SIGNAL PRE-PROCESSING SUBSYSTEM FOR THE PURPOSE OF INDUSTRIAL CONTROL

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Abstract: Commonly used methods of signal processing are often too complex and many of them induce time delay between the original and processed signal. A problem arises how to supply the controller with quality input signals without substantial delay taking limited computing power of the controller's hardware into account. A possible solution based on a signal pre-processing subsystem (SPS) delivering quality input signals to the controller is described in this paper. Concept of the SPS is based on a hardware unit with a real-time operating system managing a composition of application tasks. Hardware and software structure of the SPS is composed to enable to utilize the following specific signal processing strategy. Different signal processing methods process a particular signal simultaneously and an algorithm of continuous decision making provides the momentary best possible result in the form of a weighted combination of outputs generated by single signal processing methods. Solution is intended for enhancement of the automatic thickness/gauge control (AGC) for cold rolling mills.

1 INTRODUCTION

The quality of a process control is substantially influenced by the quality of the controller's input signals. In cases where the quality of input signals is low, methods of signal processing come into account. But these methods are often complex and require a computing power. At the same time the methods of signal processing (e.g. filtering) usually bring some time delay of the signal (Vaseghi, 1987). If the controlled process is fast, quality of input signals is low and the control algorithm is complex at the same time, a problem arises how to deliver quality input signals without substantial delay to the control algorithm with a limited computing power of the controller's hardware. With the aim to solve this problem, the computing power is usually increased within the controller's hardware unit by the use of higher clock frequency of CPU or by adding of another CPU or another CPU board. But there are cases where this solution is not possible without the change of the whole hardware base or where current technical limits are reached. Then, another possibility is used. The controller's hardware is distributed to more hardware units connected to a computer network.

This paper describes the latter possibility - a solution of this problem using a signal pre-processing subsystem (SPS). The SPS is designed for delivering quality input signals for the controller via a computer network. Solution is introduced in the application of the automatic thickness/gauge control (AGC) of a metal strip produced by a cold rolling mill.

2 MOTIVATION

Some industrial applications of control indicate that the standard concept using an all-in-one hardware unit for input signal acquisition, control algorithm execution and output signal distribution has in some cases its drawbacks:

- While the control algorithm and the part of the controller ensuring the algorithm execution are more or less standardized for a particular

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application, the part of the controller supplying the control algorithm with input signals is highly dependent on the nature and quality of input signals and usually has to be changed substantially.

- Computing power of controller's hardware unit may not be sufficient for execution of both the complex control algorithm (Ettler, 1992) and application of sophisticated signal processing methods on low-quality input signals.
- Because of an effort to minimize time delay imposed by some signal processing methods on the signals, the scan frequencies of signal acquisition must be much higher than the actual frequency of control loop, and this brings further demands on computing power of the hardware unit.
- Last but not least, the all-in-one hardware unit solution does not allow to position the input signal data acquisition and digitization as near as possible to the sensor which is desirable to avoid long distance wiring and to reduce noise influence.

3 SOLUTION

Possible solution of the above mentioned drawbacks includes decomposition and functional and topological distribution of the controller's hardware unit. This approach is widely spread and is commonly used in many control applications. Main contribution of our solution consists in complex approach to the processing of input signals with the aim to find a base for a more or less universal solution of input signal quality improvement in a set of similar control applications.

3.1 Decomposition and Distribution

The original all-in-one solution of the controller is to be decomposed first. The input signal acquisition is detached from the controller's hardware unit and realized by a separate hardware unit called signal pre-processing subsystem (SPS). Generally, there can be a set of SPSs in the framework of a particular control application. The control algorithm and output signal distribution is executed within the original hardware unit.

The SPS is located as near as possible to the sources of the acquired input signals.

The SPS processes the inputs and resulting enhanced signals are transferred to the controller via a dedicated high speed computer network.

3.2 Signal Pre-processing Subsystem

The signal pre-processing subsystem (SPS) is the new key component of the controller.

3.2.1 Concept of Signal Processing in SPS

Processing of controller's input signals in the SPS has the following key ideas:

- Scan frequencies of input signal acquisition are an order higher than the frequency of control algorithm loop.
- Acquired signal data is buffered before further processing.
- One input signal is processed by several signal processing methods in parallel.
- The currently best result of the particular signal processing methods or a weighted combination of several ones is chosen as final input to the controller with the help of a probabilistic algorithm of continuous decision making.
- The latest values of processed signals are transmitted via the network to the controller upon request.

