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Distributed measurements and control systems for rapid prototyping of fluid power drive controllers

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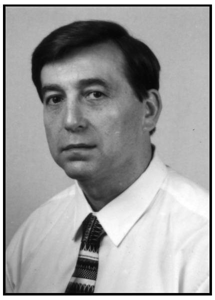

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Abstract

The paper deals with distributed measurements and control systems for rapid prototyping of artificial intelligence controller of fluid power drives. The proposed distributed system of measurements and control consists of two PC computers Target and Host. The Target PC makes up the direct control layer and is connected to the controlled systems – fluid power drive, while the Host PC makes up the supervisory control layer and serves as an operator of the direct control layer. PC computers works in Windows environment with Matlab/Simulink software package. On the basis of the distributed system of measurements and control system the fuzzy logic controller of electro-pneumatic servo-drive and adaptive controller of electro-hydraulic servo-drive were designed.

Keywords: distributed measurements and control systems, rapid prototyping, fluid power control systems.

Rozproszony system akwizycji danych pomiarowych i sterowania do szybkiego prototypowania regulatorów serwonapędów płynowych

Streszczenie

W artykule przedstawiono koncepcję rozproszonego systemu akwizycji danych pomiarowych i sterowania do szybkiego prototypowania regulatorów inteligentnych napędów płynowych. Zaproponowany rozproszony system pomiarów i sterowania składa się z dwóch komputerów Target PC i Host PC. Komputer Target PC stanowi warstwę sterowania bezpośredniego i połączony jest z obiektem regulacji – serwonapędem płynowym. Komputer Host PC stanowi warstwę sterowania nadrzędnego oraz pełni rolę operatora w stosunku do sterowania bezpośredniego. Komputery PC pracują w środowisku Windows z oprogramowaniem Matlab/Simulink. W oparciu o rozproszony system pomiarów i sterowania zaprojektowano regulator rozmyty do serwonapędu elektropneumatycznego i regulator adaptacyjny do serwonapędu elektrohydraulicznego.

Słowa kluczowe: rozproszony system pomiarów i sterowania, szybkie prototypowanie, system sterowania napędów płynowych.

1. Introduction

In the extended procedures of data acquisition and processing measurement when the advanced control algorithms in fluid power control drives (electro-hydraulic servo-drive and electro-pneumatic servo-drive) are applied both the processing capacity and PLC controllers communications are considerably limited. On the basis of PC computers running Windows XP environment with Matlab/Simulink software package advanced configurations of distributed measurement, control and adjustment systems were set up. To facilitate data acquisition and control fluid power drives a distributed environment running on two PC computers was created. The first computer directly controls is connected to controlled systems – fluid power driver while the second functions as a supervisory control layer and the operator towards the direct control layer. In the supervisory control layer complex controlled processing is carried out, the state of controlled system is analyzed and the parameters of control procedures are adjusted to obtain the optimal control conditions. The supervisory control layer in addition to identification and optimization procedures may contain a model of controlled system with control algorithm. In the direct control layer the processing, measurement and filtration procedures are conducted. The supervisory control system generates executable files and sends them to the direct control system. Data transmission between PC computers is carried out by TCP/IP protocol (LAN, Ethernet) or by means of serial ports of RS232 type. Industrial distributed measurement and control systems are based on Ethernet networks. The PC computers used in real time systems generate sampling frequency up to 100 kHz. Sampling frequency depends upon processing speed and controlled systems' parameters. Distributed measurements and control systems support many input/outup formats while additional modules: *xPC Target Explorer* lub *xPCrctool* are used for data processing and acquisition.

The proposed distributed measurements and control systems based upon two PC computers Host and Target is shown on the Fig. 1.

