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# Extending functionality of the control system using MTConnect data collection standard

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**Abstract.** The necessity is substantiated and the concept of the implementation of the MTConnect data exchange standard in CNC systems for the monitoring of equipment operating in the contract manufacturing system is presented. The methods of data exchange are analyzed. The architecture of a CNC system with support for the MTConnect standard and a mechanism for the transfer, processing and storage of data are proposed. Testing of technical solutions in the AxiOMA Control CNC system is demonstrated.

## 1. Introduction

In connection with the increase in the volume of small-scale and single-unit production, large manufacturers are being supplanted in industry, and small enterprises operating in accordance with the system of contract production appear in their place. The essence of contract manufacturing is that the customer company transfers the production of products to other enterprises that accept many different orders for sale. Thus, the concept of contract manufacturing allows large corporations involved in the creation of high-tech equipment, transferring production to outsourcing, to concentrate on their basis the scientific potential involved in research, design, development and implementation of innovative technologies. It is possible to provide a high level of equipment load for small enterprises.

The executing company receives either a developed technological process by which it will manufacture products, or it receives documentation and technical requirements for the product and independently develops the technological process and makes these products. Its task and responsibility to the customer is to ensure compliance with the technological cycle and quality control of finished products in accordance with customer requirements.

Currently, the outsourcing of most enterprises is world-wide, and therefore, inevitably there is a need to control the quality of technological processes at remote facilities. Thus, there is a transition from simple contract production to virtual corporations, when individual production ceases to be separate contracting organizations, and becomes an integral part of a large virtual corporation and is responsible for the release of quality products on time. Under these conditions, increased requirements for the performance of machines. It is important for the contracting company that the contractor guarantees that its equipment now, in its actual condition, can carry out the program to produce the required number of products in accordance with the prescribed technological process. This requires systems for automatic assessment and maintenance of the status of critical components of the machine, which in general is the health of the machine.



## 2. Data Exchange Standards

The work of a virtual corporation is impossible without using of various world standards. Corporations are large customers and sources of financing for their contractors, they impose strict requirements on the formats for exchanging documents and data. Contractors, wishing to participate in the production chain, need to provide support for the necessary exchange formats at their level. Thus, manufacturers will choose equipment that will be able to interact with higher-level systems through standard data exchange protocols. For machine tools, the implementation of such protocols falls at the level of the control system. That is, support for standardized data exchange methods for numerical control systems is a competitive advantage.

For example, Boeing uses the STEP-NC standard to develop components, assemblies and other assembly units of aircraft, which allows integrating models and technology for various industries (electronic components, hydraulic and pneumatic components, machining industries, etc.) within a single document. ) In terms of feedback, other international standards apply, for example, MTConnect or OPC UA [1].

MTConnect is one of the standards for data exchange designed to receive process and operational data directly from numerical control systems. The standard defines the following things:

- an exchange protocol in the form of XML documents and their schemes,
- format for the description of the components of machine tools and data sets for each of them,
- methods of organizing data streams from technological equipment.

OPC UA is another standard for interfacing with machine tools. That was appeared before the MTConnect standard. Compared to MTConnect, OPC UA has wider functionality, for example, method calls, subscriptions with a “dead zone” and aggregations, processing of historical data and providing type safety. In addition, it allows to transfer data other than text in binary format, which significantly reduces the amount of data transmitted [2,3].

## 3. AxiOMA Control System Architecture with MTConnect Support

Data from CNC technological equipment must be collected, processed, accumulated and used for monitoring and decision making within the framework of the Industry 4.0 concept [4-8]. The company can operate machine tools with various control systems. Each control system receives data on the status of drives, safety devices, etc. [9-11]. To transfer data from various CNC systems to the level of MES-systems, SCADA-systems, enterprise management systems, it is necessary to use a single standard protocol.

