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UTILIZATION OF MICROCONTROLLERS IN PROCESS CONTROL

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ABSTRACT
This paper is focused on microcontrollers and their utilization in process control. New modules that implement delta representations and adaptive controllers were added to the library of control algorithms. This library can be used especially for Motorola microcontrollers. The aim of this library is to make programming easier.
The library with a few base modules was originally developed only for M68HC11 and was written in assembler. However, new modules were created in C language based programming tool called CodeWarrior. This tool brings many advantages. Modules are in separated files as it is common in C language. The files contain functions that represent specific control algorithm and this algorithm can be tune by setting of function parameters.
This paper also deals with utilization of these modules in process control. There are different types of microcontrollers and not all of them are suitable for controlling processes. We discussed limitations and possibilities of Motorola microcontrollers.
New algorithms are compatible among different types of Motorola microcontrollers and also with older modules written in assembler. New modules were examined on real systems with module for continuous identification and the results of control process are included in paper.
Keywords: microcontrollers, CodeWarrior, control

1. INTRODUCTION
Microcontrollers are often used for control of technological processes. These useful devices contain all needed parts for process control. The modern methods of automation theory are used widely for better performance and new microcontrollers provide enough memory space and of course needed speed for more and more complicated but precise control algorithms. The utilization of microcontroller for this purpose brings many advantages such is low costs or small size. However, there are some disadvantages. The programming process is quite sophisticated in comparison to standard computer. Two base approaches are used nowadays. The first one is to use the low level programming language such is assembler. The second one is via special programming software commonly based on C language. The CodeWarrior is a tool provided directly by Motorola's sister company Metrowerks. This tool can combine both approaches – assembler and C language. [1]

For easy programming process we started to develop library that can provide base functions for process control with many different control algorithms and other supportive modules. There were firstly modules only for M68HC11 microcontroller created entirely in assembler [2, 3].

Later we started to produce modules in C language. That brought compatibility and easier utilization of created modules in control project. These modules can be used independently on microcontroller type. Only one module has to be modified because it operates directly with microcontroller's peripheries. The timers, real time, serial communication or AD converter can be controlled by this module.

Modules are optimized for utilization of continuous identification. This method can identify controlled system and compute the parameters. The module for continuous identification works with method of the smallest squares [2, 3].

The choice of microcontroller is very important. The microcontroller should be equipped with basic peripheries [1] and of course these peripheries should have enough parameters. Whole library is created for utilization in many different microcontrollers; however, not all microcontrollers can provide the best properties.

2. METHODS

There are many types of microcontrollers that provide analog-to-digital converters, real time, timer, serial interface, PWM etc [1]. The special module has many functions for control these pheripheries. It depends on user and controlled system which functions would be chosen. The analog-to-digital converters were used for taking a process value, real time or timers were used for sample timing and serial communication was used for communication with superior system (PC). PWM was used as a digital-to-analog converter and this brought some problems. There are two different approaches how to control PWM.

2.1. PWM (pulse-width modulation)

Controlled system can be very fast and in this case the best choice is to use internal PWM for control this system. Internal PWM can be found in several microcontrollers; however, this function is not standard. This internal PWM is very quick. It depends on clock source (bus clock) and other properties defined by user in registers of PWM. It usually operates in MHz.

The second approach can control slow systems. The PWM in this case is replaced by timer and the pulse-width is generated by software. The pulse-width can be set to 0.2 second to several seconds. The higher limit usually depends on controlled system. This approach can be successfully used in microcontrollers with at least two timers. The one timer can be used also, but the control process is not much precise.

