Measurement 47 (2014) 78–91

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Enhance performance of inspection process on Coordinate Measuring Machine

Syed Hammad Mian *, Abdulrahman Al-Ahmari

Advanced Manufacturing Institute, College of Engineering, King Saud University, P.Box 800, Riyadh 11421, Saudi Arabia

ARTICLE INFO

Article history:
Received 23 February 2013
Received in revised form 4 August 2013
Accepted 19 August 2013
Available online 28 August 2013

Keywords:
Coordinate Measuring Machine (CMM)
Measurement sequence
Inspection
Optimization plot
Brute force (BF)
Genetic algorithm (GA)
Simulated algorithm (SA)

ABSTRACT

Coordinate Measuring Machine (CMM) has been an important inspection tool in quality control for several years owing to its high accuracy and precision. Effectiveness of inspection plan generated by CMM greatly depends on measurement cycle time. Lesser the inspection time taken by CMM to measure a given part better will be the performance of inspection process. Therefore, it has been critical to reduce measurement time for efficient performance of inspection process. In this paper, methodologies to generate most suitable measurement path resulting into minimum inspection time has been introduced. These methodologies are based on different algorithms to reduce measurement cycle time for CMM. The different algorithms have successfully been explored and compared to show their effectiveness in minimizing inspection time for stationary CMM equipped with touch trigger probe. The proposed methodologies have also been implemented and tested on real-world mechanical part with certain number of features to demonstrate their applicability.

1. Introduction

Coordinate Measuring Machine (CMM) equipped with contact probe has been standard and most frequently used measuring instrument for dimensional inspection. Regardless of the availability of large number of non-contact measuring devices, CMMs mounted with touch probe have been preferred choice for inspection purposes. This is due to the fact that it can offer very high accuracy depending on the environment within which it operates. Since, CMMs requires huge capital investment therefore their proper utilization has been primary concern in industries. Moreover, ever increasing demand of high quality components and stiff competition in market requires manufacturers to reduce inspection time without compromising inspection quality. It becomes even more important to speed up inspection process on manufacturing line when number of features being measured increases. CMM probe travels to various features on the part depending on inspection plan during the inspection process. Therefore, determination of most appropriate inspection path has been critical for improved performance of CMMs. In any inspection plan, CMM measurement probe can travel to measure any feature but efficient inspection plan results in measurement sequence that minimizes inspection time. Thus, effective inspection path provides shortest route to measure number of features on the part being inspected. Overall improvement of CMM inspection process can also include minimizing number of probe re-orientation, reduction of stand-off distance (clearance, retract, approach distances etc.) etc., during inspection run besides measurement sequence. However, in present work, only measurement sequence has been considered because it is most critical aspect and contributes significantly to the performance of CMM. The motivation for this work has been provided by demands of effective methods and techniques that can be used to improve efficiency of inspection process thus reducing inspection time.

* Corresponding author. Mobile: +966 553118695.
E-mail address: syedhammad68@yahoo.co.in (S.H. Mian).

0263-2241/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.measurement.2013.08.045

The objective of this research includes determination of best possible probing sequence to measure different features on part. This problem requires generation of ideal path that measurement probe should take while moving between different features. The work at hand focuses on application of various algorithms and their comparisons to minimize measurement time. Although, applications of CMM for inspection purposes has extensively been spread throughout manufacturing industries yet measurement sequence planning especially by using heuristics such as genetic algorithm (GA), simulated annealing (SA) and brute force (BF) has not fully been developed. Therefore, in this work, methodologies to implement well established techniques such as GA, SA, and BF which have already shown many successful manufacturing applications have been proposed for improvement of inspection process.