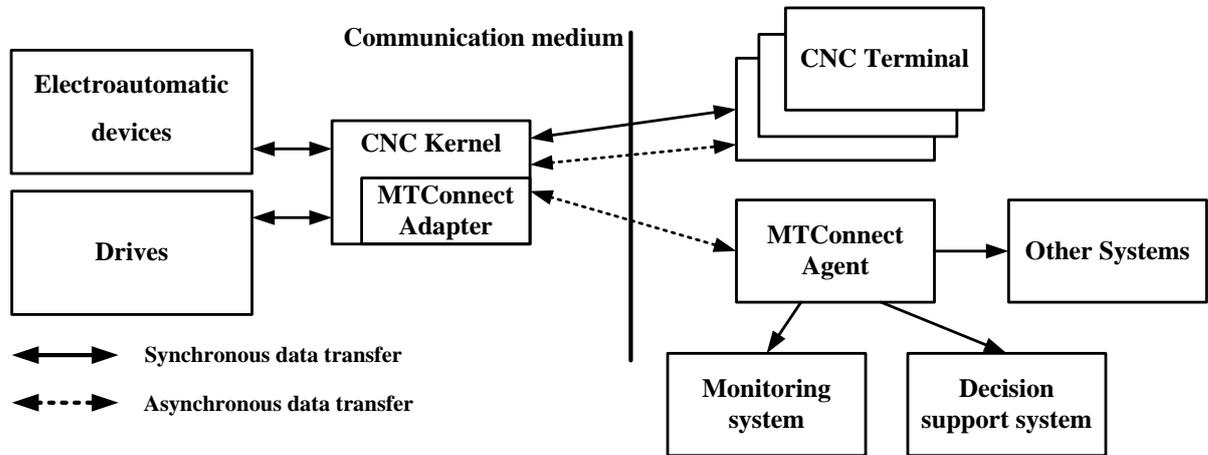
MTConnect standard support for a numerical control system comes down to the implementation of two main modules: an adapter and an agent [12-15].

MTConnect adapter convert the data received from the machine tools in the native format of the CNC system to the dictionary format defined by the MTConnect standard.

MTConnect agent is a module that collects data received from various systems and integrates with a top-level management system.

Any CNC system can provide its technological and operational information in its internal format. Typically, this format is used for interaction between the components of the CNC system. Figure 1 shows the interaction between the terminal and the kernel of the AxiOMA Control system [16-19]. CNC system kernel receives information from the drives and electroautomatic devices of machine tools. By means of a communication medium, which can be used as Ethernet, or various industrial buses (PROFINET, SERCOS-III and others), the data is transmitted to the terminal part. Data can be transmitted via synchronous or asynchronous channels: a synchronous data exchange channel works as follows - a client requesting data waits for it to arrive and uses it (for example, processing a user presses a button on a panel), an asynchronous channel - a client requests data, for example, a terminal it requests the values of the current coordinates, and continues to work, the updated coordinates arrive at the terminal with a certain frequency and are displayed on the screen [20,21]. The adapter can be implemented as part of the control system kernel, or as a separate process. Using MTConnect protocol, data is transferred asynchronously through the Adapter to the Agent. Data received by the agent can be

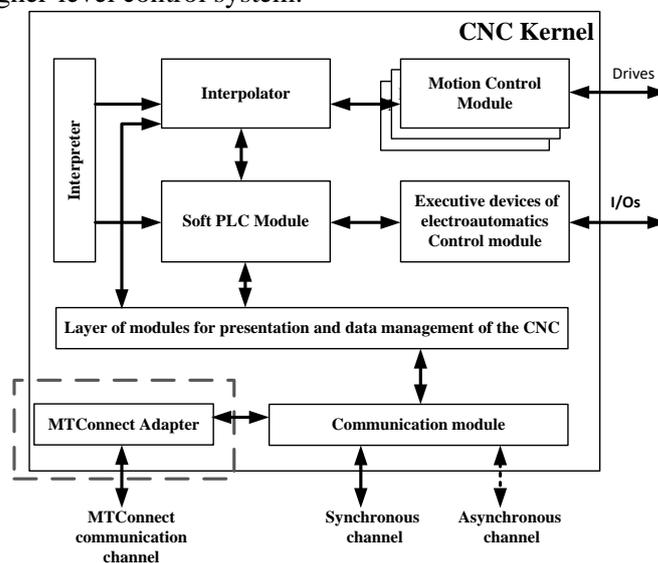
transferred to monitoring systems to monitor the status of machine tools, to decision support systems, to other systems, such as data analysis systems, enterprise databases, etc.



**Figure 1.** Interaction between the terminal and the kernel of the AxiOMA Control.

Data exchange is carried out using a communication module as part of the kernel of the CNC system. To solve the problem of integrating support for the MTConnect protocol in the AxiOMA Control CNC system, the adapter module is integrated as an intermediate component between the communication module and the physical data transfer interface (Figure 2).

