CHAPTER 1

INTRODUCTION

In manufacturing environments, it is often a challenge to find an effective means of reducing costs and improving product quality. Machining is one of the most important and widely used manufacturing processes. Owing to the numerous interacting machining variables involved in machining process, the quality characteristics such as average surface roughness ($R_a$), tool wear ($TW$) and material removal rate ($MRR$) are the most important issues in the automation of cutting processes. $R_a$ is one of the indices of product quality. The proper functioning of a machined part is largely dependent on the quality of its surface. The continuous demand for product quality and higher productivity asks for better understanding and control of the machining process. To increase the product quality and production rate, the tool should have good performance with minimum wear and maximum $MRR$. A better understanding can be achieved through experimental measurement and theoretical simulations and modeling of the process and its resulting product. Online quality characteristics identification is finding an important role in modern engineering. The experimentation plays a vital role in Science, Engineering, and Industry.

1.1 Motivation of this Research

Since the turning, milling and micro-turning processes are widely used in the most important operations in the automobile, air-craft, electronics, communications, military application, fuel cells, subminiature actuators, sensors, medical devices, automotive and other industries, these three machining operations are considered in this work.
In the present industrial scenario, the major concern is to produce the quality products at competitive price. Since the direct contact methods (stylus instruments) of measuring $R_a$ are having limited flexibility in handling free-form parts, the indirect method using optical instruments has emerged. Besides, the measurement speed of the stylus is also slow.

Extensive research has been performed on machine vision applications in manufacturing, because it has several advantages compared to the stylus method, such as the ability for in-process or in-cycle implementation, rapid measurement capability, no chance of parts wear due to the noncontact nature and the ability to provide information over a surface area.

Recently, there have been significant research efforts to apply evolutionary computational techniques for determining the neural network weights and growing research interest in the applications of evolutionary algorithms in many diverse fields of science and engineering. Among these algorithms, the differential evolution algorithm (DEA) is a relatively novel optimization technique for efficiently solving numerical-optimization problems.

The majority of previous research efforts utilize simple image processing techniques that are prone to error especially under varying illumination conditions. Additionally, any variations in position and surface texture cause severe degradation in performance. However, this methodology is inevitably problematic since performing good segmentation is in general extremely difficult.

Recently, optical scattering techniques have been proposed as an improved approach to monitor $R_a$, utilizing direct sensing image of work piece. $R_a$ is one of the main results of process parameters such as tool
geometry (i.e. nose radius, edge geometry and rake angle) and cutting conditions (i.e. feed rate, cutting speed, depth of cut etc.).

To resolve an image of a micro-work piece adequately, one would require a microscope. Most of the micro-machining vision techniques rely on offline processing and cannot be integrated into a partial real-time monitoring system. These techniques however are insufficient for micro-machining where the tool and work piece itself are usually invisible to the human eye. Since, the diameter is so small, accuracy is inherently compromised. Furthermore, due to the micron scales of micro-machining, detection as well as determination of $R_a$ or breakage is quite challenging.

Since micro-tools are very small in diameter and the tool deflection due to cutting forces can be quite significant. Even a very small tool post for setting the tool can affect the tool engagement and cutting forces considerably. Finding the dynamics of the tool tip in micro-scale is however challenging. The effects of all the above mentioned aspects on tool wear and the machined $R_a$ of the work piece are extremely difficult to determine quantitatively in micro-scale. Since, modeling and optimizing of the cutting process is necessary to optimize the cutting conditions to account for changes in tool geometry, due to $TW$ and any additional unknown initial process parameters.

The utilization of an ordinary camera on the other hand poses a real challenge. The camera will require a zoom lens, which in turn may distort the image due to difficulty in determining an optimal combination of focal length, field of view and amount of zoom that minimizes the distortion of the image. Secondly, given that, the machined portion will have a shiny surface it is difficult to select appropriate lighting that will provide a suitable contrast and good image. In order to maintain machining quality and to prevent damage to
the work-piece, accurate monitoring or early prediction of machined $R_a$ is important.

### 1.2 Scope of this Research

Image texture can be quantitatively evaluated using the properties such as fineness, smoothness, coarseness, granulation, etc. Various statistical and structural methods have been developed to investigate these features. In order to improve efficiency in a manufacturing system, Prediction of $R_a$ is very essential. Mathematical models are available for the prediction of $R_a$ which requires large number of data for successful implementation. In general, geometric model development forms the basis of the approach through rigorous mathematical equations. This model is then implemented by a computer algorithm in order to handle the complex calculations.

