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FUZZY-BASED CRANE CONTROL SYSTEM

Наведено нейронечітку систему управління краном для керування розхитуванням вантажу під час руху крану. Розглянуто основіні проблеми, які виникають під час розроблення систем управління з використанням традиційфних моделей управління. Також проаналізовано основні принципи побудови ПІД контроллерів, їхні переваги та недоліки порівняно з нечіткими системами управління. Розглянуто інтелектуальні системи управління та їх застосування для подальшого використання під час розроблення системи управління краном.

Ключові слова:портальний кран, система нечіткого виведення, нейронечіткий контролер.

In this paper a fuzzy-based crane control system for managing load swings during crane movement is presented. It is reviewed the main difficulties of constructing control system using traditional control models. Additionally, principles of construction PID controllers and their advantages and disadvantages over fuzzy systems are analyzed. Intelligent control systems and their appliance are revised for further usage in crane control system.

Key words: gantry crane, fuzzy inference system, neuro-fuzzy controller.

Introduction and analysis of the literature

The most impressive feature of human intelligence is the ability to make correct decisions in conditions of incomplete and fuzzy information. Construction of the models that reflect human thinking and their use in computer systems today is one of the most important problems in science.

Artificial intelligence that easily copes with the tasks of managing complex technical objects was helpless in such simple situations. For creating intelligent systems that can adequately communicate with a person needed a new mathematical tool to translate controversial statements in the language of strict mathematical formulas. Fuzzy logic is very useful in cases of high accuracy and repeatable operations when people might be stuck or even not able to perform such operation.

Let we have crane and we need to carry some object from point to point in the shortest time. The main problem in moving object via crane is the emergence of swinging it that leads to performance degradation, increasing transportation time and reliability of gear could cause an accidents.

One of the ways to improve efficiency of process of a control system is based on the using of human experience and the fuzzy modeling that used controller based on fuzzy logic and allows considering the adverse effects, caused by system nonlinearities.

Therefore, it is necessary to predict and to provide measures for the suppression of these swinging. Then based on fuzzy model predict power that will be applied to the crane depends on elapsed distance and swinging angle to eliminate swinging at the destination point [1].

Statement of the problem

The main objective of this work is analysis of classical control systems as that are based on PID controllers and intelligent control systems as that are using neuro-fuzzy controllers. As a result of this analysis, it was decided to use neuro-fuzzy approach for developing crane control system. Crane control system based on fuzzy logic can employ crane operator knowledge for controlling load during it transportation from point to point. Such a control system gives a possibility to automate crane management process and no longer depend on human factors as exhaustion, oscitancy and other.

The difficulty of constructing control systems

The difficulty of constructing control system defines by complexity of control object. The basic complicated features of control object are the following [2]:

- Lack of mathematical description. No algorithm for computing state of the object by observations its inputs (controlled and uncontrolled) and the observed state of the environment.
- Indeterminacy (stochasticity). It is mainly caused by the object complexity and associated with it numerous secondary processes that are neglected during the construction of a mathematical model.
- Non-stationary. It appears in drifting of the object characteristics.

PID controllers: principles of construction and modification

One of the main elements included to the control system is automatic controller-device that alters or stabilizes the output value of a control object by defined algorithm in a way of affecting on its input value.

Controllers divide to the extreme and stabilization according to one of many classifications. Extreme controllers can be used in objects that are characterized with extreme static characteristic which position in the coordinate space drifts over time depending on external influences. The most widely used stabilizing controllers.

Stabilizing controllers are classified to integrated (I), proportional (P), proportional-integral (PI) proportional-differential (PD) and proportional-integral-differential (PID) depending on the type of control functions. Control law is formed with feedbacks. It determines the type and quality of the transition process in the automatic control system with the given dynamic properties of control object.

Consider the control law and dynamic characteristics of the controllers [1].

P and PI controllers cannot prevent the expected control deviation reacting only on already existing deviation. There is a need for a controller that would be produced additional control action proportionally to speed deviation of controller value from the defined value:

$$m_A = T_A \frac{de}{dt} \tag{1}$$

Such control action is used in differential and PID controllers. PID controllers affect the object proportionally to deviation of controlled value, integral of this deviation and controlled value change rate:

$$m_A = k_p e + \frac{1}{T_I} \int_0^t e\, dt + T_A \frac{de}{dt} \tag{2}$$

PID controllers are universal by their possibilities. It is possible to get any control law using PID controllers.

