced. This is based on evaluation of the closed loop properties carried out by simulation over grid of normalized closed loop parameters. The achieved transients are analyzed and evaluated by using several known and newly introduced performance measures and the results are then stored as the loop performance portrait. Such performance portrait may then be used for optimally localizing a nominal operating point, or an uncertainty set corresponding to specified limit loop parameters. The tremendous power of computers in organizing and evaluating experiments, as well as in processing, visualizing, storing and recalling the achieved results is used to extend spectrum of different qualitative & quantitative properties that are evaluated and stored in computer database, to be chosen "on demand" and in different combinations by engineer carrying out robust design requiring particular specifications. Potential of the performance portrait method will be demonstrated by deriving various characteristics of different controllers. The paper will show that this new approach to the robust constrained PID control and its design using the performance portrait method enables to solve with a reasonably increased efficiency and elegancy also the traditionally hard control problems, as e.g. the robust constrained Smith predictor design for unstable systems and to answer questions like „which controller is better suited to the given robust problem – the simplest possible one, or a more complex one?". However, as every time in the research history, each newly answered question opens several new questions. These may be related to the possible precission of the grid computations, to guaratnees that no unwanted phenomena occur, to possible rules for optimally choosing the number of calculated points and intervals for the performance portrait calculation, etc.

Keywords: PID control, robust control, constrained control, systems with long time delays, performance portrait method

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ROBUST DECENTRALIZED CONTROLLER DESIGN: STATE SPACE VERSION OF THE EQUIVALENT SUBSYSTEMS METHOD

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Abstract: The paper deals with the robust decentralized PID controller design for performance for linear MIMO systems using output feedback with state decentralized structure. The proposed design procedure is a straightforward state space extension of the frequency domain Equivalent Subsystems Method (ESM) guaranteeing feasible performance achieved in equivalent subsystems for the full system.

The main concept of the Equivalent Subsystems Method originally developed as a Nyquist-based frequency domain decentralized controller (DC) design technique are the so called *equivalent subsystem* generated by shaping Nyquist plots of decoupled subsystems using any selected characteristic locus of the matrix of interactions. Local controllers of equivalent subsystems independently tuned for stability and specified feasible performance in terms of degree of stability constitute the resulting decentralized controller guaranteeing the same degree of stability for the full system. The ESM state-space version proposed in this paper provides new perspectives to further development of the approach.

The model of the MIMO system is considered in the form

$$\dot{x} = (A_d + A_m)x + \sum_{i=1}^{m} B_i u, \qquad y = \sum_{i=1}^{m} C_i x$$

where $A_d = block\ diag(A)$ and both B and C have a decentralized structure.

Equivalent subsystems are defined in the following way:

$$A_i^{eq} = A_i + pI,\ i = 1,...,m$$

where p is the maximum real part of all eigenvalues of the off-diagonal matrix A_m., i.e.

$$p = \max_i [Re\{ \lambda_i (A_m)\}]$$

Robust decentralized PID controller has been designed using the polytopic description of the uncertain system and applying the robust optimal control design procedure with extended cost function (Rosinová and Veselý, 2006) for state-space equivalent subsystems generated in each vertex of the polytopic uncertainty domain

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A TOOL FOR SUPPORT OF ONLINE SYMBOLIC COMPUTATIONS

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Abstract: The paper presents possibilities how to accomplish computations - mainly symbolic computations - in online applications and in web environment. The proposed solution is illustrated on the example that is devoted to transformations among different mathematical models of linear dynamic systems.

Keywords: symbolic calculations, Maxima, web applications

1 INTRODUCTION

The expansion of Internet led to the development of web applications in the engineering area, too. Many of them need to accomplish various computations that in general can be numerical and symbolical. In the field of automation these computations are needed for solving of differential equations, calculations of control algorithms, identification, signal processing, etc. It would be very reasonable that the developer that develop such application would be not required to program all mathematical algorithms but he or she could use an online tool that would be available on the Internet for each interested user. This could save him/her a lot of time. The tool could be useful also for students that would be able to check results of their mathematical, physical or other problems without necessity to instal an additional software on their computer.

The introduced solution is based on the Maxima computer algebra system that is combined with Gnuplot, LaTeX and Dvipng softwares. For the building of the web application we used XHTML, CSS, JavaScript with jQuery library and PHP scripting language.

The presented tool can be used in two ways:

- in the form of online web environment where the user can solve required numerical or symbolical mathematical tasks,
- in the form of preprepared php functions that can be used in frame of own web application to include the tool functionality in own solution.

Both approaches are introduced in the final version of this paper.

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