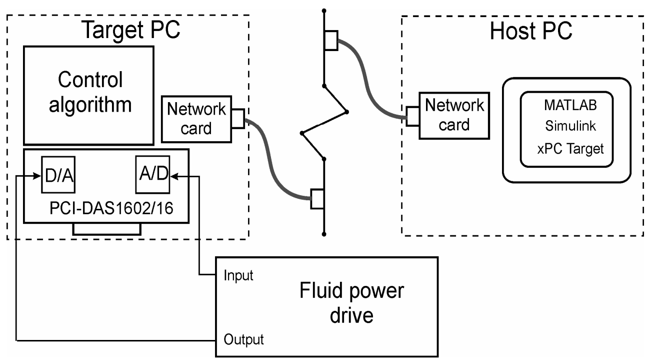

Fig. 1. Schematic diagram of distributed measurements and control systems for fluid power drives

The distributed system was used for rapid prototyping of fluid power servo-drives (electro hydraulic and pneumatic servo-drives) in real time. On PC computes Matlab/Simulink and *xPC Target* were installed. In Matlab/Simulink package it is possible to create processing procedures for both conventional and artificial intelligence controllers and to execute own control and visualization applications. PC has the card of analog input/output and *Real-Time xPC Target* system which is used for measurement data acquisition and fluid power drives control. Target PC can simulate the flow of control and measurement signals in real time by means of HIL *(Hardware-in-the-Loop)* method. Applications run by Simulink model use a real time kernel of the PC computer.

Host PC and Target PC communicate with each other by TCP/I protocol. The communication of supervisory control layer in Host PC with direct control layer in Target PC may occur continuously, periodically or at operator's specified time intervals. The software suite used in Host PC and Target PC and connections between the two computers are shown on Fig. 2. Working with the rapid prototyping suite consists in building a model of the control algorithm in Simulink. Next the model is compiled and sent to the Target PC which serves as the controller of fluid power drives together with the input/output card and the *Real-Time xPC Target* system. Measurement sensors and transducers are attached to the Target PC through the measurement card. Thanks to *xPC Traget Spy* software the visiualization of the processed data and the analysis of the process of controlling fluid power drives is possible.

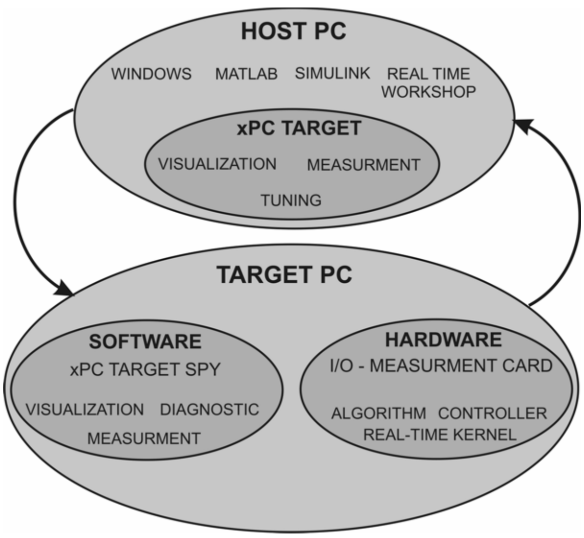

Fig. 2. Diagram of Host PC and Target PC connections according to [1]

The proposed distributed measurement and control system enables rapid prototyping of intelligent controllers allowing tuning of current controller parameters in real time as well as prognosing the future behaviour of the control process. Examples of rapid prototyping of fuzzy logic controllers and adaptive controllers of fluid power drives are presented in the following sections of the paper.

2. Distributed control system for rapid prototyping of fuzzy logic controller

On the basis of the proposed distributed measurement and control system a test stand for fast prototyping of fuzzy logic controller of electro-pneumatic servo-drives was set up. The distributed control system with FLC (*Fuzzy Logic Controller*) of PD type controlling pneumatic servo-drive is schematicaly presented in Fig. 3 [2]. Fuzzy PD controller constructed in Fuzzy Logic Tollbox of Matlab Simulink package was suggested for the purpose of controlling pneumatic servo-drive. The pneumatic servo-drive together with fuzzy PD controller constitute a system of MISO type with two inputs: position error $e(t) = y_o - y(t)$ and change of position error $\Delta e(t)$ and one output: proportional valve coil voltage $u(t)$. Output and input signals underwent fuzzification process with regular distribution of 7 fuzzy sets of triangular and trapezoid membership functions). The database rules of fuzzy controller are 49 Mac Vicar-Whelen rules described in the table entered to Fuzzy Logic Toolbox. In the inference process the firing degree was determined by means of MIN operator, implication operator and all the inputs of particular rules were aggregated by MAX operator. In the defuzzyfication process the center-of-gravity-method (COG) was applied. The dialogue window ”Rule Viewer” of Fuzzy Logic Toolbox is a kind of diagnostic device which enables tracing which fuzzy rules were activated on particular states of input. It also enables observation of fuzzy system output value. The fuzzy logic controller of PD type was tuned by means of Simulink Response Optimization Toolbox of Matlab-Simulink package.

