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Design and Implementation of Manufacturing Execution System with open hardware

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Abstract This paper designed and achieved a low cost prototype of manufacturing execution system. A software development and open source hardware (arduino) have been used. The prototype can record and monitor the changes of status or sensor measurements from different production lines and get performance reports. Moreover, it can be applied even where there is no PLC. The system is configurable and allows to group raw data to show clearer information in the report.

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1.1 Introduction

This paper proposes a low cost Manufacturing Execution System (MES) by integrating open hardware, data warehouse, online analytical processing. The data warehouse for this system is provided by the massive amounts of data collected from a device connected to digital and analogical sensors. The result of this prototype is the integration of the MES system to improve manufacturing cycle time.

1.2 Architecture of MES

The MESA International definition of MES is: "MES delivers information that enables the optimization of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission-critical information about production activities across the enterprise and supply chain via bi-directional communications".

Ruey-Shun (2006) says that “MES focuses mainly on monitoring and summarizing the status of operational systems “. Precisely, this is what the prototype of this article will do.

As seen in figure 1, the system architecture is mainly composed of five elements: hardware device, data recorder, data warehouse, server of online analytical processing and web server.

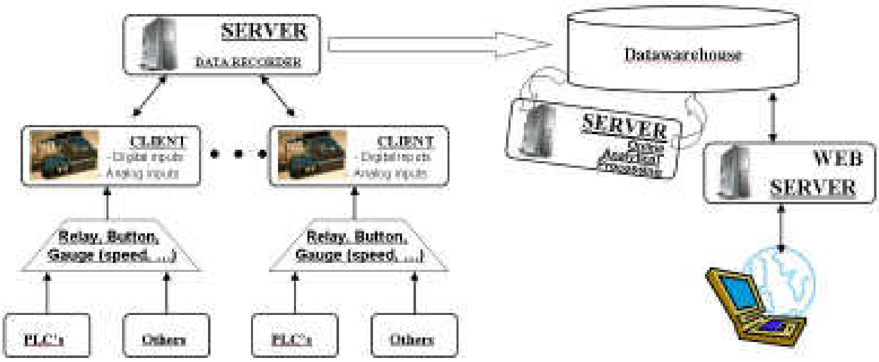


Fig. 1 Architecture of MES

1.2.1 Hardware device

Hardware devices used are Arduino Duemilanove and Ethernet Shield. It is low cost and open source hardware. Arduino has an ATmega368 microcontroller and can sense changes from a great variety of input sensors and can affect its.

It can be use the ethernet shield to communicate with software running on a computer. The digital signals are obtained from relays and the analogical signal as a continuous input voltage.

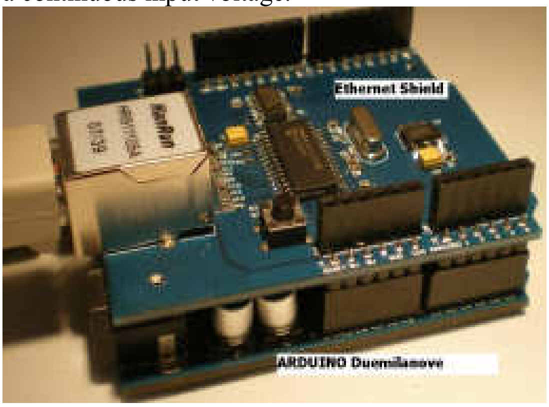


Fig. 2 Arduino Duemilanove and Ethernet Shield

1.2.1.1 Protocol OSC

The Open Sound Control protocol (OSC) was invented in 1997 by Adrian Freed and Matt Wright (Wright 2002). It is used in streaming audio for sending digital content and control between multimedia devices. Other uses of the OSC protocol are in control and robotics areas (Schmeder 2010). In the OSI Model, OSC is classified as a layer 6 or presentation layer entity. It has no license requirements and it is not a standard.

Hartmann, B (2008) developed a firmware to send osc message from an arduino board to a PC. It was used as the basis for the development of this prototype.

The prototype of MES system should be able to know the status of all variables at all times, as well as changes in them. The arduino device is capable of sending the value of all inputs; one that has changed and a sequential value for control it.

Although an arduino device has 14 digital input/output and 6 analogical inputs, it was determined that each arduino device captures 6 digital inputs and 1 analogical input. Therefore, as shown in table 1, there have been defined an own protocol based on OSC.

Table 1 OSC protocol implements

Signal Change			Value of pin				
/Type /in (digital) /adc (analog)	/Pin	/Value	/pin analog	/pin digital n.1	…	/pin digital n.6	/Control number

In figure 3 shows an example of data sent, which are received on the server that makes data recorder on database.

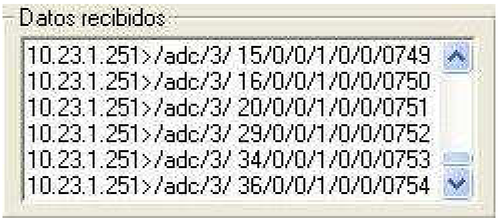
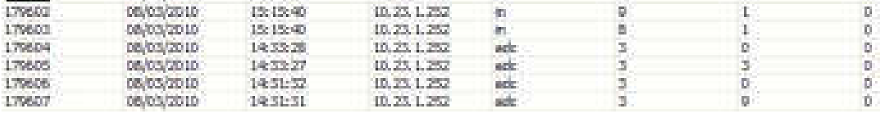


Fig. 3 Example of the messages sent OSC

Schmeder (2010) says "A common transport protocol used with the OSC format is UDP/IP". UDP is classified as a transport layer or number 4 of the seven layers OSI model and provides end-to-end communication services for applications. UDP is often utilized for broadcasting, because it has no handshaking dialogue.

