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Procedia CIRP 55 (2016) 236 – 241

www.elsevier.com/locate/procedia

5th CIRP Global Web Conference Research and Innovation for Future Production

Collaborative maintenance in flow-line manufacturing environments: An Industry 4.0 approach

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Abstract

In a manufacturing shop-floor, context-aware intelligent service systems, along with mobile solutions can be used for the provision of information services to shop-floor personnel according to their situation. This paper presents an Industry 4.0 system that provides decision support for line operators and maintenance personnel, in an industrial production scenario, where maintenance needs immediate response. A multi-layered, Service Oriented Architecture (SOA) based system, which integrates several sub-systems, such as sensor data fusion, context modelling and contextual data information provision has been developed. The solution includes a number of context-aware apps that support the collaborating users to address maintenance issues. A case study was conducted, providing insight into the suitability of the proposed solution and bringing to light further aspects that will improve the proposed context-aware system.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: context-aware; Industry 4.0; case study;foundry

1. Introduction

The Industry 4.0 paradigm promotes the connection of physical items such as sensors, devices and enterprise assets, both to each other and to the Internet. The enormous amount of information gathered and generated by ICT systems and sensors installed at the shop-floor needs to be presented in a manner that could truly speed up production processes, enable immediate reaction to issues and shortcomings. However, the existing ICT solutions originally intended for the support of production processes, currently lack in providing the right information to the right persons, at the right time and location by imposing the development of context awareness for manufacturing information distribution systems.

Maintenance is a critical activity that takes place at the manufacturing shop-floor. Insufficient maintenance has an impact both on the performance of the production process as well as on the quality of the finished product. A proper level of detailed maintenance instructions should be provided to the maintenance personnel, according to their level of expertise. In addition, advanced context information collection and management technologies, e.g., Near Field Communication (NFC) and Service Oriented Architecture (SOA) technologies, in the shop floor, provide opportunities for the development of such context-aware information systems, in aid of the maintenance operators and engineers.

A manufacturing system can be defined as a combination of humans, machinery and equipment that are bound by a common material and information flow [1]. In Industry 4.0, machines, parts, systems and human beings will be highly connected and highly integrated. Every physical object will formulate a Cyber-Physical System (CPS) and it will always be linked to its digital footprint as well as to intensive connection with the surrounding CPSs of its on-going processes [2].

As the transformation into a highly networked environment takes place new challenges emerge. A key issue found in this rich information exchange environment is that any

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production
doi:10.1016/j.procir.2016.09.013

information overload be avoided and that the right information be delivered to the right people, at the right place and in the proper format [3]. This can be achieved if information delivery is aligned to the context of the agent that will receive the information. In general, context-awareness is the property for the provision of suitable services to a user, through an analysis of his context [4]. As context can be considered any information, characterizing the situation of an entity that can be a person, place, or object, relevant to the interaction between the user and a context-aware application [5]. The context aware applications define a holistic and dynamic model that takes into account the context of tools, machines, parts, products, while at the same time, utilizes information regarding the planning of manufacturing processes. Context-awareness can be used in order for the visibility of operations and their performance to be increased. It aims at enabling factory shop-floor and office personnel to make a decision, based on a systematic understanding of the system having derived from a factory's real-time sensed context, instead of a decision based on a fragmentary system view and a limited expert knowledge [6]. In order to have context-aware ICT, a context acquisition and management infrastructure should be implemented. The architecture of a context aware ICT system depends on different requirements, such as the location of sensors, the number of possible users, response times or the availability of computing power. More insight into alternative architectures is provided in [7] and [8]. In [9], an ontology based approach is used for the development of a context repository in a manufacturing environment. Similarly in [10], an ontology-based approach for context modelling has been developed. In [11], an ontology-based context model also for real time decision making is proposed for the optimization of the key performance indicators of Flexible Manufacturing Systems (FMS). An approach for the realization of self-adaptive and highly available production systems, based on a context aware approach, allowing self-adaptation of flexible manufacturing processes in production systems and effective knowledge sharing to support maintenance, is presented in [12]. In [13], a system for context-aware AR maintenance applications is proposed. The use of AR goggles, coupled with other mobile devices for the communication of people, working on the shop-floor and in the engineering offices is proposed in [14]. Finally, in [15] they propose a collaborative system that provides decision support for team leaders.

In this work, the multi-layered approach has been selected for the implementation of the context-aware infrastructure with the use of ontology for the modeling of context data and the mobile device approach for delivering information to the users. The approach has been demonstrated in support of a maintenance scenario in the automotive industry.

2. Industrial pilot

An important process, through the value chain of the automotive ecosystem, is performed in the foundry. The foundry usually follows a fishbone-like structure, as presented in Fig. 1. In each sub-line, different cores are produced for different models of the automotive company. The foundry, among others, produces engine blocks, cylinder engine heads, brakes' components, gearbox components and others. In each sub-line there are a number of stations that prepare the mold and the cores and at the end of each sub line there is the flasks' line. Each flask consists of two parts: the upper section and the bottom section, which are put together at the end of the line. Only one part type is produced at a time. The machines are linked by automated material handling devices, such as conveyors. The structure of a flow line presupposes that there is a well-defined, rigid process sequence for the different parts, and that the lot size of each part is high enough to guarantee that the capacity of the equipment be fully exploited and not wasted on the setups. In the foundry, Fig. 1, the core making sub-lines prepare the cores (e.g. for the cylinder heads) and then the sub-lines are feeding lines to the molding line. In the molding lines, there are flasks and the cores are mounted onto the flasks. As a last step, the melted iron is poured into the flasks and then moved to the cooling area. The major shortcoming of this type of production system is that one machine failure could stop the line's entire production, making maintenance a challenging process. There are a considerable number of breakdowns per day, with considerable duration of line interruptions. A typical day may have a few hours of line interruption. There are several sources for the breakdown detection: a) the line operator detects a failure indication, while monitoring the SCADA system, b) the field operator detects a malfunction, during the regular inspection of machines and processes and c) an operator reports a problem to the line or field operator. The duration of resolving the problem of a breakdown is critical. Team members typically use radio for voice communication among them.

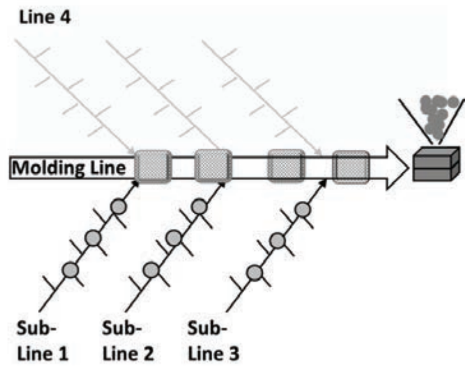

Fig. 1. Foundry fishbone structure

The operations in the line are supported by a number of legacy ICT systems. All line stoppages that are not resolved within a two-minute period are logged in a maintenance repository together with information regarding their causes. A typical SCADA system is also available and it provides real-time information on the line status as well as current information on line stoppages.

A team composed of 6 members resolves the breakdown issues. The way of communication depends on the breakdown case, its nature and the assigned priority. For a working shift,