The MTConnect adapter translates data in the internal format of the AxiOMA Control CNC system into the format defined by the international MTConnect specification. Data in the MTConnect format is transmitted to a higher-level control system.



**Figure 2.** MTConnect Adapter in the kernel AxiOMA Control system.

#### 4. Testing the operation of the MTConnect Adapter in the CNC AxiOMA Control

The MTConnect standard supports four types of queries:

- Probe request - equipment metadata that is requested and is currently presented in the agent;
- Sample request - a set of values for data objects currently available for streaming data from an agent, taking into account any filtering defined in the request;

- Current request - the current value of the data objects associated with each piece of streaming data available from the agent, taking into account any filtering defined in the request;
- Assets request - information about the active equipment (parts of equipment) of MTConnect from the agent, subject to any filtering defined in the request.

Using Probe Request as an example, consider the execution of a request (Figure 3). The top-level control system (MES-, SCADA-system and others) creates a request to determine the axes, their types and units of measurement along the axes for the machine tool. This request is addressed by the MTConnect Agent, which generates an XML document with the appropriate parameters. Further, this document is transmitted to the MTConnect Adapter, which accesses the CNC system, receives the appropriate parameters from it. Then these parameters are added to the XML document and transferred to the MTConnect Agent. MTConnect Agent transfers the received information to the top-level management system, which parses this document and presents it in a form convenient for the user, for example, in the form of a table.

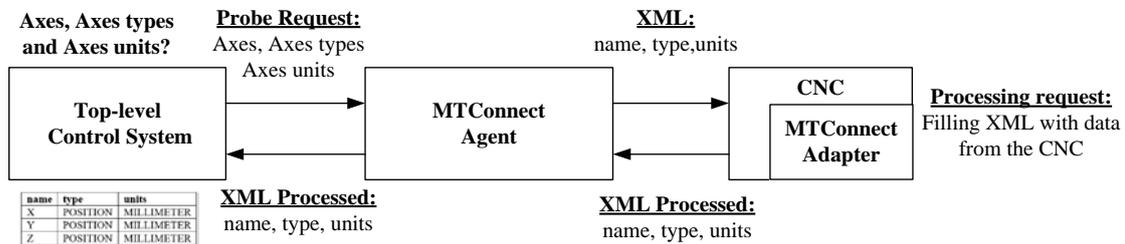


Figure 3. Example of the executing a Probe Request.

4.1. Probe Request

Using this request, it is possible to get the hierarchical structure of equipment connected to the CNC with the MTConnect adapter.

As an example, consider the adapter receiving the axis parameters from the CNC system: the name of the axis, its type (speed or position feedback), the units of movement along the axis (mm, inch). To execute the Probe Request, the adapter accesses the control for data by sending a request to http://127.0.0.1:5000/probe. The CNC system for querying can interrogate devices using its mechanisms or transmit machine parameters. It is enough information from machine parameters for this example with axes. Information is transferred to the MTConnect Adapter, written to an XML file. Figure 4a shows a fragment of an XML document with axis information. The XML file is then transferred through the MTConnect Agent to the top-level management system. Figure 4b shows a variant of the presentation of the received data by the top-level control system.

```
<Axes id="axes" name="axes">
<Components>
<DataItems>
<DataItem name="X" type="POSITION"
units="MILLIMETER">
<DataItem name="Y" type="POSITION"
units="MILLIMETER">
<DataItem name="Z" type="POSITION"
units="MILLIMETER">
</DataItems>
</Components>
</Axes>
```

name	type	units
X	POSITION	MILLIMETER
Y	POSITION	MILLIMETER
Z	POSITION	MILLIMETER

a)