Advantages and disadvantages of PID Controllers

PID controllers that have been described above have poor quality attributes in controlling of non-linear and complex systems and in the case of lack of information about the control object. In these cases controller's features can be improved by using fuzzy logic, neural networks and genetic algorithms methods. These methods are also called as "soft-computing" that is emphasizing their difference from the «hard-computing» methods because they can operate with incomplete and inaccurate information. Combination as fuzzy-PID, neuro-PID and neuro-fuzzy-PID controller with genetic algorithm can be applied to one controller. The main disadvantage of neural networks and fuzzy controllers is their time consuming tuning, creating fuzzy rules or neural network training [2].

Intelligent control systems

Intelligent control system is a system capable to «understanding» and learning in correspondence to control object, disturbances, external environment and working conditions. The main difference of intelligent systems is a mechanism of systemic knowledge processing. Mechanism of knowledge receiving, storing and processing for implementing control functions is a main architectural feature that distinguishes intelligent control system from traditional.

The following two common principles are the base of intelligent control system creating:

- Situational control. Management based on the analysis of external data, situations and events.
- Use of modern information technology of knowledge processing.

There are several modern information technologies for creating intelligent control systems:

- Expert systems.
- Artificial neural network.
- Fuzzy logic.
- Evolutionary methods and genetic algorithms.

The concept of intelligence is based on:

- Ability to work with formalized human knowledge (expert systems, fuzzy logic).
- Inherent human ways of learning and thinking (neural networks, genetic algorithms).

Structurally intelligent control systems contain additional units that perform system knowledge processing based on those information technologies. These units can be performed either as add-on conventional controller with properly adjusting its settings or directly include them to the control circuit [3–5].

Application of intelligent control systems

The most significant reasons of intelligent control systems spreading are:

- The special qualities of intelligent control systems including low sensitivity to changing of parameters of control object.
- The synthesis of intelligent control system with the applications of modern hardware and software support is often simpler than traditional ones.

There are cases where the use of intelligent control system acquitted and gives the best results:

- Regulatory system for which the control object model is determined only qualitatively or it is not available at all.
- As add-on for traditional systems for providing them adaptive properties.
- Simulation of human operator actions.
- Organizational management system of top levels (strategic and tactical).

The areas of efficient use of classical, neural networks and fuzzy control systems according to control object are shown in Fig. 1.
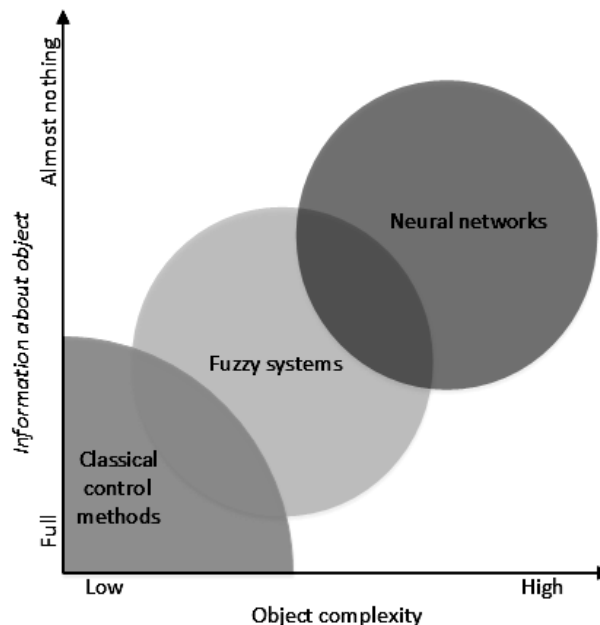

Fig. 1. The areas of efficient use of different control systems

The use of a hybrid approach as a combination of classical control methods, fuzzy logic and neural networks allows creating control systems effective in a range of situations that is why the limits of different approaches shown in Fig. 1 very relative [6, 7].

