# Smart Manufacturing Through Sensor Based Efficiency Monitoring System *(SBEMS)*

V. Balaji[1], P. Venkumar[2], M.S. Sabitha[3](✉), S. Vijayalakshmi[4], and R.M. Rathikaa Sre[5]

[1] ZF Electronics TVS India Private Ltd., Madurai, India
balaji.v@zftvs.com
[2] Kalasalingam University, Krishnankoil, India
p.venkumar@klu.ac.in
[3] R & D Center, Bharathiar University, Coimbatore, India
muralisabi@gmail.com
[4] Thiagarajar College of Engineering, Madurai, India
svlcse@tce.edu
[5] Mepco Schlenk Engineering College, Sivakasi, India
rathikaasrerm@gmail.com

**Abstract.** The emergence of IoT (Internet of Things) fuels an incipient generation of modern applications and enhancing effectiveness. Smart manufacturing is the significant aspect to meet the innovation and competitiveness in the production environment. The application of IoT avails to increment the overall understanding in the factory through connected smart objects. This paper proposes an integrated solution of sensor affixed machines, data acquisition model and data analytics. The proposed system design and implementation is pertaining to a manufacturing company to monitor the efficiency of processes in each stage in the production environment. The focus is on monitoring and inferring insights on the efficiency of machines and operators in a cloud environment. Experimental evaluation shows a drastic amendment in the shop floor visibility area by integrating sensors for data acquisition and providing insights through the analytic tool.

## 1 Introduction

Industry 4.0 verbalizes about the technological evolution which leads to smart industry. This industrial revolution moving towards cyber physical systems from embedded system. The integration of embedded system, machine automation, cloud computing pave the way to cyber physical system which creates a paradigm shift from centralized to decentralized production.

The aim of many leading manufacturing industries is to move towards cyber physical systems over the year 2020. Authentic challenge in front of them is to bridge the gap between authentic and virtual world. This technological shift impacts in various domains like healthcare, communication, security, climate, etc., not solitary inhibited to


A. Abraham et al. (eds.), *Proceedings of the Eighth International Conference on Soft Computing and Pattern Recognition (SoCPaR 2016)*, Advances in Intelligent Systems and Computing 614, DOI 10.1007/978-3-319-60618-7_4

manufacturing industries. Industry 4.0 v creates special value for the products and leads to an incipient business model.

Smart manufacturing will bring the manufacturing perspicacity by integrating the plant modeling, latest data technologies and cloud computing. Connecting all these will bring the highest caliber of manufacturing in the future. Manufacturing intelligence is not an independent activity, it collects the intelligence from supply chain, customer engagement through engenderment and distribution methods. Smart manufacturing is a paradigm shift, incipient business model evolution and a path for future factory.

In recent years, manufacturing industries are moving towards a new production model to address the technological challenges and advances. Consequently, modern approaches required to integrate the normal production environment with the latest technology to amend the communication in the environment and to address proactive measures in productivity amelioration. In this paper, we propose the utilization of sensor based efficiency monitoring system (SBEMS) to perform astute tasks such as online monitoring of efficiency and productivity amendment. The IoT is evolving from simple sensors with network connectivity to a collection of interrelated and interoperable objects, called Smart Objects (SO) [1–5].

At present, undeniable trend of using computing technologies and usage of embedded system converts the ordinary objects into Smart Objects [6]. The proposed SBEMS system integrates sensor, machine and cloud to generate the data automatically from the machine and provide intelligent insights for speedier action. This system provides a cost effective integration of sensors in manufacturing environments. It is a low cost, low energy device that facilitates the monitoring of efficiency and enable the analytics to obtain online information of manufacturing processes. The data is transmitted and stored and the analytics provide useful insights according to the application and requirement for making intelligent decisions. The gathered information is very much useful for the environment as it enables immediate attention in the shop floor. It provides the shop floor visibility to the physical world. This kind of automation and connectivity in cloud are one of the key elements in the IoT paradigm.

Sensor connectivity with real object creates huge research scope in various domains. Connecting objects in cloud is also a significant research area. For scalability and feasibility of large systems it is necessary to introduce and test the analytics area which can handle huge volume of data. The tool should be capable of deriving intelligent insights, solutions for long term problem and where proactive action is desirable. The proposed work focuses on the integration of sensors, machines, data acquisition kit and data analytics tools. In this paper, Sect. 2 discusses views of various researchers, Sect. 3 deals with the architecture of the proposed system.