The test stand consists of the following elements:

- pneumatic rodless cylinder (Festo DGP-25-224) with piston diameter of 25 mm and stroke length of 224 mm,
- servo-valve – proportional 5/3 directional control valve (Festo MPYE-5-1/8-HF-010-B) controlled by 0-10 V voltage of nominal flow rate 700 l/min and switching frequency 100 Hz,
- non-contact micropulse displacement transducer (Balluff BTL5-A11-M0600-P-S32), analog output signal – voltage 0-10 V,
- 16-bit measurement card (Measurement Computing Corporation AD/DA PCI-DAS1602/16) with 8 analog inputs and 2 outputs,
- PC computers Host and Target.

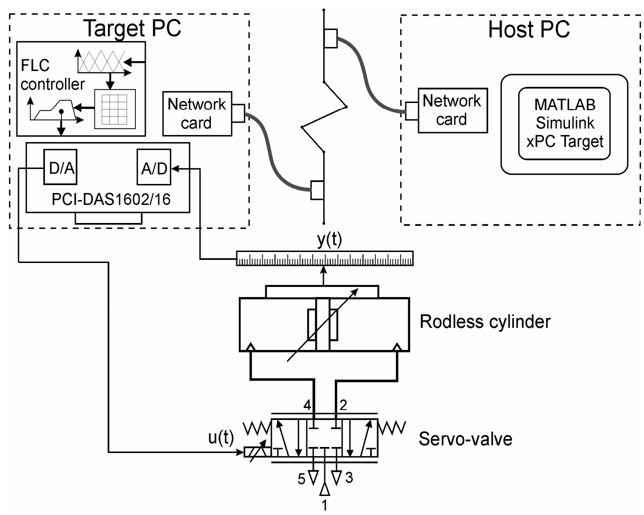

Fig. 3. Schematic diagram of electro-pneumatic servo-drive control system [3]

The proposed pneumatic servo-drive distributed control system contains two PC computers Target and Host where the first computer directly controls the pneumatic servo-drive and the second functions as the operator towards the direct control layer. In the computer marked as Host the software Matlab-Simulink together with xPC Target for rapid prototyping and real time control were installed. Target possesses an analog I/O card and a real-time xPC Target system which activates measurement data and controls pneumatic servo-drive. Host and Target communicate with each other by means of the TCP/IP protocol. Our work with the package for rapid prototyping consisted in construction and compilation of Simulink model, and sending the compiled model onto Target which together with analog I/O card and Real-Time xPC Target system functioned as real controller. Thanks to xPC Target software, the visualization of the analyzed control process was possible. The fuzzy logic PD controller enables precise positioning of pneumatic servo-drive with the precision specified for industrial manipulators. A lot of simulation and experimental tests were carried on pneumatic servo-drive with fuzzy controller which was used for its transpose and follow-up control. The designed fuzzy system is efficient, stable and resistant to disturbances and can be applied in any configurations of pneumatic servo-drive without necessity to tune the regulator, apply signal filtration or additional operations in track control or restrict the signals generated. The control system using fuzzy logic control was constructed and practically applied in various servo-pneumatic systems used in production automation – especially in the control of manipulating machines, manipulators, industrial robots as well as rehabilitation and physiotherapy manipulators [4].

3. Distributed control system for rapid prototyping of adaptive controller

On the basis of the distributed measurement and control system a test stand for rapid prototyping of adaptive controller of electro-hydraulic servo-drive was set up [5]. To test electro-hydraulic servo-system control algorithms the experimental test stand presented in Fig. 4 was constructed.

