Towards robust early stage data knowledge-based inference engine to support zero-defect strategies in manufacturing environment

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Abstract

Decision Support Systems are considered as a robust technology able to provide an advantage to several manufacturing companies. As part of the Z-Fact0r EU project, an autonomous and self-adjusted inference engine; namely the Early Stage-Demand Support System (ES-DSS) will be deployed. The scope is to facilitate real-time inspection, condition monitoring and control - diagnosis at the shop-floor, utilizing continuously mine multiple data streams and run the suitable models to monitor operations and quality performance, to classify products on the basis of quality metrics, as well to predict occurrence of defects and deviations from production and quality requirements.

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1. Introduction

Manufacturing represents a significant factor of EU’s GDP and its employment. Thus, the efficiency and sustainability of manufacturing processes of high-tech products along with the development of solutions for zero
defect applications is more than imperative. To this effect, European manufacturing companies will strengthen their position and keep an advantage in the highly competitive and continuous changing business environment.

The EU Factory for the Future (FoF) project, Z-Fact0r (Zero-defect manufacturing strategies towards on-line production management for European FACTORies) focuses on zero-defect manufacturing on small-medium enterprises (SMEs) on their shop-floor level. Zero-defect manufacturing is still a vast business opportunity for innovative high-return of investment (ROI) solutions to ensure better quality and higher productivity in the European manufacturing industries. This paper will describe Z-Fact0r’s activities for the development of an Early Stage – Decision Support System (ES-DSS), an autonomous and self-adjusted early stage inference engine for real-time inspection and control, condition monitoring and control-diagnosis at shop-floor level. The main objective of behind this idea is to use the proposed ES-DSS to continuously mine multiple data streams from the lower production levels so as to monitor operation and quality performance, to run appropriate models so as to classify production on the basis of quality metrics initially set and most importantly to predict occurrence of defects and deviations from production and quality requirements. The ES-DSS will be a key contributor to the Knowledge Management Decision Support System (KMDSS) of Z-Fact0r solution in an effort to provide more robust and decisions and better support.

The remainder of this paper is organized as follows. In Section 2, related work on decision support system in manufacturing is presented. Early-stage inference engine is described in Section 3, while in Section 4 we provide a brief description of the ES-DSS. In Section 6, we discuss about machine learning and adaptive anomaly detection of the ES-DSS and in Section 6 we draw our conclusion.

2. Related work

Decision support systems (DSS) are information systems designed to support organizational and/or operational decision-making, helping people make decisions about problems that are changing rapidly and cannot be easily defined in advance. The goal of a DSS is to provide an interface to decision makers, in order for the latter to combine raw data and expert knowledge to solve problems and make decisions. As far as manufacturing is concerned, quality control (which is a superset including fault detection and quality assurance in general) is an integral part of the processes involved, as it ensures that no faulty products will be delivered, thus saving time and money which are necessary investments towards rectifying production failures.

Most state-of-the-art methods applied on DSSs rely on data mining and machine learning techniques or some other kind of statistical modeling and/or inference, since processes, products and components generate large amounts of data containing historical information. Data mining algorithms can extract useful knowledge from these large datasets to get significant improvements in the process. For example, equipment faults can be detected, the number of items to be ordered can be predicted or optimal control parameters can be determined.

Moreover, raw materials, resources and complementary involved processes have widely varying costs with additional energy costs. The combination of these process variables contributes to obtaining final product properties, also involves manufacturing costs. Process information analysis and certain optimization algorithms lead to minimization of manufacturing costs and reduce energy consumption, while maintaining the quality of the final product.

Some examples of DSSs in manufacturing and other critical applications are briefly presented below. The problem of quality ranking of electronically commutated (EC) motors is addressed in [1] with the utilization of a novel copula-based DSS. The proposed DSS provides full ranking of EC motors by integrating the experts’ preferences and the company’s quality standards. This approach overcomes the shortcomings of the traditional regression models, such as partial ranking and inconsistent evaluations according to experts’ expectations. Real-time quality control capability, in liquid transfer operations on a closed-loop controlled by a MEMS flow sensor liquid transfer device, is presented in [2]. Real-time data acquisition enables the interpretation of system variables. Using fuzzy logic as a decision support tool, an overall quality metric and failure mode is deduced from these variables for each channel per operation. Detection of ordinary fault conditions, like clogged tips or unexpected empty source wells, activates automatic recovery actions without human intervention, leading to 24/7 utilization of an automated laboratory system. Utilisation of fuzzy logic techniques which deals with monitoring and fault detection under uncertainty in space applications is presented in [3]. In optimal control cases, where the underlying
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