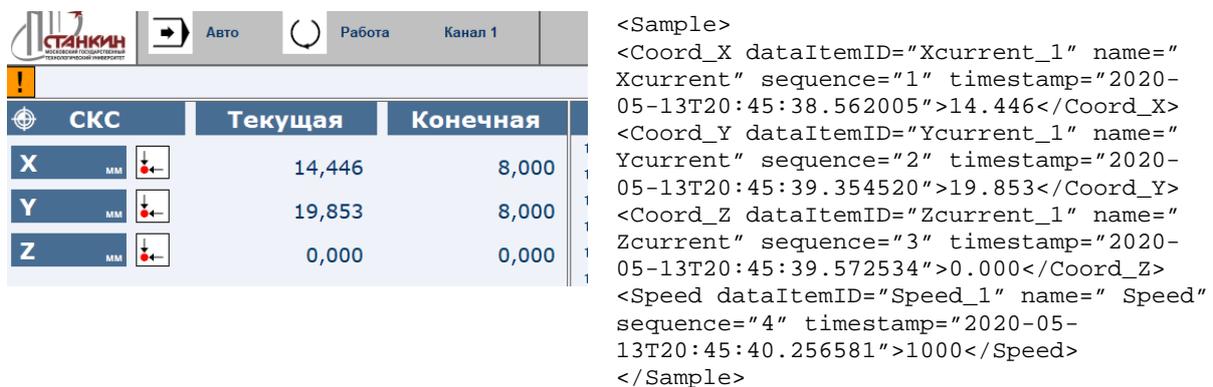
b)

Figure 4. Fragment of an XML document with information about the axes (a) and a variant of the presentation of the received data (b).

#### 4.2. Current Request

Using this request, it is possible to get the current values of data objects connected to the CNC with the MTConnect adapter.

As an example, consider the adapter receiving the parameters of the current coordinate values and spindle speed. To execute the Current Request, the adapter accesses the CNC for data, sending the request to `http://127.0.0.1:5000/current`. The CNC system, upon request, transmits data on the current position and speed values to the adapter. Information is written to the XML file. Figure 5 shows a fragment of an XML document with information. The XML file is then transferred through the MTConnect Agent to the top-level management system. An agent can collect data from several pieces of equipment, so in each container you can specify the name of the equipment and its global identification number.



**Figure 5.** Example of writing an XML document to obtain the current values of the coordinates along the axes and spindle speed.

#### 4.3. Sample Request

As an example, consider the adapter receiving the parameters of the coordinate values and spindle speed for a certain period. To execute the Sample Request, the adapter calls the control for data, sending a request `http://127.0.0.1:5000/sample?from=0&count=5`. Sample requests are sent with parameters, where the from parameter determines from which starting point of the data sequence in the agent buffer to receive data (sequence) and count determines the amount of received data after the starting point. The result will be a document containing data that fell within the specified range. The CNC system, upon request, transmits data on the current position and speed values to the adapter. Information is written to an XML file.

### 5. Conclusions

Integration into the Russian AxiOMA Control CNC system of support for the international standard for MTConnect data exchange significantly increases the competitiveness of the system. It allows it to be easily integrated into higher-level production control systems together with control systems of other, including leading foreign, manufacturers.

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### References

- [1] Liu C, Vengayil H, Lu Y and Xu X. 2019 A Cyber-Physical Machine Tools Platform using OPC UA and MTConnect *Journal of Manufacturing Systems* **51**:61-74. doi: 10.1016/j.jmsy.2019.04.006
- [2] Jasperneite Ü, Neumann A and Pethig F 2015 OPC UA versus MTConnect *Control & Drives* 16-21.