## 2 Motivation and Previous Work

IoT (Internet of Things) is a network of physical objects which integrates embedded objects, sensors, analytics software and the cloud to collect, transfer and analyze data. It can also be defined as decentralized systems of various smart objects (SO). Smart Objects are emerging entities of IoT which enable connectivity through sensors and provide desired services after analytics. The paradigm shift of SO describes new capabilities and provide new services in the object itself. SO provides the following features [7, 8].

- Exclusive identification
- Connectivity and communication with external environment
- Capability of decision making and controlling the environment
- Providing additional services

SOs is used in various applications. INOX is 'A Managed Service Platform for Interconnected Smart Objects' which suggests an architecture for integrating the IoT features required for the independent network management and many services. It elaborates how sensors can be used in the integrated environment. INOX integrates application development, flexible service deployment and virtualized element for better service management.

P. O'Donovan et al. [10] discussed about the importance of Industry 4.0. The major contribution of this research is a set of data and system requirements for executing equipment maintenance system in industrial setup, and an information system model that offers a scalable and fault tolerant big data pipeline for coordinating, processing and analyzing equipment related data.

Linxia Liao et al. [11] proposed a self-aware machines based on data gathered utilizing the MTConnect protocol. Apart from existing applications of OEE (Overall Equipment Effectiveness) reporting, the proposed system incorporates different sources of data for work-piece and watching the machine state, and equipment time to predict the failure prediction in manufacturing setup, and gives feedback to shop floor supervisor.

In another approach [9], sensors are considered as small system with specialized processing capabilities and it senses to virtualize its capabilities in the data center and perceived that they are as powerful as normal computers. It deals about the indoor and outdoor communication with virtualized SOs.

The above researches intended to continue with the stated SBEMS system.

## 3 Architecture of the Proposed System

The overall architecture of the proposed system depicted in Fig. 1. The entire system illustrated in five layers.

In a manufacturing setup, shop floor is an area where assembly or production carried out by machines or by human beings. This setup has represented in Layer 1. The proposed model has tested in a manufacturing area where different types of machines like Stamping, Molding, Piercing, Soldering etc., are available.

All the shop floor machines interact with the Sensors, Operators and the Supervisors. The sensor is an object that detects the changes and responds to some type of actions from various machines. It converts the physical parameters to electrical signals. Even though various types of sensors are available in the market, the following were used in the proposed system

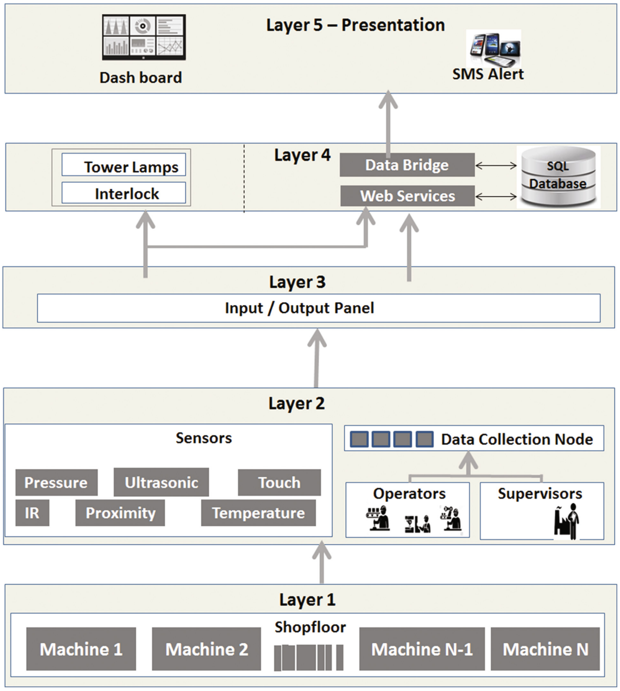



**Fig. 1.** Architecture of the proposed system

- Infrared (IR) Sensor
- Reed sensor
- Proximity sensor

An IR sensor can detect the reflective or bright objects within the range of 3 cm to 300 cm. The proximity sensor is used to sense the metallic items. These three sensors have been integrated with various machines in the shop floor.

The shop floor people (operators/supervisors) register their employee id and job order number through a data communication node (DCN) which has fixed on all the machines on the shop floor. All the input required for the proposed system has gathered in Layer 2 through signals detected either automatically by sensors or by human data entry.

