Volume 6 Issue 2(2018) 130-131 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

Enhancing the speed of inspection in coordinate measuring machine using genetic algorithm

Amit Kumar Sinha*, Ankush Anand
School of Mechanical Engineering, Shri Mata Vaishno Devi University, Katra, Jammu & Kashmir, India-182320

Article Info

Article history:
Received: 10 January 2018
Received in revised form
25 January 2018
Accepted 15 May 2018
Available online 15 June 2018

Keywords

Coordinate measuring machine (CMM), Measurement, Inspection, Genetic algorithm (GA)

Abstract

Due to high accuracy and precision, coordinate measuring machine (CMM) has been an important tool of inspection in quality control for several years. Effectiveness of inspection 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, for efficient performance of inspection process, it is critical to reduce measurement time. Goal of our research is to improve measurement accuracy and reduce the cycle time of inspection. There are various methods to generate most suitable measurement path which will result in minimum inspection time. These methods are based on different algorithms to reduce measurement cycle time for CMM. Genetic algorithm, which is one of the optimization techniques can be used to find the minimum cycle path and hence can be used to increase the speed of inspection.

1. Introduction

With the advancement of numerically controlled machine tools, the demand has grown for some means to support these equipment. There has been growing need to have an instrument that can do faster first piece inspection and many times, 100% dimensional inspection. The coordinate measuring machine (CMM) plays a vital role in the inspection process. Some of the CMMs can even be used as layout machines before machining and for checking features location after machining. CMM consists of a platform on which the work piece being measured is placed and moved linearly or rotated. A probe attached to a head cable of lateral and vertical movements records all measurements. They are versatile in their capability to record measurement of complex profiles with high sensitivity (0.25 micro meter) and speed. The probing system in CMM machines includes stylus and stylus tip which have their own dynamic characteristics during the measuring process. The stylus tip contact with the detected surface is the source of signals that will develop the pattern on the working objects. Therefore, performance of the CMM overall system is very much controlled by the motion, precision of the probe tip and its actuator. Therefore, probe stylus tip is laterally at centre of the CMM operation and a key element of coordinate measurements. The detection probes branch into two main categories; these are contact (tactile) probes and non-contact probes. 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. Our main objective will be improvement of measurement path to reduce inspection time.

2. Literature survey

The quality of geometrical complex manufacturing parts like automotive bodies, turbine blades, hydraulic life body, casing etc. are generally inspected with the help of CMM. A lot 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 measuring time, minimal traverse path, and minimal degree of wear. However, main objective has always been improvement for measurement path to reduce inspection time. There have been many techniques that can be explored and implemented to reduce measurement time in complex parts made up of several features. Techniques such as genetic algorithm (GA), particle swarm optimization (PSO), ant colony optimization (ACO), bacteria forging (BF) etc. on account of their numerous benefits have been finding many applications in manufacturing industries. Ahmari and Aalam [2] have suggested a design of experiment based model for optimizing process variables of surface reconstruction during reverse engineering. They have validated their proposed model by using two different point clouds which generated from both fixed as well as portable coordinate measuring machine laser line scanner. Lai et al. [3] proposed a genetic algorithm based model for estimating errors for cylindricity. Precision of different manufacturing process/methods during making automotive components can be easily evaluated in a very small time due to the facility of CMM [4]. Mansour [4] suggested that those mechanical components which have large geometrical complexity can be precisely manufactured by using CMM. Poniatowska [5] developed a deviation model for evaluating accuracy of free form surface by using coordinate measuring machine. Qu et al. [6] mapped the measuring head of CMM with travelling salesmen problem (TSP) and with the help of genetic algorithm they have identified the optimal measuring path of CMM. Error in manufacturing components can be judged by analyzing the raw data of CMM. Wen and Song [7] developed a genetic algorithm based model for evaluating planar and spatial straightness errors.

Successful application of GA by Cus and Balic [8] 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. In this regards, genetic algorithm can be useful for getting optimized measuring path in CMM. Measurement path during inspection process can be determined by measurement sequence where as length of measurement path determines total measurement distance and hence measurement time. In this paper, GA based algorithm is used to get best solution in minimum time.

3. Methodology overview

The main objective of our work is to determine effective measurement path that can minimize inspection time. Measurement time for inspection process differs depending on the length of measurement sequence. Therefore, objective (fitness) function for this problem can be defined as follows:

$$E = \sum_{i=1}^{n} \sqrt{(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2 + (z_i - z_{i+1})^2}$$

Where,

n: Number of measuring features

(x_i,y_i,z_i): Coordinate of features (their locations on the part)

E: Length of measurement sequence (total distance travelled by CMM probe through the part

Corresponding Author,

E-mail address: amitsinha5005@gmail.com;
Phone No--+91- 8493023061

Measurement sequence that can minimize value E actually represent effective probe path resulting in minimum measurement. The working and implementation of genetic algorithm is explained as genetic algorithm is search algorithm based on the mechanism of natural selection and natural genetics. It is based on the "Survival of the fittest" concept (Darwinian theory). According to which better and better solutions evolve from previous generation until a near optimal solution is obtained. So it simulates the process of evolution. A genetic algorithm is an iterative procedure that represents its candidate solutions as string of genes called chromosomes. In this method offspring that are better and better are produced as measure of fitness function, which is a measure of the objective to be obtained (maximum or minimum). Since we are doing a minimization problem as we have to select the minimum path, that offspring which will have lowest fittest function will be considered as the fittest one. The idea of GA appears first in 1967 in J D Bagley's thesis "The behaviour of adaptive systems" which employ genetic and correlative algorithms. The theory and applicability was then strongly influenced by J H Holland, who can be considered as the pioneer of genetic algorithm. The various steps in genetic algorithm are:

3.1 Step 1: Generation of initial population

First step in GA is to create a set of individuals (measurement sequences) to represent initial population. Initial population is this problem has been generated using random numbers. Then, each individual in the given population has to be evaluated using their fitness values.