Real-time operating system is the base for the application software structure. Structure and code of the application tasks are kept as simple as possible to spare the computing power and enable to increase the scan frequencies of the SPS.

The increase of the signal acquisition scan frequencies brings obviously better starting conditions for subsequent signal processing methods. Contribution of the increased scan frequency of the SPS in comparison to the input signal acquisition frequency of the original all-in-one controller is illustrated by Figure 3.

Sufficient computing power of the SPS dedicated to signal processing enables to process one signal by several signal processing methods in parallel.

The selection and combination of the outputs from the particular signal processing methods is the matter of a specialized probabilistic algorithm of continuous decision making. Outputs from this algorithm are buffered in the SPS and prepared for transmission to the controller.

3.2.2 Transmission of Pre-processed Input Signals from the SPS to the Controller

As mentioned above, the pre-processed input signals are ready and continuously updated in the SPS's memory. For the transmission of the processed signals to the controller, a local area network (LAN) is used. It can bring difficulties together with

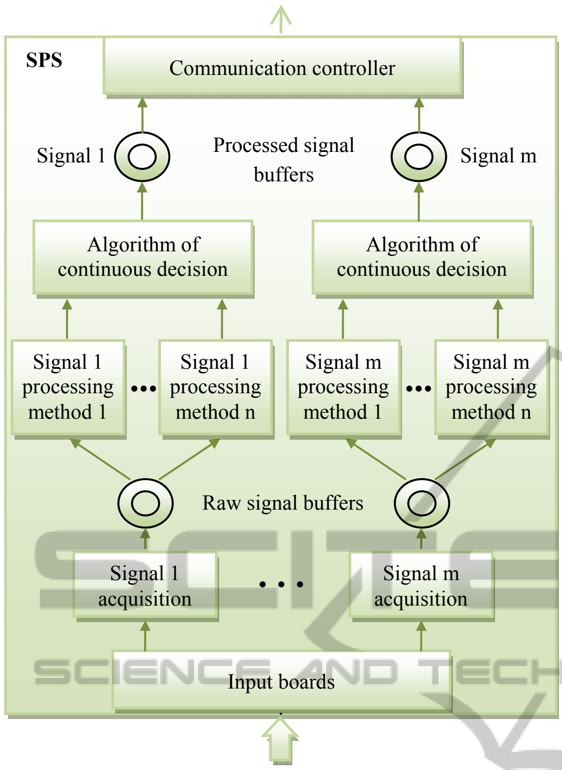

Figure 1: Internal structure of the signal pre-processing subsystem.

advantages mentioned above. Possible unreliability and time delay of data transmission via the LAN must be taken into account. These problems are discussed in many papers concerning the networked control systems. A method for testing of networked control systems is described in (Hassapis et al., 2005).

For the purposes of testing and proof of functionality of the SPS concept, a common type of network is used. SPSs and the controller are connected by standard Gigabit Ethernet network. This type of network can ensure sufficient stability of the scan period under following conditions:

- The amount of transmitted data is relatively small.
- The communication has the character of frequently transmitted short packets.
- The network is dedicated to SPSs and controller only.
- Controller acts as a logical master and triggers communication with SPSs - slaves.
- A low level communication protocol is used (e.g. TCP/IP sockets).

An alternative to this simple solution is one of the real-time industrial networks.

4 PILOT APPLICATION

As the pilot application of the SPS, the automatic thickness/gauge control (AGC) of a metal strip produced by a cold rolling mill was selected.

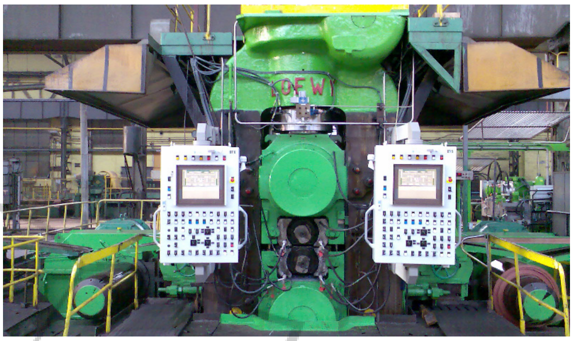

Figure 2: An example of a cold rolling mill.

This is an application where principles of the technological process are well known and control algorithms are proved. Further improvements of control algorithms bring only small increase of the production quality. On the other hand, there is a big potential in the quality improvement of input signals that positively influences control algorithm results and thus the production quality can be increased.