- [3] Martinov G, Issa A and Martinova L 2019 Controlling CAN Servo Step Drives and Their Remote Monitoring by Using Protocol OPC UA *2019 International Multi-Conference on Industrial Engineering and Modern Technologies, FarEastCon 2019* 1-5. doi: 10.1109/FarEastCon.2019.8934338
- [4] Martinov G M, Kovalev I A and Chervonnova N Y 2020 Development of a platform for collecting information on the operation of technological equipment with the use of Industrial Internet of Things *IOP Conference Series: Materials Science and Engineering* **709(4)** 044063 IOP Publishing. doi:10.1088/1757-899X/709/4/044063
- [5] Martinov G M, Pushkov R L and Evstafieva S V 2020 Collecting diagnostic operational data from CNC machines during operation process *IOP Conference Series: Materials Science and Engineering* **709(3)** 033051 IOP Publishing. doi:10.1088/1757-899X/709/3/033051
- [6] Martinov G M, Ljubimov A B and Martinova L I 2020 From classic CNC systems to cloud-based technology and back *Robotics and Computer-Integrated Manufacturing* **63(June)**. doi: 10.1016/j.rcim.2019.101927
- [7] Martinova L, Sokolov S and Babin M 2020 Organization of Process Equipment Monitoring *2019 XXI International Conference Complex Systems: Control and Modeling Problems (CSCMP)* Samara: IEEE doi:10.1109/CSCMP45713.2019.8976506
- [8] Lei P, Zheng L, Li C, Li X 2016 MTConnect Enabled Interoperable Monitoring System for Finish Machining Assembly Interfaces of Large-scale Components *Procedia CIRP 9th International Conference on Digital Enterprise Technology - DET 2016 – “Intelligent Manufacturing in the Knowledge Economy Era* **56** 378 – 383. doi: 10.1016/j.procir.2016.10.060
- [9] Martinova L I, Kozak N V, Nezhmetdinov R A, Pushkov R L and Obukhov A I 2015 The Russian multi-functional CNC system AxiOMA control: Practical aspects of application *Automation and Remote Control* **76(1)** 179-186. doi:10.1134/S000511791501018X
- [10] Nikishechkin P A, Chervonnova N Y and Nikich A N 2020 An approach of developing solution for monitoring the status and parameters of technological equipment for the implementation of Industry 4.0 *IOP Conference Series: Materials Science and Engineering* **709(4)** 044063. doi:10.1088/1757-899X/709/4/044063
- [11] Nikishechkin P, Chervonnova N and Nikich A 2018 Approach to the construction of specialized portable terminals for monitoring and controlling technological equipment *MATEC Web of Conferences, International Conference on Modern Trends in Manufacturing Technologies and Equipment (ICMTMTE 2018)* **224** 1-9. doi:10.1051/mateconf/201822401089
- [12] Edrington B, Zhao B, Hansel A, Mori M and Fujishima M 2014 Machine monitoring system based on MTConnect technology *Procedia CIRP* **22** 92 – 97. doi: 10.1016/j.procir.2014.07.148
- [13] Liu X F, Shahriar M R, Al Sunny S M N, Leu M C, Cheng M and Hu L 2016 Design and implementation of cyber-physical manufacturing cloud using MTConnect *Proceedings of the ASME 2016 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2016* 1-10 doi: 10.1115/DETC2016-60483
- [14] Lynn R, Louhichi W, Parto M, Wescoat E and Kurfess T 2017 Rapidly deployable mtconnect-based machine tool monitoring systems *ASME 2017 12th International Manufacturing Science and Engineering Conference, MSEC 2017 collocated with the JSME/ASME 2017 6th International Conference on Materials and Processing* 1-10. doi: 10.1115/MSEC2017-3012
- [15] Lynn R, Wescoat E, Han D and Kurfess T 2018 Embedded fog computing for high-frequency MTConnect data analytics *Manufacturing Letters* **15(B)** 135-138. doi: 10.1016/j.mfglet.2017.11.002
- [16] Grigoriev S N and Martinov G M 2016 An ARM-based Multi-channel CNC Solution for Multi-tasking Turning and Milling Machines *Procedia CIRP* **46** 525-528. doi:10.1016/j.procir.2016.04.036

- [17] Martinov G M and Kozak N V 2016 Specialized numerical control system for five-axis planing and milling center *Russ Eng Res* **36(3)** 218-222. doi:10.3103/S1068798X16030126
- [18] Martinov G M, Nikishechkin P A, Grigoriev A S and Chervonnova N Yu 2019 Organizing Interaction of Basic Components in the CNC System AxiOMA Control for Integrating New Technologies and Solutions *Automation and Remote Control* **80(3)** 584–91. doi:10.1134/S0005117919030159
- [19] Martinova L I and Martinov G M 2018 Automation of machine-building production according to industry 4.0 *RPC 2018 - Proceedings of the 3rd Russian-Pacific Conference on Computer Technology and Applications* 1-4. doi:10.1109/RPC.2018.8482165
- [20] Pushkov R, Salamatin E and Evstafieva S 2018 Method of developing parametric machine cycles for modern CNC systems using high-level language *International Conference on Modern Trends in Manufacturing Technologies and Equipment (ICMTMTE 2018)* **224** 1-7. doi:10.1051/mateconf/201822401116
- [21] Martinov G M, Grigoryev A S and Nikishechkin P A 2015 Real-time diagnosis and forecasting algorithms of the tool wear in the CNC systems *Advances in Swarm and Computational Intelligence* **9142** 115-26. doi:10.1007/978-3-319-20469-7\_14