3.2 Step2: Encoding

Individuals (chromosomes) in GA based algorithms are constituted by set of genes which can be represented either as integers, Boolean or string variables etc. Encoding of chromosomes has been one of the vital steps in GA which mainly depends on the nature of problem to be solved. Since, objective of present proble requires determination of optimum measurements sequence therefore permutation encoding has been selected. In this type of coding, every measurement sequence (chromosome) has to be represented by string of numbers such as 1 4 6 2 5 8 and so on where each number (1 4 6 2 5 8) represents a feature. For example, 1 represents feature 2 and so on. Subsequent steps in this algorithm require application of evolutionary operators such as selection, crossover, and mutation to produce new set of more fit individuals.

3.3 Step 3: Selection

Selection of individuals from a given set of population depends on their fitness values. Since, given optimization problem is a minimization problem therefore, individuals with minimum fitness would have more chances to be selected for next generation. In this problem, individuals in the population have been ranked based on their fitness and then measurement sequence with minimum fitness value i.e. one involving minimum distance of CMM probe has been selected. The next important step in this algorithm involves implementation of "crossover and mutation" operators. The performance and effectiveness of any GA based algorithm greatly depends on application of these two basic operators.

3.4 Step 4: Crossover

Crossover operation also called as recombination involves interchanging of genes between two parent chromosomes (individuals) to produce an entirely two new set of child chromosomes. Crossover is the exchange of genes between the chromosomes of the two parents. In the simplest case, we can realize this process by cutting two strings at a randomly chosen positions and swapping the two tails.

PARENTS	CHILDRENS
0001101|00111	000110101100
|	
1100110|01100	110011000111

One point crossover is a simple and often-used method for GA which operates on binary strings.

3.5 Step 5: Mutations

Mutation is a background operator which produces spontaneous random changes in various chromosomes. A simple way to achieve mutation is to alter one or more genes. In GA, mutation serves the crucial role of either

(a) replacing the genes lost from the population during the selection process so that they can be tried in a new context or

(b) providing the genes were not present in the initial population.

3.6 Step 6: Termination

The generational process is repeated until a termination conditions has been reached. Common termination conditions are:

(a) The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results.

(b) A solution is found that satisfies minimum criteria

(c) Fixed number of generations reached

(d) Combinations of the above

A simple genetic algorithm using a while loop is suggested in Table 1:

4. Conclusions

Main problem associated with executive of GA based algorithm is concerned with appropriate settings for GA parameters. GA parameters include crossover rate, mutation rate, population size, and number of iterations (stopping criteria). To overcome this issue, design of experiment (DoE) technique should be utilized for generating design conditions. Design condition based on full-factorial should be utilized to identify all combinations of various levels for GA parameters. After successful execution of GA at different combinations, results have to be analyzed for best GA parameters settings.

Table 1: Pseudo code of GA

```
{
  initialize population;
  evaluate population;
  while termination criteria not satisfied
  {
    select parents for reproduction;
    perform crossover and mutation;
    repair();
    evaluate population
  }
}
```

References

[1] Töpfer, Susanne, G Linß, U Nehse. Inspection Strategies and Inspection Planning for Dimensional Measurements of Micro- and Nano-structured Components using Cascaded Sensor Systems. In Proc. of Joint Int. IMEKO TC1+ TC7 Symposium, Ilmenau, Germany, 2005.

[2] Al-Ahmari, AMAJ Aalam. Optimizing parameters of freeform surface reconstruction using CMM. Measurement, 64, 2015, 17-28.

[3] HY Lai, WY Jywe, CH Liu. Precision modeling of form errors for cylindricity evaluation using genetic algorithms. Precision Engineering, 24(4), 2000, 310-319.

[4] G Mansour. A developed algorithm for simulation of blades to reduce the measurement points and time on coordinate measuring machine (CMM). Measurement, 54, 2014, 51-57.

[5] M Poniatowska. Deviation model based method of planning accuracy inspection of free-form surfaces using CMMs. Measurement, 45(5), 2012, 927-937.

[6] L Qu, G Xu, G Wang. Optimization of the measuring path on a coordinate measuring machine using genetic algorithms. Measurement, 23(3), 1998, 159-170.

[7] X Wen, A Song. An improved genetic algorithm for planar and spatial straightness error evaluation. International Journal of Machine Tools and Manufacture, 43(11), 2003, 1157-1162.

[8] F Cus, J Balic. Optimization of cutting process by GA approach. Robotics and Computer-Integrated Manufacturing, 19(1), 2003, 113-121.