The sensors on receiving the signals from various machines transmit them to the Input/Output (IO) Panel in Layer 3. The DCN acts as an input as well as a display device. It enables the shop floor people to enter required information through DCNs.

The key function of the IO panel is to convert analog signals into digital values for further processing. This will communicate with the data bridge application and web services in Layer 4. The received signals are further processed and the processed data will be used for analysis purpose.

At the time of data processing, the interlocks will be active on receiving the signals from the IO panel and will stop the machine from working. This has been implemented to overcome the harmful situations like which damages the machines and the products. Subsequently the tower lamps fitted in every machine get triggered on receiving a signal from the IO Panel. This will alert the shop floor people about any action which will be needed to be taken by them.

The IO panel transfers the data to the computer system and then the data can be used by data analytics tool.

The topmost layer is the visualisation layer. During harmful situation, the system will pass the information to concern people in the form of SMS. Apart from this, a visual display system available in the shop floor displays the dashboards. The dashboards visually displaying automated data monitoring through easily understandable graphics. This system facilitates in providing real time efficiency monitoring, status of the machine in one shot.

Even though several manual systems are available to monitor the manpower efficiency by physically feeding the data into the system, SBEMS differs better in the sense that it alerts the decision makers online and no need to enter the data into the system. The expected outcome of the proposed system lies in Layer 4 and Layer 5. The unfavorable conditions were notified by sending SMS and shedding red light in tower lamp. Other than these exceptions, the dashboard available in the shop floor helps the supervisors to monitor and derive actions on potential problems and the shop floor progress. The outputs of the dashboard discussed in the next section.

## 4 Results and Discussion

The system is designed to visualize and send the alert messages. The online dashboard is a web service that provides users to view the shop floor related information such as machine running status, production count, inventory status, hourly output, rejections, reasons or rejections etc.

Various input and output screenshots discussed below.

**Home Screen Page**

This page appears when DCN is powered up. Shop floor people can come to this page from any other page by clicking the home button (Fig. 2).

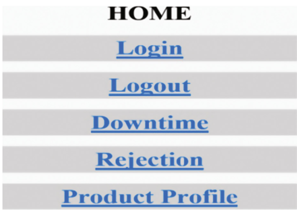



**Fig. 2.** Home screen

### Login and Logout Page

For login, shop floor persons has to select his/her user name from the drop down and the equipment on which he/she is going to work (Fig. 3).

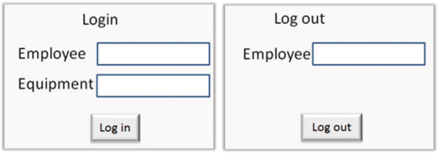



**Fig. 3.** Login and logout screen

To logout, one has to just click the log out tab. Various outcomes in the dashboard of the proposed system discussed below.

### Trends view

This object can be used for observing the behavior of the sensor signal to the physical parameter it is sensing. On the extreme left the shop floor person can select the sensor for which they want to monitor the signal trend. The checkbox column P is meant for selecting positive or negative edge of the signal to be monitored. Checkbox columns 0 to 20 are the values of the sensors placed 500 ms apart from current value to 10 s old values. If n is the number on top of checkbox column, then the value of that checkbox is an X 500 ms old (Fig. 4).

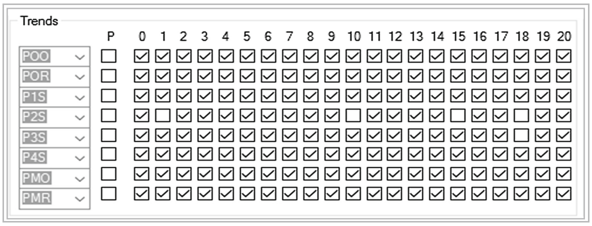
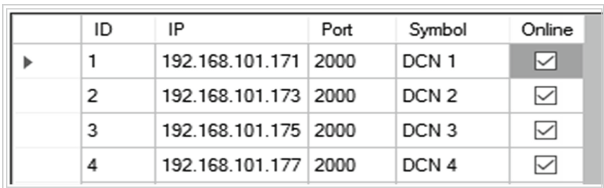



