MTConnect Challenge

Smart Factory Through MTConnect

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Abstract

Today’s machine shops are full of different machines; however only a small percentage is monitored and/or managed efficiently. The advancements in machine communication protocols as well as web technologies will enable increasing number machines to be monitored to improve productivity. This will prevent the shop floor from being a stand-alone unit in the organization thus making it an integral part of the business system. The rich machine data has great potential in simplifying the decision making process to create operational excellence and competitive advantage.

This work will present ideas for real-time monitoring/management of machines through a web-based application using MTConnect protocol. The proposed system will create visibility/transparency in the production environment by providing utilization/productivity metrics as well as real-time process parameters. The same system will also provide real-time warnings/alarms and map those to machine health condition. MTConnect protocol has been selected due to its rapidly enlarging community and support from various equipment manufacturers. The proposed system (with 2D/3D end-user interfaces) is web-based which makes it cross-platform and more manageable compared to standalone software.

Proposed Idea

The purpose of this work is to introduce a smart, web-based, cross-browser, cross-platform (mobile/desktop) and customizable machine monitoring and management application (with 2D/3D end-user interfaces) that uses MTConnect protocol in order to:

1. Create visibility and transparency in the production environments,
2. Improve machine utilization and production efficiency by managing production metrics,
3. Identify machine faults/warnings for predictive maintenance,
4. Reduce lead times in responding to alarms and downtime.

The proposed application is intelligent in the sense that it will not only display real-time and historical machine data, but also process and analyze this data in order to extract useful features through smart algorithms.

Figure 1: Proposed System Overview
Figure 1 illustrates the system overview for the proposed system where machines are equipped with MTConnect adapters/agents as the communication protocol. The XML data from machine agents are continuously parsed and recorded in a SQL database through a standalone service application residing on the central server. A web application residing on a server reads data from the database and provides both real-time data and historical reports to various internal customers (such as maintenance, production, management etc.) within the manufacturing organization.

Following are a list of features for the proposed web application:

1) It will have an interactive 2D dashboard for end-user to visualize real-time machine parameters such as machine status, machine utilization, alarms and other real-time parameters. The interface will look like the template in Figure 2 in the case of a CNC machine shop (based on XML tags for machining process [Ref 1]). Each field on the web-based dashboard will be click/tap-enabled (for desktop/mobile devices). Clicking/tapping on each field will give a history chart for each data item (e.g. clicking on alarms will give alarm history). The machine colors will change in real-time based on the execution status whereas alarms will switch colors depending on problem severity. The 2D interface will be developed using the latest HTML5 technology [Ref 2] in order to deploy it on both desktop and mobile devices in a platform-independent manner.

2) The dashboard in Figure 2 will be fully customizable by the end-user to display selected real-time parameters depending on the type of equipment. For example, the end-user can choose to display machining parameters in the case of a CNC or real-time GD&T results in the case of a CMM. The idea is to have a standard but customizable web interface for different types of equipment. Furthermore, a layout view will enable end-users to create custom factory layouts to position machines by simple drag/drop.

3) There will be a separate reporting module where the end-user can generate custom reports/plots and convert those to excel/pdf formats.

4) Apart from the 2D dashboard, the proposed application will have an innovative 3D web-based virtual dashboard for real-time machine simulation using the WEBGL technology [Ref 3]. To show the feasibility of this idea, the authors have developed a simple 3D WEBGL machine interface (Fig. 3) for CNC machining process to display real-time parameters and axial/rotary motions using mock-up MTConnect data as defined by the standard [Ref 1]. The end user will be able to add/remove components based on the equipment type to build a 3D machine and start seeing the virtual machine in action.
Figure 3: 3D Real-Time Web-based GUI using WEBGL

Such 3D interfaces can help end-users to better visualize/connect to their machines during operation and at the same time used as a simulator for training new machinists. Furthermore, the 3D interface will be interactive in that the end-user can click/tap on any 3D object to display related data visualizations.

5) 1-4 are important in that they introduce 2D and 3D graphical dashboards with some feasibility demonstrated. Another real power of the application will be in its capability to process and analyze real-time/historical data in order to extract important features using smart algorithms. Below will give selected examples of such smart detection examples considering machining, welding and inspection.

**Machining (CNC equipment)**
- Detecting tool crash (which causes axial misalignments if not maintained) during machining by analyzing axial load data.
- Detecting excessive spindle temperatures or vibrations and mapping to component conditions.
- Computing cutting time (chip removal time) using spindle speed and axial load data (which is not an MTConnect data tag).
- Measure energy consumption and reduce energy waste through optimizing process parameters.