2.2. System identification

The controlled system was identified by continuous identification. The module can identify the system as follows [4]:

$$G\left(z^{-1}\right)=\frac{B\left(z^{-1}\right)}{A\left(z^{-1}\right)}=\frac{b_1 z^{-1}+b_2 z^{-2}+\ldots+b_{nb} z^{-nb}}{1+a_1 z^{-1}+a_2 z^{-2}+\ldots+a_{na} z^{-na}} \tag{1}$$

The data vector and vector of estimates is defined in equation (2) and (3):

$$\phi^T{}_{k-1}=\left[-y_{k-1},-y_{k-2},\ldots,-y_{k-na},u_{k-1},u_{k-2},\ldots,u_{k-nb}\right] \tag{2}$$

$$\hat{\Theta}^T(k)=\left[\hat{a}_1,\hat{a}_2,\ldots,\hat{a}_{na},\hat{b}_1,\hat{b}_2,\ldots,\hat{b}_{nb}\right] \tag{3}$$

The module for continuous identification can be used for delta representation too. The order of controlled system cannot be higher than two. This module can identify the system as a system of the first and second order (4) [5]:

$$G\left(z^{-1}\right)=\frac{b_1 z^{-1}}{1+a_1 z^{-1}} \qquad G\left(z^{-1}\right)=\frac{b_1 z^{-1}+b_2 z^{-2}}{1+a_1 z^{-1}+a_2 z^{-2}} \tag{4}$$

2.3. Control algorithms

The library already contained the modules for standard control algorithm like Ziegler-Nicholse or Pole-placement method. The first algorithm was chosen for comparison of standard method and delta modification. Delta modification is defined in transformation [5, 6]:

$$\gamma = \frac{z-1}{\lambda T_0 z + (1-\lambda) T_0} \tag{5}$$

There are several different delta transformations. Forward and backward transformation or for example Tustin transformation. All of these transformations are based on equation (5). The only difference is in parameter $0 \le \lambda \le 1$. The $\lambda = 0$ was used in this project so that the forward transformation was in the format [5, 6]:

$$\delta = \frac{z-1}{T_0} \tag{6}$$

The system is than identified as follows [6]:

$$G(\delta) = \frac{\beta_1 \delta + \beta_2}{\delta^2 + \delta \alpha_1 + \alpha_2} \tag{7}$$

The data vector and vector of estimates had to be changed to [6]:

$$\phi^T = \left[-\frac{y(k-1) - y(k-2)}{T_0}, -y(k-2), \frac{u(k-1) - u(k-2)}{T_0}, u(k-2) \right] \tag{8}$$

$$\hat{\Theta}^T = [\alpha_1, \alpha_2, \beta_1, \beta_2] \tag{9}$$

3. RESULTS

The modules were examined on heat systems. The set point was 60 and 70 degrees of Celsius and the sample time was 6 second. In this case the pulse width in PWM was set to 0.5 second.

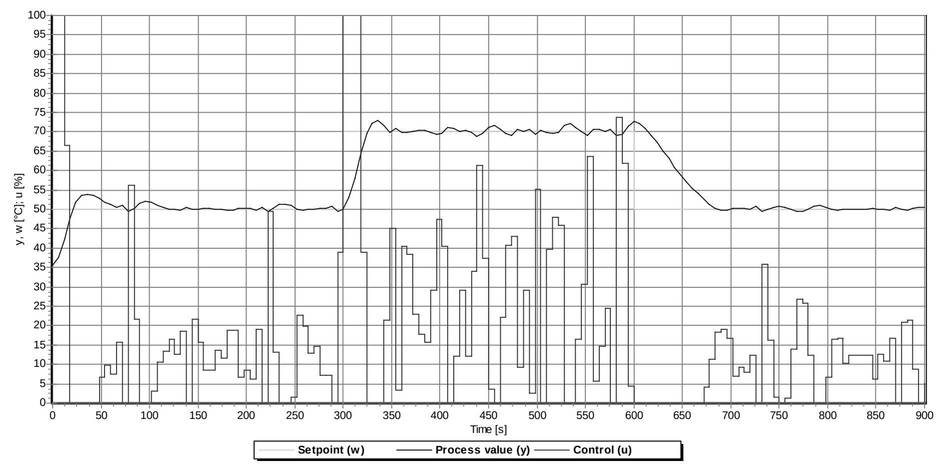

Figure 1. Control process of Ziegler-Nicholse algorithm

As can be seen in figures the delta modification provides better process value with the same sample time. The controlled system was identified as a second order system. In the last figure can be seen the performance of one adaptive algorithm used on the same system but with 10 second sample time.