ANFIS modeling refers to the way of applying various learning techniques developed in the ANN literature to fuzzy modeling. The ANFIS systems have potential to capture the benefits of both the fascinating fields into a single frame work. This system eliminates the basic problem in fuzzy system design (i.e. obtaining a set of fuzzy if-then rules) by effectively using the learning capability of an ANN for automatic fuzzy if-then rules generation. As a result, these systems can utilize linguistic information form of the human expert as well as measured data during modeling. Such applications have been developed for signal processing, automatic control, process control, data base management etc. The neuro fuzzy hybrid system combines the advantages of fuzzy logic system which deals with the explicit knowledge that can be explained and understood, and neural networks, which deals with the implicit knowledge that can be acquired by learning. A combination of these two technological innovations delivers the best results. The DEA is an evolutionary algorithm which uses a rather greedy and less stochastic approach to problem solving than do classical evolutionary
algorithms such as genetic algorithms, evolutionary programming, and evolution strategies.

The miniaturized multi-purpose micro machining setting up procedure is a very time-consuming activity, especially when different materials have to be processed and different shapes to be obtained. In this case, the objective of the process planning procedure is to find the set of parameters that gives a high $MRR$ with good $R_a$. The prediction of $R_a$, $TW$ and $MRR$ in machining is a challenging task, but is necessary for proper optimization of the process.

1.3 OUTLINE OF THESIS

The growing demands for product quality and economy have made it necessary to incorporate monitoring of the process parameters in automated manufacturing system. The present global industrial scenario is to produce quality products at competitive price in order to face the tough competition prevailing in the market which is dictated by customer. This is possible with increased productivity aimed at zero error. Generally surface finish is affected by various sets of machining parameters, which in turn affect the quality of the product. Engineering properties such as fatigue, hardness and heat transfer are affected by surface finish.

With growing demand of industrial automation in manufacturing, machine vision plays an important role in quality inspection and process monitoring. Machine vision for industry has generated a great deal of interest in the technical community over the past several years. Extensive research has been performed on machine vision applications in manufacturing, because it has the advantage of being non-contact as well as faster than the contact methods.
The greatest limitation of automation in the machining operation is tool wear. To achieve good condition of tool and better surface finish, the machining parameters like cutting speed ($V$), feed rate ($F$) and depth of cut ($D$) should be optimized. Hence, modern sophisticated machine tools also need optimization procedure for the selection of machining parameters. In most of the modern technological situations, more than one response variable is pertinent to the success of an industrial process or system.

Basically $R_a$ measurement can be divided into two approaches; direct and indirect contact methods. Direct contact is the most commonly used method to employ a diamond stylus to trace over the surface being investigated and to record a magnified profile of the irregularities. These are generally time-consuming processes, demanding expensive human intelligence, and must be done in off-line.

Indirect contact is the machine vision method which allows for the assessment of $R_a$ without touching or scratching the surface. It provides the advantages of a measurement process for 100% inspection and the flexibility for measuring the part under test without fixing it in the precise position. In contrast to the stylus-based methods that trace the $R_a$ in one dimension, machine vision can generate many more readings of a 2D surface in a given time, and this makes the estimation method for roughness measurement more reliable.

The first and most important task in roughness assessment with machine vision is to extract the roughness features of surfaces. Typical noise processes tend to dramatically alter local spatial variation of intensity while having relatively uniform representation in spatial frequency. Frequency domain features should be less sensitive to noise than spatial domain features.
Nowadays, intelligent techniques play a vital role for modeling, simulation and optimization of machining processes due to accuracy and less computation time. Hence, it is necessary to construct a model to predict the surface finish which places a vital role in inspection. In this study, an attempt has been made to predict the response variables such as $R_a$, $TW$ and $MRR$ for the macro and micro machining processes using the intelligent techniques like ANN trained by BP, ANFIS and ANN trained by DEA. Response Surface Methodology (RSM) has been employed to determine the machining parameters which will in turn prolong the tool life.

The thesis is organized as follows:
Literature Review is discussed in chapter 2. Chapters 3 to 5 describe the research work done in (a) Macro-machining (b) CNC milling process and (c) Micro machining. Chapter 6 deals with Results and Discussion and Chapter 7 provides Summary and Conclusion.