**Inspection (CMM equipment)**
- Real-time web visualization of GD&T results.
- Real-time automated detection of quality non-conformances instead of error-prone manual evaluation.

**Joining (Welding equipment)**
- Real-time Monitoring welding parameters (current, voltage, wire feed rate, welding force etc.) for GMAW, RSW, FSW etc. in order to automatically detect welding discrepancies (such as porosity, discontinuity) to avoid consecutive scraps.

**Technical Requirements**

1) **MTConnect Adapters:** Many machine tool companies are developing their own MTConnect adapters (Adapters available for Mazak Matrix/Fusion, Fanuc, Siemens, Heidenhain, Okuma Controllers). As more equipment manufacturers (e.g. welding, inspection, machining, forming etc. equipment) provide their own adapters, the number/diversity of machines that are monitored/managed will go up. This is possible through different industries partnering with MTConnect Institute to develop their adapters (ensure all their equipment, by default, come with those adapters). This will
trigger more software programmers to participate in application development utilizing MTConnect.

2) **Server-Side Development and Database (Back-end):** For back-end development, either .net or java platform can be utilized. A stand-alone service application will continuously parse/record XML data into an SQL database. Other back-end scripts will read data from the database and communicate it to the front-end.

3) **Client-Side Development (Front-End):** The front-end dashboard in Figure 2 will be developed using HTML5, Javascript and CSS3. HTML5 is the latest web technology enabling rich web GUI development and supports the “write once, run everywhere mentality” which guarantees that the web application will look and feel the same on any operating system including desktops and mobile devices. Also for data graphs and charts, there are various Javascript chart libraries that can easily be utilized. On the other hand, the 3D web interface in Figure 3 will be developed using WEBGL technology which is a Javascript API for rendering 3D graphics [Ref. 3].

**Benefits**

1) **Identification and Elimination of Non-value Added Time (downtime):** Downtimes can be identified through monitoring machine execution status (Fig. 4). Analyzing the alarm/warning data in synchronization with executing status (fault mapping), downtime reasons (tool set-up, calibration, idle periods, low coolant etc.) can be identified and eliminated in order to reduce cycle times.

![Figure 4: Downtime/Alarm Mapping](image)

2) **Change in Maintenance Culture:** Note that machines register alarm information in controller memory, but this information is rarely used due to lack of accessibility of concerned parties. In most cases, it is up to the machine operator to acknowledge the alarm. Currently, most machine shops have a maintenance culture that is reactive, meaning maintenance actions are taken only when something fails or if the operator acknowledges the alarm. The proposed system will make the warning and alarm history available to concerned parties (e.g. maintenance, production). This will enable troubleshooting of the machine before catastrophic failures in order to reduce costly maintenance and downtime.

3) **Reduction in Mean Time To Repair (MTTR):** Once a machine generates an alarm, it takes a lengthy journey for data to reach maintenance department (Fig. 5). Usually, the operator first looks for a shop supervisor. Once the supervisor is notified, he/she submits a ticket to maintenance team. The whole process may take from few hours to a day or more depending on the setting. The proposed system eliminates information travel time
by making the alarm history immediately available to the maintenance team through a web application (desktop/mobile) or an email server.

![Image of a diagram showing current and proposed practices]

**Figure 5: Reduction in MTTR**

4) **Process Variation Reduction:** Each equipment in the shop floor should be run at optimal operating conditions that are set by programmers or engineers; however this is rarely the case in shop floors. For example a CNC machine is usually overridden by machinists to run at lower feeds/speeds (which increases cycle times) or a welding machine run at non-optimal welding current/voltage (resulting in weld discrepancies). Through monitoring process parameters, process variations can be identified and adjusted accordingly to achieve targeted part quality. The same system can also be used to acknowledge legitimate parameter adjustments for process improvements.

5) **Scrap Reduction:** There is a huge opportunity to reduce scrap rate through monitoring machines. For example, in CNC machining, tool crash is a common phenomenon resulting in axial misalignment due to overloading. If not acknowledged properly, it will result in consecutive scraps/reworks due to out-of-print part dimensions; therefore such axial overloading should automatically be detected in real-time. Another example is real-time detection of welding discrepancies such as porosity, inclusions or poor fit-up (due to non-optimal welding current/voltage) which will prevent consecutive scraps.

**References:**

**Nomenclature:**