1.2.2 Data Recorder

Development software on a PC receives UDP data frames. Depending on the device, the received data are combined with the date / time of pc for storage in the table on the database. This application has an ini file which associates the device's ip to the table of the database.



179601	08/03/2010	15:15:40	10.23.1.252	in	8	0	0
179602	08/03/2010	15:15:40	10.23.1.252	in	9	1	0
179603	08/03/2010	15:15:40	10.23.1.252	in	8	1	0
179604	08/03/2010	14:33:28	10.23.1.252	adc	3	0	0
179605	08/03/2010	14:33:27	10.23.1.252	adc	3	3	0
179606	08/03/2010	14:51:52	10.23.1.252	adc	3	0	0
179607	08/03/2010	14:51:51	10.23.1.252	adc	3	9	0

Fig. 4 Raw data store in a table.

1.2.3 DataWareHouse

The database stores all data, but to minimize the space without losing information, a record is saved only when a change in status or value of the analog signal are done. To achieve this efficiently, the firmware of the hardware device is set on condition that only send data when a change occurs. This is a significant difference compared to other protocols such as OLE for process control (OPC), in which the communication is synchronous or asynchronous, but never when the value of the signal (Grega 2010). OPC has become a widely accepted solution for intercommunicating different hardware and software (Tai-hoon 2010).

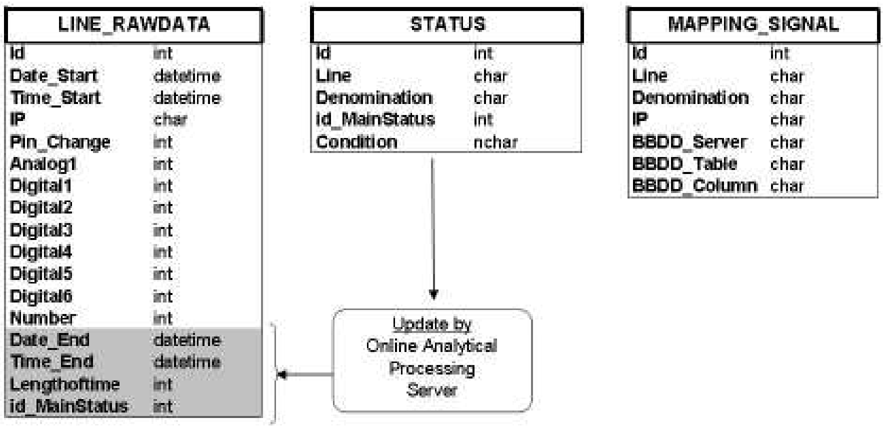


Fig. 4 Data tables of datawarehouse

1.2.4 Server of online analytical processing

This server performs an analysis of the raw data to determine the prevailing status and duration. At the same time, keep the information gathered in another table to speed up subsequent queries.

Since it can take multiple status at once, you must set one that is principal. As shown in Table 1, this will allow to obtain a report with length of time for each principal status.

Table 1 Example of report of status

Group of status of the production line of cutting/slide	%	Length of time	
		Minutes	Hours
1.- Stop	9,9	47,367	0,789
2.- Run	42	200,317	3,339

3.- Introduction raw material.	35,4	168,75	2,812
4.- Extraction raw material	7	33,517	0,559
5.- Removal raw material	4,4	21,017	0,35
6.-Partition raw material	1,3	5,983	0,1
Total	100	476,95 min.	7,949 hours

For analogical values, these can be grouped by rank, to facilitate data interpretation. In the prototype, the analog variable used is the line speed. This can be seen in Table 2.

Table 2 Example of report of speed

Processing Speed (meters/ min)	Length of time minutes	Length of time hours
Speed 1 - 49	56	0,933
Speed 50 - 99	26	0,433
Speed 100 - 149	32,15	0,536
Speed 150 - 199	20,833	0,347
Speed 200 -	59,2	0,987
Total	194,183	3,236
Mean Speed		125,5 meters/minute

1.2.5 Web Server

For the prototype, a web server has been used. It facilitates to monitor and generate a reports from any computer with a browser. Although an internet information server from Microsoft was used, it could be used others.

1.3 Conclusions

A low-cost prototype of MES system has been designed and produced. It is valid for all cases in which you can get a digital or analogical signal from a sensor or a gauge.

This prototype has been validated in a manufacturing environment, where there have obtained excellent results. It has allowed to improve the cycle time of the production line. It has revealed differences between the statements wrote down manually and machine status.

Therefore, in the implementations of continuous improvement, like Lean Manufacturing, we are recommended to use a system like this prototype, in order to monitor whether targets are achieved.

Another substantial novelty of this prototype in comparison with other systems is that it maintains an asynchronous communication and only sends a data when a variation occurs.

1.4 References

Grega W. (2010) Supervisory control and real-time constraints. Proceedings of International Multiconference on Computer Science and Information Technology pp. 791-796. ISBN 978-83-60810-27-9,

Hartmann, B (2008) Arduino_Osc http://protolab.pbworks.com/w/page/19403606/Arduino_Osc. Cited 01 Jan 2012

MESA International (1997). MESA International White Paper Number 6:MES Explained: A High Level Vision

Ruey-Shun C, Yung-Shun T, et al (2006) Design and Implementation of an Intelligent Manufacturing Execution System for Semiconductor Manufacturing Industry. IEEE ISIE 2006, July 9-12, 2006, Montreal, Quebec, Canada

Tai-hoon K, (2010) Integration of Wireless SCADA through the Internet. International Journal of Computers and Communications Issue 4, Volume 4

Wright. W (2002) Open Sound Control 1.0 Specification. http://opensoundcontrol.org/spec-1_0. Cited 01 Jan 2012