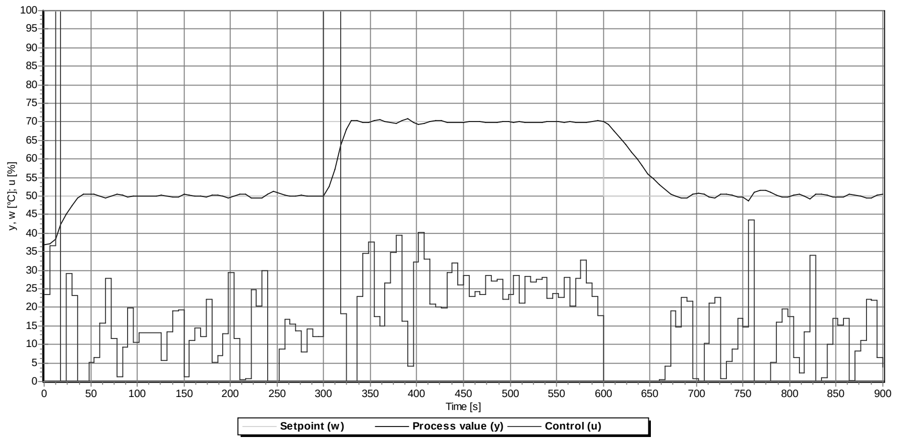

Figure 2. Control process of Ziegler-Nicholse algorithm with delta modification

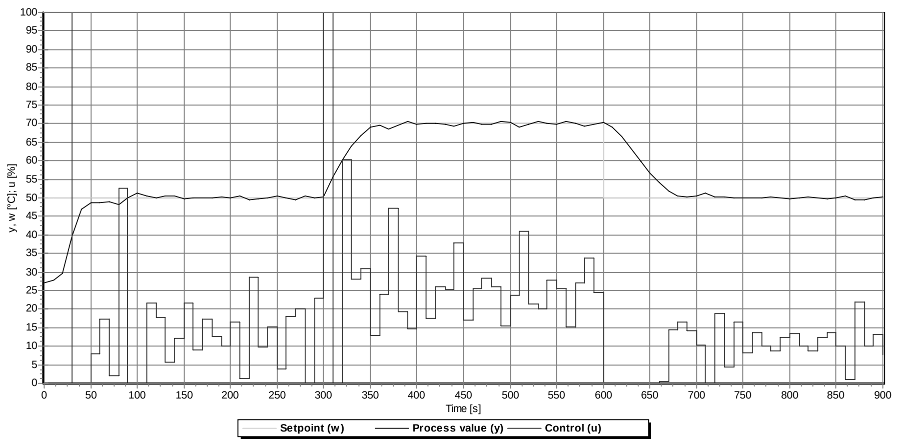

Figure 3. Control process of adaptive algorithm

4. CONCLUSION

Utilization of modern automation algorithms in microcontrollers is simple with such a library. All modules are in separate files that can be included to final project. The delta modification will be used also for adaptive and other algorithms for better performance with small sample times. This library can be continuously upgraded by including new modules with many new algorithms.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Morton, D. Todd.: Embedded Microcon-trollers. Prentice Hall, Upper Saddle River 2001. ISBN 0-13-907577-1

[2] Dolinay, J.: Diploma work – Programové moduly řídicích a identifikačních algoritmů pro mikropočítač 68HC11. Zlín 2002,

[3] Dolezel, P., Vasek, V.: Modules for Adaptive Process Control for the M68HC08 Microcontroller. Annals of DAAAM for 2005 & Proceedings. Vienna 2005. ISBN 3-901509-46-1

[4] Bobál, V., Chalupa, P.: Self-Tuning Controllers Simulink Library. Zlín 2003. Available on: http://www.utb.cz/stctool/,

[5] Bobál, V., Böhm, J., Prokop, R., Fessl, J.: Praktické aspekty samočinně se nastavujících regulátorů: algoritmy a implementace. Brno 1999. ISBN 80-214-1299-2,

[6] Bobál, V., Dostál, P., Sysel, M.: Self-Tuning PID Controller Using d – Model Identification. Proceedings of the 7th Mediterranean Conference on Control and Automation. Haifa, Israel 1999.