**Fig. 4.** Trends view - screenshot

### Live Monitoring

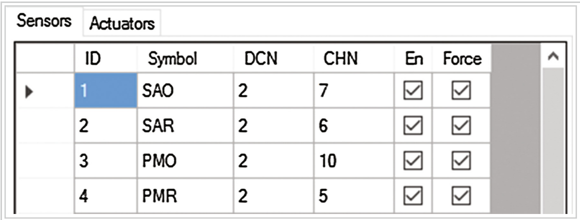
This object shows IP addresses, ports, logical names and online status of individual DCN with IO boards (Fig. 5).



| | ID | IP | Port | Symbol | Online |
|---|---|---|---|---|---|
| ▶ | 1 | 192.168.101.171 | 2000 | DCN 1 | ☑ |
| | 2 | 192.168.101.173 | 2000 | DCN 2 | ☑ |
| | 3 | 192.168.101.175 | 2000 | DCN 3 | ☑ |
| | 4 | 192.168.101.177 | 2000 | DCN 4 | ☑ |

**Fig. 5.** Live status monitoring - screenshot

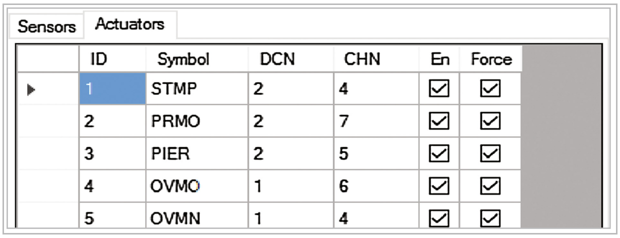
**Sensors**
This object lists down all the sensors with symbol names, channel to which it is connected. If column names En is ticked then the actual value of the sensor is getting used in the software logic. Otherwise, value of Force column is used in logic. The administrator can also change the DCN and CHN assignment (Fig. 6).




| ID | Symbol | DCN | CHN | En | Force |
|---|---|---|---|---|---|
| 1 | SAO | 2 | 7 | ☑ | ☑ |
| 2 | SAR | 2 | 6 | ☑ | ☑ |
| 3 | PMO | 2 | 10 | ☑ | ☑ |
| 4 | PMR | 2 | 5 | ☑ | ☑ |

**Fig. 6.** Sensors selection – screenshot

**Actuators**
This object list down all the actuators with symbol names, channel to which it is connected. If column En is ticked then value generated in the logic is passed to the actuator. Otherwise, value of Force column is passed to the actuator (Fig. 7).




| ID | Symbol | DCN | CHN | En | Force |
|---|---|---|---|---|---|
| 1 | STMP | 2 | 4 | ☑ | ☑ |
| 2 | PRMO | 2 | 7 | ☑ | ☑ |
| 3 | PIER | 2 | 5 | ☑ | ☑ |
| 4 | OVMO | 1 | 6 | ☑ | ☑ |
| 5 | OVMN | 1 | 4 | ☑ | ☑ |

**Fig. 7.** Actuators selection - screenshot

One can also change the DCN and CHN assignment.

**I/O Panel**
Independent of whether the sensor or actuator is enabled or not, independent of whether a particular channel has been assigned symbol or not, this object will indicate the physical condition of the sensor inputs and actuator output at IO Panel.

**Personal Alert Application:** Using this application package the supervisor can automatically generate SMS base personnel alerts, which caters to the following groups (Fig. 8).

This application enables the supervisor to send SMS periodically to the interrelated users and also a warning message for critical situations.

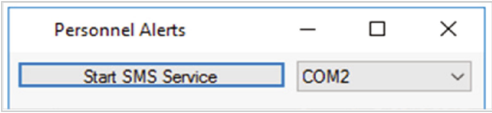



**Fig. 8.** Personal alert screen

**Supervisor Tab**

For every stage of the operation in any high speed line, this page provides

(a) Maximum Hourly Capacity of the Stage
(b) Currently our production
(c) Lower Limit of production (applicable if the equipment is meant to be 24 × 7)
(d) Inventory Upper Limit after the stage (This alerts the current state operator to stop the production)
(e) Current Inventory between current stage and next stage
(f) Inventory Lower Limit after the stage (This alerts the current stage operator to start the production)
(g) Current Stage Hourly rejection count
(h) Current Stage operating condition viz: planned downtime, unplanned downtime, production mode, setup mode etc.
(i) Latest downtime reason.
(j) Latest rejection reason.
(k) Current operator (Fig. 9).


