CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Intense international competition has focused the attention of manufacturers on automation as means to increase productivity and improve quality. The surface quality of any machined parts plays a very important role in the performance of good-quality machined components and significantly improves fatigue strength, corrosion resistance, creep life etc. Surface roughness also affects several functional attributes of parts, such as friction, wear, light reflection, heat transmission, ability of distributing and holding a lubricant, coating etc. Therefore, the desired surface finish is usually specified and appropriate processes are required to maintain the quality.

Surface finish of machined parts plays an important role on mechanical properties. The surface finish of workpiece is an issue of main concern to the manufacturing industry (Boothroyd 1989) and the determination of surface roughness of the workpiece using inspection is a very important technology. The traditional stylus method is the most widely used technique in industry. In this, a precision diamond stylus is drawn through the surface being examined and the perpendicular motion is amplified (Damodarasamy 1991) for further processing. The accuracy of stylus method depends on the radii of diamond tips used. When the surface roughness falls below 2.5 µm, the stylus instruments are affected by large system error (Damodarasamy 1991). The disadvantage of such method is that they require
direct physical contact and line sampling which may not represent the real characteristics of the surface (Younis 1998).

In recent times, computer vision technology has attained tremendous vitality in a lot of fields. New applications continue to grow and existing applications expand. Several investigations have been performed to inspect surface roughness of a workpiece based on computer vision technology. It has been observed that surface roughness of a workpiece is strongly characterized by the surface image (Lee 2001). Machine vision has the advantage of grabbing the images on-line without accounting for factors like noise and vibrations of machine tool. Advances in the semiconductor industry has made machine vision field to find its way from crude binary systems that were extremely sensitive to changing light conditions to rugged industrial systems processing gray level images at the rate of several hundred millions of instruction per second.

1.2 PROBLEM STATEMENT AND PROPOSED SOLUTION

Machine vision has evolved to become a mainstream automation tool, enabling computers to replace human vision in high speed and precision manufacturing techniques. Machine vision systems are used to capture images, extract information using vision sensors and make intelligent decisions. The sequence of operations - image capture, early processing, region extraction, region labeling, high-level identification, and qualitative/quantitative conclusion are the characteristic of image understanding and machine vision problems. Images processed using a computer are digitized first, after which it may be represented by a rectangular matrix with elements corresponding to the brightness at appropriate image locations.
Images usually acquired through modern cameras may be contaminated by a variety of noise sources and decreasing intensity and in most cases the type of noise and state of lighting are also not known apriori. There is a need for design of recognition systems with capability to adapt to changing environments automatically. This requires computing architectures that are less complicated, highly flexible and more cost-effective as compared to the traditional ones, which calculates the coefficients of a general-purpose model.

In this research work, an important parameter of machined components namely surface roughness $R_t$ is estimated with greater degree of accuracy compared to the existing methods. The main focus of this work is to find more efficient and more general algorithms and implement them on more technologically sophisticated equipment. In particular, parallel architectures are being used to ease the enormous computational load of operations conducted on image data sets. The advantage of the proposed structure is that the image enhancement operation is evolved from primitives and does not require any apriori information about the type of noise. The developed system employs a genetic image interpretation based on a hypothesis and verify principle to evolve image operators and perform adaptive image processing. Also, the evolution is performed at the simplified functional level and uses simple logical functions and adders as primitive components. This research work solves partially the unsolved problem of automating the sequence of relevant operations required to solve a specific task.

The developed work is tested in online on images of specimens grabbed by the computer vision system with linearly decreasing intensity. The grabbed image is enhanced using virtual reconfigurable circuit configured using evolutionary algorithms and features are extracted using two different schemes, one using Fourier transform (FT) and the other using wavelet
decomposition. The FT method is used to extract the features of image texture namely the major peak frequency \( F_1 \), and the principal component magnitude squared value \( F_2 \). Using the wavelet (Db4) multiresolution decomposition algorithm the energy details of the sub band images namely Energy total (\( E_t \)), Energy horizontal (\( E_h \)), Energy vertical (\( E_v \)) and Energy diagonal (\( E_d \)) are extracted. These extracted features of the enhanced image are given as input to a trained neural network and the surface roughness parameter \( R_t \) is estimated. For comparative study image enhancement schemes using conventional filtering technique are considered and it is established that evolved solutions outperform the conventional one both in terms of performance and implementation cost.

The evolved image filter is implemented in real-time on a Xilinx FPGA based image processing board, which is available as a commercial off-the-shelf hardware device. This allows complex and fast computation to be performed by dedicated hardware instead of software in digital computer, as hardware units can operate in parallel.

