# Chapter 6
# Machine Fault Diagnosis and Prognosis using Self-Organizing Map

**Kesheng Wang**
*NTNU, Norway*

**Zhenyou Zhang**
*NTNU, Norway*

**Yi Wang**
*University of Manchester, UK*

## ABSTRACT

*This chapter proposes a Self-Organizing Map (SOM) method for fault diagnosis and prognosis of manufacturing systems, machines, components, and processes. The aim of this work is to optimize the condition monitoring of the health of the system. With this method, manufacturing faults can be classified, and the degradations can be predicted very effectively and clearly. A good maintenance scheduling can then be created, and the number of corrective maintenance actions can be reduced. The results of the experiment show that the SOM method can be used to classify the fault and predict the degradation of machines, components, and processes effectively, clearly, and easily.*

## 1. INTRODUCTION

Traditional preventive maintenance schemes as age-replacement are time-based without considering the current health state of the product, and thus are inefficient and less valuable for a customer whose individual asset is of the utmost concern. The major role of degradation analysis is to investigate the evolution of the physical characteristics, or performance measures, of a product leading up to its failure (Lee, Ni, Djurdjanovic, Qiu, & Liao, 2006). A maintenance scheme, referred to as Condition-based Maintenance (CBM), is developed by considering current degradation and its evolution. CBM methods and practices have continued to improve over recent decades. The main idea of CBM is to utilize the product degradation information extracted and identified

DOI: 10.4018/978-1-4666-6078-6.ch006

from on-line sensing techniques to minimize the system downtime by balancing the risk of failure and achievable profits (Vachtsevanos, Lewis, Roemer, Hess, & Wu, 2006). The decision making in CBM focuses on predictive maintenance according to the states of monitored products. It performs maintenance action just when it is needed before the failure happens. To do so, many diagnostic and prognostics tools, methods and algorithms have to be developed to detect and predict the fault as early as possible.

The function of fault diagnosis is to find out root cause of the observed process or machinery degradation. The tasks of fault diagnosis are detecting, isolating, and identifying an impending or incipient failure condition—the affected component (subsystem, system) is still operational even though at a degraded mode. Fault detection means detecting and reporting an abnormal operating condition. Fault isolation means determining which component/system/subsystem is failing or has failed. Fault identification means estimating the nature and extent of the fault. Therefore, through fault diagnosis, the condition of manufacturing machines can be determined accurately impending or incipient failure conditions without false alarms.

Fault prognosis, on the other hand, is predicting the Remaining Useful Life (RUL) according to the current state of product. It predicts when the observed process or equipment is going to fail or degrade to the point that its performance becomes unacceptable. It aims at extrapolating the behavior of process signatures over time and predicts their behavior in the future.

Fault diagnosis and prognosis are the basis for the strategy of CBM which can reduce the maintenance cost and production loss, and improve the reliability and prolong the life of the machines. This chapter mainly discusses how to apply Self-organizing Map (SOM) in fault diagnosis and prognosis for manufacturing systems. The features in time domain of vibration signals are extracted, and then conditions of machine are predicted and the faults are classified. The following of this chapter is organized as follows. Section 2 reviews the related work in fault diagnosis and prognosis. In Section 3, the concept and principle of Self-organizing map (SOM) are introduced. Section 4 presents the experimental setup for validation of the proposed method. The features extracted from time domain are described in Section 5. Section 6 shows the procedure of experiment and its results. The conclusions are given in Section 7.

## 2. RELATED WORK

Over the last several decades, there has been a wide range of approaches and implementation strategies for performing manual, semi-automated, or fully automated fault diagnosis and prognosis on critical systems in commercial and defense markets (Vachtsevanos, et al., 2006). In recent years, the fault diagnosis and prognosis has gained much attention in development of Intelligent Systems (Berenji et al., 2006). As mentioned in Section 1, fault diagnosis aims at detecting fault of a machine after their occurrences, while fault prognosis aims at predicting faults before their occurrences. Fault diagnosis is a type of classification problem, and artificial intelligence techniques based classifiers could be used to classify normal and faulty machine conditions effectively and efficiently (Kankar, et al., 2011). Fault prognosis is a type of classification problem as well, and the difference with diagnosis is that the prognosis should classify the whole condition into continuous or several discrete extents of degradation from perfect condition to absolutely failure. Therefore, the artificial intelligence techniques based classifiers could be used in fault prognosis as well because it is also a classification problem. A machine fault diagnosis and prognosis solution consists of two main steps: the one is feature extraction from raw vibration signals or other raw signals to extract some useful features that demonstrate the information of fault, and the other is to use these