Available online at www.sciencedirect.com

ScienceDirect

Journal of Computational Design and Engineering 3 (2016) 91–101

www.elsevier.com/locate/jcde

E-quality control: A support vector machines approach

Tzu-Liang (Bill) Tseng[a], Kalyan Reddy Aleti[a], Zhonghua Hu[a], Yongjin (James) Kwon[b,*]

[a]Department of Industrial, Manufacturing and Systems Engineering, The University of Texas at El Paso, El Paso, TX 79968, USA
[b]Department of Industrial Engineering, Ajou University, Suwon 443–749, South Korea

Received 7 January 2015; received in revised form 15 June 2015; accepted 15 June 2015
Available online 9 July 2015

Abstract

The automated part quality inspection poses many challenges to the engineers, especially when the part features to be inspected become complicated. A large quantity of part inspection at a faster rate should be relied upon computerized, automated inspection methods, which requires advanced quality control approaches. In this context, this work uses innovative methods in remote part tracking and quality control with the aid of the modern equipment and application of support vector machine (SVM) learning approach to predict the outcome of the quality control process. The classifier equations are built on the data obtained from the experiments and analyzed with different kernel functions. From the analysis, detailed outcome is presented for six different cases. The results indicate the robustness of support vector classification for the experimental data with two output classes.

Keywords: Support vector machines; Part classifications; Remote inspection; Networked robotic station; e-quality

1. Introduction

It is more likely that the rapid advancements in sensor, computer, communication, and information technologies are bringing about the fundamental changes in manufacturing settings. This includes fully-automated, 100% quality inspection that can process a large amount of measurement data [1–6]. Other production related activities and business functions will be also integrated into the company information management network, which guarantees the instant access to critical production data for enhanced decision making [7–9]. This new approach is referred to as e-quality control, and one of the enabling tools is the ability to predict the variations and performance losses during the various production stages. This means that the traditional quality control scheme, which relies on sampling techniques, would be replaced by the sensor-based, automatic, computerized inspection methods that provide the unprecedented level of data processing and handling. Since the production equipment is integrated into the network, the condition of the machines can be monitored, while the product quality from specific machines can be instantly identified. In order to test the new quality control approach, the authors have developed a networked quality control station. This includes two network-accessible assembly robots, two networked vision sensors, and other ancillary equipment which constitutes the cell. The overall setting of the system is presented in Fig. 1.

The vision sensors see the part and measure the dimensions. The captured image has 640×480 pixel size and the analysis results are produced by the computer algorithms. Part gauging is established by using a pattern matching technique. For each part, the vision sensor conducts the pre-defined quality control tasks, and sends the information to the awaiting robot. If the part passes the quality standard, it will be picked up by the robot and dropped into the bin. Otherwise, the bad parts will be carried away by the conveyor belt. The picture of entire setup is shown in Fig. 2.

In the context of e-quality control, the objective of this paper is to apply the machine learning approach in the form of support vector machines (SVMs) to predict the outcome of the part classification. Data obtained from the remote inspection

*Corresponding author.
E-mail address: yk73@ajou.ac.kr (Y. Kwon).

http://dx.doi.org/10.1016/j.jcde.2015.06.010
2288-4300/

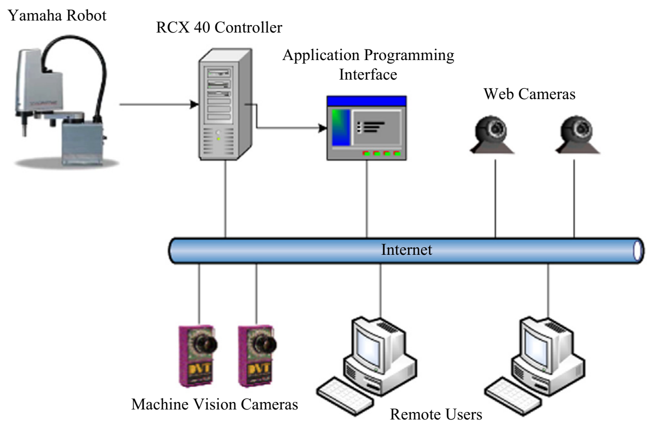

Fig. 1. Overall schematic of the proposed e-quality control system.