1.3 OBJECTIVE OF THIS WORK

The objectives of this research work are

1. To develop a novel Evolvable hardware based image enhancement technique, to improve the quality of the images of surfaces by adapting to changes to process variations and adverse conditions in a CIM environment such as contrast reversal and intensity gradients, angular uncertainties, blur caused by changes in depth field, scale changes, partial obliteration or missing features.
2. To implement the evolvable hardware unit in real-time on a Xilinx FPGA board.

3. To apply wavelet transforms and Fourier Transforms independently and extract the relevant features of image texture.

4. To train a neural network and use it for estimating the surface roughness $R_t$ of components manufactured using processes such as grinding and milling.

5. To compare the surface finish obtained using each network with that using stylus approach.

The methodology used to implement the objectives of this research work is outlined in Figure 1.1.

1.4 BENEFITS OF THIS RESEARCH WORK

Conventionally stylus instruments are used to evaluate the surface roughness of machined parts. This is a direct contact method and has limited flexibility in handling the different geometrical parts to be measured. Also, the measurement speed of the stylus instrument is slow and the accuracy depends on the radii of the diamond tip. Due to these limitations the stylus instrument based approach may not represent the real characteristics of the surface. Alternately, optical measuring methods were applied to overcome the limitations of stylus method, but they are also sensitive to lighting and noise. Previous investigations performed on the use of computer vision technology to evaluate the surface roughness show that practical surface roughness instruments are difficult and the techniques are limited to offline. This is mainly due to the reason that the time involved in evaluating the surface
Figure 1.1  Methodology in the proposed computer vision system for measuring surface roughness

roughness is large and also apriori information about the lighting conditions is required. The direct solutions for obtaining High Resolution (HR) images are mainly related to sensor manufacturing techniques that attempt to increase the number of pixels per unit area by reducing the pixel size. In addition, there exists a limitation to the reduction of pixel size due to the shot noise problem, which severely degrades the image quality.

As an alternative, in this thesis, to obtain high-resolution images from low cost/resolution sensors, super-resolution or resolution enhancement
algorithm is implemented using a novel Evolvable Hardware technique. This technique requires no \textit{apriori} information about the lighting conditions and source of noise. The implementation of the evolvable circuit on dedicated Xilinx FPGA based hardware allows complex and fast computation to be performed by dedicated hardware instead of software in digital computer, as hardware units can operate in parallel. This removes the time constraint and makes the system many times faster than the conventional ones. Also, from the evolutionary enhanced image, features are extracted using the wavelet transform technique and an artificial neural network is used to estimate the surface roughness. Again, this approach outperforms the conventional techniques of image feature extraction and estimation such as the Fourier transform approach and regression approach respectively.

Thus the concepts presented in this thesis can be used in online to estimate the surface roughness of a workpiece with greater degree of accuracy compared to the existing techniques. The implementation cost of the proposed scheme is also low compared to the existing techniques.

1.5 OUTLINE OF THE THESIS

In Chapter 1 the thesis problem description and the proposed solutions are presented. The objectives of this work and the proposed methodology are also outlined in this chapter.

Chapter 2 describes an exhaustive survey of the works done so far in the area relevant to this thesis. The survey covers the direct and indirect methods of measuring schemes for surface roughness. Literature study on structural and statistical approaches of surface texture analysis performed on various machining operations is also presented.
In Chapter 3 different measurement parameters used in evaluating the surface roughness of a machined component are discussed. The experimental setup used for grabbing the images is also discussed. The details of the high speed image processing card on which the image processing algorithm is implemented is also presented.

Chapter 4 describes the theory of Evolvable Hardware (EHW) and the image enhancement using the proposed EHW architecture. The implementation of the genetic unit and the evolution of image operators for illumination enhancement and noise removal are also presented in this chapter. The implementation of the evolvable hardware based image enhancement unit and its real-time implementation using the xilinx FPGA board is presented. The functionality of each module and the entire EHW design is realized using a Hardware Descriptive Language – HDL.

Chapter 5 describes the brief theory of the Fourier transform and wavelet transform. The extraction of image texture features using the above transforms is discussed. This chapter also describes the fundamentals of neural network and the merits of using neural architectures for chosen application. The back propagation algorithm, machining parameters used for training the network and estimation of surface roughness is also discussed.

The results are presented in chapter 6 of this thesis. Different performance measures are evaluated and comparative values are presented under different cutting conditions. The merits of this research work are established in this chapter.

In Chapter 7 conclusion and suggestion for further study is presented.