Fuzzy-based crane control system

Crane installations are used for moving load within a given path. Usually a professional operator supervises this task. During this process, the cargo may swing in a pendulum-like motion. If the swings exceed an adequate limit they must be reduced or task must be interrupted until the swings stop. One of the ways to improve control efficiency of such kind of process is using an automated control system which is based on operator knowledge of crane management [8, 9].

Swings adjusting is based on controlling of the two main input parameters as the angle relative to the vertical axis of the cargo and cargo position relative to the start/end point. As a result of investigation of different fuzzy inference systems (FIS) T-Controller system is selected for further development of neuro-fuzzy based crane control system. T-Controller is the FIS that uses fuzzy logic rules for an adequate assessment of the power that supplied to the input of the crane. Rules are formed on the formalization of knowledge and professional experience of the experts of certain industry [8].

Analysis of operator's actions show that the operator uses some "rules of thumb" to describe his management strategy [10]:

- Start with a medium power.
- If you're still far from the destination point, then adjust the engine power so that the cart has become a little more far for the "head" of the crane.
- If you are close to the destination, it is necessary to reduce the speed so that cart got a little ahead of the cranes "head".
- When the cart is very close to the destination, provide the minimum engine power.
- When the cart has reached its destination and swinging is zero, turn off the engine.

The automated crane control system is shown in Fig. 2. It visualizes the power applied to the load at the corresponding angle and position point. Crane movement process can be simulated using Euler and Runge-Kutta methods that are used for solving differential equation of crane motion.

N	Angle	Distance	Power
0	0	0	6
0	0	0	6
1	-0.001287167544	0.000558657216	5.99600959131429
2	-0.003743676996698	0.00162515160645438	5.98839177423961
3	-0.00725952088386736	0.00315279546206902	5.97748003241379
4	-0.0117319045033526	0.00509870226645418	5.96358069809676
5	-0.0170646915216368	0.00742348220186356	5.94697512712955
6	-0.0231678964122008	0.0100909621528354	5.92792169890832
7	-0.0299572199224076	0.0130679282334051	5.90665765547568
8	-0.0373536240596184	0.0163238890225039	5.8834007926964
9	-0.0452829433668231	0.01983085783831	5.85835101544065
10	-0.0536755295152099	0.0235631525167134	5.83169176773776

Fig. 2. Generated data by Euler method

Conclusion

Today, fuzzy logic items can be found in many industrial products such as electric trains control systems or military helicopters appliances. Active fuzzy logic consumers are the bankers and financiers, as well as experts in the field of political and economic analysis, which everyday tasks require to make the right decisions in difficult circumstances of unpredictable market. They use a fuzzy system to create models of various economic, political and stock situations.

Logistics systems give a possibility to use the experience and the results of experiments to provide much effective solutions for many widespread problems. They do not replace nor compete with traditional

control methods. Fuzzy logic extends the ways of implementation of automated control methods that are used in applications and adds the ability to use observations in system management. A simple example is a gantry and bridge cranes that use fuzzy inference system can provide a clear and simple solution to the problem that much more difficult to be solved using traditional management methods.

Fuzzy-based crane control system uses linguistic rules based on crane operator knowledge for managing cargo swings during crane installation work.

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METHODICAL ERRORS OF MEASUREMENT OF THE HUMAN BODY TISSUES ELECTRICAL PARAMETERS

Sources of methodical measurement errors of immitance parameters of biological tissues are described. Modeling measurement errors of RC-parameters of biological tissues equivalent circuits into the frequency range is analyzed. Recommendations on the choice of test signal frequency for measurement of these elements is provided.

Key words: biological tissue, equivalent circuit, impedance, methodical error, frequency range.

Introduction

The method of bioimpedance is widely used in the diagnosis of human physiological state, monitoring of chronic diseases and the evaluation of body composition [1, 2]. This method is non-invasive, relatively inexpensive and simple of implementation.

There are different methods of bioimpedance analysis depending on the purpose of using, methods of implementation, the frequency range. The main methods are the method of using a single frequency of the test signal, multifrequency method, bioimpedance spectrometry, analysis of bioimpedance of the whole body and individual segments [3]. Condition of the human body as a whole or its individual tissues is evaluated by monitoring the temporal changes or comparison the parameters of impedance or admittance.