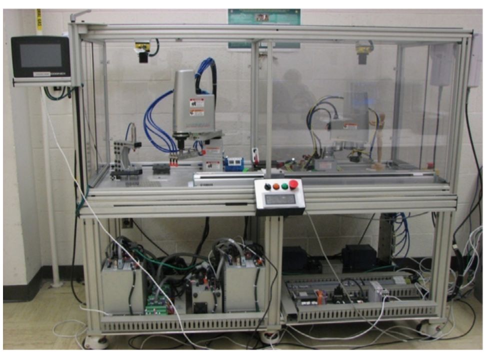

Fig. 2. Networked robotic setup at ISEL lab, UTEP.

experiments will be analyzed using SVM classifier equations to build a model, which can be used for predictions (i.e., good vs. bad quality). The motivation behind this work is to build robust classifiers, which can sort the incoming parts based on the vision-sensor generated dimensional data into the predefined groups in an automated way.

2. Literature review

Data mining, which is also referred to as knowledge discovery in databases, means a process of nontrivial extraction of implicit, previously unknown and potentially useful information (such as knowledge rules, constraints, regularities) from data in databases. In modern manufacturing environments, vast amounts of data are collected into the database management systems and data warehouses from all involved areas, such as product and process design, assembly, materials planning and control, order entry and scheduling, maintenance, recycling, and so on. Different researchers tried to solve the quality control and inspection using various machine learning approaches in an effort to address different types of problems. Automated diagnosis of sewer pipe defects was done using support vector machines (SVMs), where the results showed that the diagnosis accuracy using SVMs was better than that derived by a Bayesian classifier [10]. A combination of fuzzy logic and SVMs was used in the form of Fuzzy support vector data description (F-SVDD) for the automatic target identification for a TFT-LCD array process, where the experimental results indicated that the proposed method ensemble outperformed the commonly used classifiers in terms of target defect identification rate [11]. Independent component analysis (ICA) and SVMs were used as a combination for intelligent faults diagnosis of induction motors, where the results show that the SVMs achieved high performance in classification using multi-class strategy, one-against-one and one-against-all [12]. Fault diagnosis was also done based on the particle swarm optimization and support vector machines, where the new method can select the best fault features in a short time and has a better real-time capacity than the method based on principal component analysis(PCA) and SVMs [13]. Multi-class support vector machines were used for the fault diagnostics of roller bearing using kernel based neighborhood score multi-class support vector machine, where it was shown the multi-class SVM was effective in diagnosing the fault conditions and the results were comparable with binary SVM [14]. Artificial neural networks were used for addressing quality control issue as a non-conventional way to detect surface faults in mechanical front seals, which achieved good results in comparison with the deterministic system which was already implemented [15]. Fuzzy association rules were used to develop an intelligent quality management approach with the research providing a generic methodology with knowledge discovery and the cooperative ability for monitoring the process effectively and efficiently [16]. An automatic optical inspection was adopted for on-line measurement of small components on the eyeglasses assembly line, which was designed to be used at the beginning of the assembly line and is based on artificial vision, exploits two CCD cameras and an anthropomorphic robot to inspect and manipulate the objects [17].

In fact, the very insightful resources are abounded in terms of fuzzy learning with kernels and SVMs. One example includes the learning of one-class SVM, which requires non-labeled data [18,19]. Other studies also utilized the method of non-labeled data, hence being able to operate in a fully unsupervised manner [20,21]. Fuzzy analytical hierarchy process was used to select unstable slicing machines to control wafer slicing quality, where the results of exponentially weighted moving average control chart demonstrated the feasibility of the proposed algorithm in effectively selecting the evaluation outcomes and evaluating the precision of the worst performing machines [22]. Logistic Regression and PCA were the data mining algorithms used for monitoring PCB assembly quality, where the results demonstrated that the statistical interpretation of solder defect distributions can be enhanced by the intuitive pattern visualization for process fault identification and variation reduction [23]. Fuzzy logic was used for the fault detection in statistical process control of industrial processes and the comparative rule-based study has shown that the developed fuzzy expert system is superior to the preceding fuzzy rule-based algorithm [24]. SVMs were used for an intelligent real-time vision system for surface defect detection, where the proposed system was found to be effective in detecting the steel surface defects based on the experimental results generated from over one thousand images [25]. SVMs were also used as a part of the optical inspection