2. Literature review

A large amount of work is being carried out to improve performance of CMM inspection process owing to increased demands of shorter inspection time. According to Topfer et al. [1] CMM performance can be improved with optimum measurement strategy involving minimal traverse path, minimal measuring time and minimal degree of wear. However, main objective has always been improvement of measurement path to reduce inspection time. There have been many techniques that can be explored and implemented to reduce measurement time for complex parts made up of several features. For instance, Ant Colony Optimization (ACO) based algorithm by Ji and Li [2] optimized measurement path for digitization of supercharger impeller. Similarly, principle of GA has successfully been implemented by Lin et al. [3] to generate measurement path over prismatic polyhedral parts. The problems of parameter selection, different operator's behavior, premature convergence problem etc., in GA have comprehensively been studied by Qu et al. [4] to optimize CMM measurement path. Approximation algorithms such as nearest neighbor method and refinement method by Lin and Chen [5] have also identified measurement sequence for better performance of CMM inspection process. Lu et al. [6] successfully achieved optimization of CMM inspection path and reduced inspection time considerably. Moreover, Buchal and Wang [7] applied nearest-neighbor Travelling Salesman Problem (TSP) algorithm to find out best possible inspection sequence. The need of shorter inspection time and better inspection methods have been driving force behind increased attempts to minimize inspection time. Implementation of artificial neural network (ANN) by Ruegsegger [8] produced satisfactory results with optimized measurement sequence of inspection points. Likewise, application of ANN by Lu et al. [9] to optimize inspection path resulted in reduced measurement time for multiple component inspection process.

Techniques such as GA, SA, BF, on account of their numerous benefits have been finding many applications in manufacturing industries. Successful application of GA by Cus and Balic [10] to determine cutting parameters for optimized machining conditions has proved that GA based optimization methods are robust, effective and efficient. Therefore, they can be used for variety of complex optimization problems. Similarly, Kolahan and Khajavi [11] optimized cutting parameters for abrasive water jet machining using SA and suggested SA an efficient and effective solution for optimization problems. GA has also been used by Kaya [12] for its flexibility and effectiveness in order to optimize fixture layout problem. Like, Huang et al. [13] who introduced GA for sequencing of operations in welding process, Qudeiri et al. [14] also employed GA to find best sequence of operations with minimum tool travel path for CNC machining operation. Moreover, Low et al. [15] minimized traveling path of gantry robot through optimization using GA whereas Garg and Kumar [16] presented and compared optimization capabilities of GA and SA for path planning of robotic manipulators.

Geng et al. [17] proposed algorithm based on SA and greedy search techniques to solve TSP and demonstrated its effectiveness with number of TSP instances. Similarly, Baraglia et al. [18] employed hybrid algorithm combining GA and Lin-Kernighan (LK) local search heuristic for solving TSP and showed its effectiveness through experiments on various TSP instances. Chen and Chien [19] also used combination of SA, GA and ACO along with particle swarm optimization technique to solve TSP. Furthermore, Zicheng et al. [20] presented two stage SA methods to optimize TSP. First stage produced initial solution using simple SA while second stage utilized an effective SA to produce optimized solution for TSP. The effectiveness of this algorithm was confirmed through its application on number of benchmark TSP instances. As far as BF approach is concerned, researchers have been working to explore its potential in manufacturing applications. Meanwhile, BF approach has found several applications in machine scheduling problem and TSP. For example, Kodeekha [21] implemented BF method to Flexible Manufacturing System (FMS) in order to provide effective scheduling solution. BF method provides simplest, quickest and efficient method to optimize travelling path and minimize travelling time for TSP [22].

Following conclusions can be made based on literature review:

- Widespread applications of SA and GA have proved that algorithms based on SA and GA can produce qualitative and superior results in lesser computational time.
- Limited research work has been found with respect to BF approach in manufacturing applications.
- Problem of sequencing measurement features for part inspection is similar to TSP. Therefore, sequencing of features for part inspection can be formulated as standard TSP. Features on part can be considered as cities while distance between features is similar to distance travelled between two cities of TSP. Moreover, objective function in both cases is similar that is minimization of measurement time for inspection planning and travelling time in case of TSP.
- Measurement path during inspection process can be determined by measurement sequence whereas length of measurement path determines total measurement distance and hence measurement time.