The following picture illustrates the contribution of higher signal acquisition frequency of the SPS. The signal is the strip speed measured by an incremental rotary encoder.

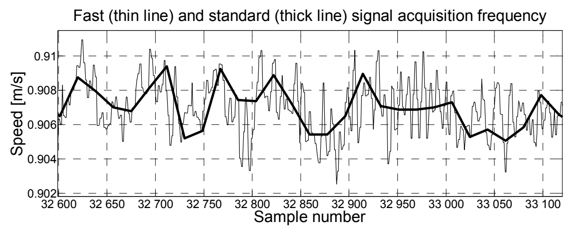

Figure 3: Comparison of raw signal data acquired by the original all-in-one controller (thick line) and by the SPS (thin line). Sample number of X-axis corresponds to the thin line.

In the following sequence of pictures, there can be seen an angular speed signal processed by the SPS. The signal measures the rotation of the deflection roll using an incremental rotary encoder.

The signal is processed by three methods that are executed simultaneously. The first method is a moving average filter with the window corresponding to one revolution of the roll. The second method is a trend preserving filter designed for a short delay filtering. The third method calculates a correction of filtered signal that improves the result especially during the time of acceleration and deceleration. This method is based on the incremental rotary encoder's properties. For detailed description see (Ettler et al., 2010). These methods are processed in parallel, and in this selected time period, a combination of the second and the third method is selected as the result.

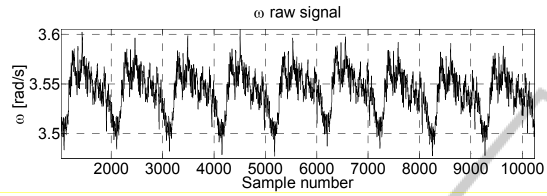

Figure 4: Angular speed raw signal.

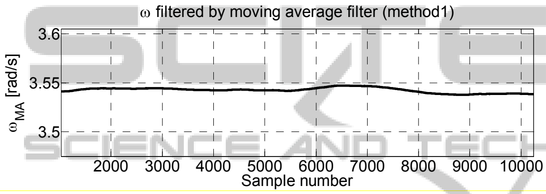

Figure 5: Angular speed filtered by moving average filter.

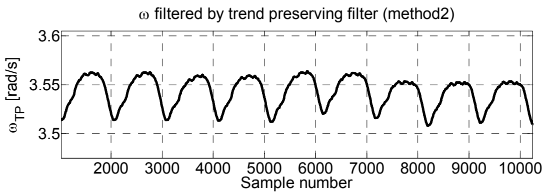

Figure 6: Angular speed filtered by trend preserving filter.

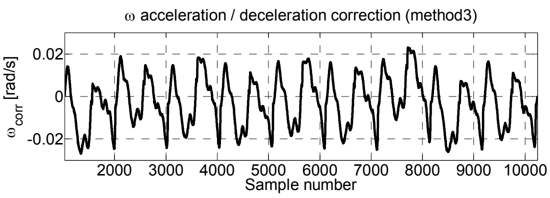

Figure 7: Correction of the filtered angular speed that improves the result especially during the time of acceleration and deceleration.

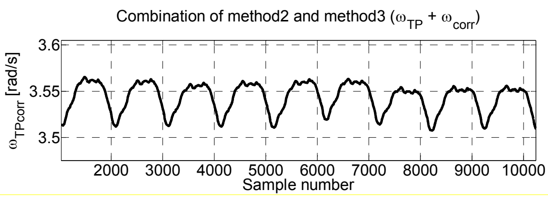

Figure 8: Combination of two methods selected as the input for the controller.

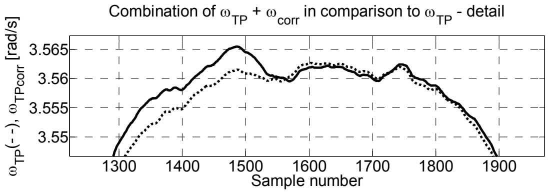

Figure 9: Comparison of the trend preserving filter output with and without (dotted line) acceleration / deceleration correction.

5 CONCLUSIONS

With the aim to improve the results of a set of high speed control applications, the signal pre-processing subsystem (SPS) was designed. The functionality of the controller with SPS was approved by the pilot application of the automatic thickness/gauge control (AGC) of a metal strip produced by a cold rolling mill. Several basic signal processing methods specific for the selected application were implemented within the SPS. Development and implementation of further methods and of the selection and combination algorithm are a part of two currently running research projects.

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