**Fig. 9.** Supervisor tab - screenshot

**Key benefits of the proposed system**

The proposed system has following benefits compared to the traditional non-automated system.

- The potential failures could be sensed well before occurrences and initiate preventive maintenance loop to counter such occurrences.
- The quality data (final inspection) could be stored for the future retrieval and traceability.
- The loss of effectiveness compensated during the measured time window itself, hence corrective actions did not lead to postmortem activity.
- Because the shop floor is internet connected and the connectivity can use from different locations using cloud for better results.

## 5 Conclusion and Future Work

To achieve competitive advantage, industries must use technological advances in manufacturing to provide value added products. This paper initiated the IoT model on the shop floor. It brings out the cyber physical system. This is a low cost and low energy model. Simplified approach used to accumulate data and normal analytics tools used to mine the insights. The data processing ensures at the best availability of causes, and the counter measures solved the issues proactively.

Overall equipment effectiveness (OEE) has become an important and key measurement in the manufacturing setup. It helps to generate more capacity and profits from the machines. The dependency on human attention is very high to ensure the accuracy & consistency of this performance measure. The proposed system does not address all parameters required for OEE calculation. Future work will extend and explore the methodologies to derive OEE automatically.

Important issues like data integrity, data confidentiality and data ownership have to be addressed well in future. The quality data (final inspection) could be stored on the product itself for future retrieval and traceability. The internal controls will lead to enhanced customer experience with a higher value proposition. Value added services for customers, increasing revenue both in numbers and in channels. The proposed work and future related work are aiming to be at the fore front of the Industry 4.0.

## References

1. Kortuem, G., Kawsar, F., Fitton, D., Sundramoorthy, V.: Smart objects as building blocks for the Internet of Things. IEEE Internet Comput. **14**(1), 44–51 (2010). Smart Manufacturing Through Cloud-Based Smart Objects and SWE 127
2. Schreiber, D., Luyten, K., Mühlhäuser, M., Brdiczka, O., Hartman, M.: Introduction to the special issue on interaction with smart objects. Trans. Interact. Intell. Syst. **3**(2), 6 (2013)
3. Fortino, G., Guerrieri, A., Russo, W.: Agent-oriented smart objects development. In: Proceedings of IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD), pp. 907–912 (2012)

4. Fortino, G., Guerrieri, A., Lacopo, M., Lucia, M., Russo, W.: An agent-based middleware for cooperating smart objects. In: Corchado, J.M., et al. (eds.) Highlights on Practical Applications of Agents and Multi- Agent Systems. Communications in Computer and Information Science (CCIS), vol. 365, pp. 387–398. Springer, Heidelberg (2013)
5. Fortino, G., Guerrieri, A., Russo, W., Savaglio, C.: Middlewares for smart objects and smart environments: overview and comparison. In: Fortino, G., Trunfio, P. (eds.) Internet of Things Based on Smart Objects: Technology, Middleware and Applications. Series on the Internet of Things, pp. 1–27. Springer, Cham (2014)
6. Hartmann, M., Schreiber, D., Mühlhäuser, M.: Workshop on interacting with smart objects. In: Proceedings of the 16th International Conference on Intelligent User Interfaces (IUI 2011), New York, pp. 481–482 (2011)
7. McFarlane, D., Sarma, S., Chirn, J.L., Wong, C.Y., Ashton, K.: The intelligent product in manufacturing control and management. In: 15th Triennial World Congress IFAC, Barcelona, Spain (2002)
8. Bajic, E.: Ambient services modeling framework for intelligent products. In: Workshop on Smart Object Systems, UbiComp 2005, Tokyo, September 2005
9. Tarazona, G.M., Espada, J.P., Nunez-Valdez, E.R.: Using collaborative virtual objects based on services to communicate smart objects. In: Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), pp. 456–461 (2013)
10. O'Donovan, P., Leahy, K., Bruton, K., O'Sullivan, D.T.J.: An industrial big data pipeline for data-driven analytics maintenance applications in large-scale smart manufacturing facilities. J. Big Data **2**, 25 (2015). A SpringerOpen Journal. doi:10.1186/s40537-015-0034-z
11. Liao, L., et al.: A self-aware machine platform in manufacturing shop floor utilizing MTConnect data. In: Annual Conference of the Prognostics and Health Management Society (2014)