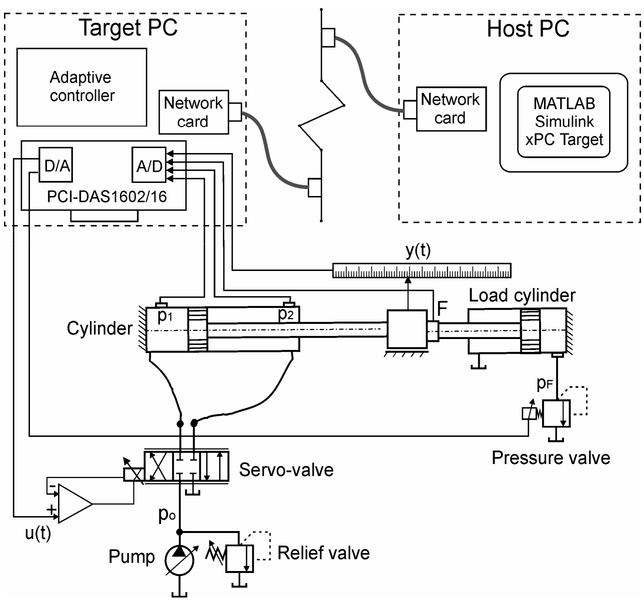

Fig. 4. Schematic diagram of electro-hydraulic servo-drive control system

The experimental test stand consists of two separately controlled control objects composed of hydraulic cylinders controlled by servo-valves (proportional 4/3 valves). The load in the analysed electro-hydraulic servo-drive resulted from slide and resistance movement caused by load cylinder. The proposed electro-hydraulic servo-drive control system contains two PC computers Target PC and Host PC where the first computer directly controls the hydraulic servo-drive and the second functions as the operator towards the direct control layer. In the computer marked as Host PC the software Matlab-Simulink together with xPC Target for identifications and real time control were installed. Target possesses an analog and digital I/O card and a Real-Time xPC Target system which activates measurement data and controls hydraulic servo-drive. Host PC and Target PC communicate with each other by means of the TCP/IP protocol. In the measurement system of hydraulic cylinders DAC and ADC converters of PCI–DAS1602/16 type manufactured by Measurement Computing Corporation were used. Piston displacement *y(t)* of hydraulic servo-cylinder was conducted by means of optical transducer. To measure pressure values in cylinder chambers $p_1(t)$ i $p_2(t)$ and pressure in supply line p_o and F force exerted by load cylinder tensometric transducers were used. The implemented software enables effective design of adaptive control systems by developing methods and techniques of identifying objects and their mathematical models off-line or in real time [6]. The distributed control system enables rapid prototyping of adaptive controllers resistant to random interferences resulting from sudden changes of masses and load forces electro-hydraulic servo-drive [7]. In hydrostatic servo-drives the attempts are made to work out such control algorithms which would be insensitive to outer disturbances caused by load mass and external forces and would ensure high precision of positioning and good dynamic properties. Servo-hydraulic positioning systems find wide application in the manipulators and robots.

4. Conclusion

The article presents the idea of a distributed system for acquiring measurement data and a control system for the rapid prototyping of artificial intelligence controllers of fluid power drives. The proposed measurement and control system consists of two computers: Host PC and Target PC. The Target PC makes up the direct control layer and is connected to the controlled systems (hydraulic and pneumatic servo-drive), while the Host PC makes up the supervisory control layer and serves as an operator of the direct control layer. The distributed system for measurement and control and the software for HIL (*Hardware-in-the-Loop)* simulation and rapid prototyping in real time was used to design the fuzzy logic controller FLC of PD type for electro-pneumatic servo-drive and adaptive controller for electro-hydraulic servo-drive. AS-Interface (*Actuator Sensor Interface*) was used in the outlined distributed measurement and control system, in which actuators i sensors constitute an integral whole, both with respect to software and hardware. The idea of a two-computer distributed measurement and control system allows for the design of highly-efficient, intelligent control systems for fluid power servo-drives with adjustable configurations. The distributed system, as an independent set of measurement and control elements with PC computers is used in modern control, adjustment and IT systems.

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Artykuł recenzowany