HEALTH STATUS ESTIMATION OF TRANSCEIVER TESTING MACHINE USING ADAPTIVE NEURO FUZZY INFERENCE SYSTEM

MUHAMMAD AMZARI BIN NAJMI

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Faculty of Engineering
Universiti Teknologi Malaysia

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To my beloved daughter, wife, mother and father

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ABSTRACT

The purpose of this study is to improve existing maintenance triggering process for Transceiver Testing Machine (TTM) in Finisar by identifying the influence factors and design a new Adaptive Neuro Fuzzy Inference System (ANFIS) model as a machine learning model approach. The ANFIS model have a capability to learn the behavior of its production historical data and estimate the health status. This health status will be used as a trigger alarm for maintenance team to perform maintenance task instead of just using default expiry time setting as a reference. The ANFIS model were validated using production historical data from several scenarios as case studies. The accuracy of training and testing data were analyzed in this study. It is shown that the ANFIS model developed give good performance and results of this study can be used as adequate reference to improve the maintenance triggering process in industry such as Finisar.

ABSTRAK

Tujuan kajian ini adalah untuk meningkatkan proses pemacuan penyelenggaraan yang sedia ada bagi Mesin Penguji “Transceiver” (TTM) di Finisar dengan mengenal pasti faktor-faktor pengaruhnya dan merekabentuk model “Adaptive Neuro Fuzzy Inference System” (ANFIS) yang baru sebagai pendekatan untuk model pembelajaran mesin. Model ANFIS mempunyai keupayaan untuk mempelajari tingkah laku data sejarah produksi dan menganggarkan status kesihatan. Status kesihatan ini akan digunakan sebagai penggera untuk pasukan penyelenggaraan bagi melaksanakan tugas penyelenggaraan dan bukan hanya menggunakan tetapan masa tamat tempoh sebagai rujukan. Model ANFIS telah disahkan menggunakan data sejarah pengeluaran dari beberapa senario sebagai kajian kes. Ketepatan data latihan dan ujian dianalisis dalam kajian ini. Adalah ditunjukkan bahawa model ANFIS yang dibangunkan memberikan prestasi yang baik dan hasil kajian ini dapat digunakan sebagai rujukan yang mencukupi untuk meningkatkan proses pencetusan penyelenggaraan dalam industri seperti Finisar.

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LIST OF ABBREVIATIONS

ANFIS	Adaptive Neuro Fuzzy Inference System
ANN	Artificial Neural Network
ATE	Automated Test Equipment
CBM	Conditional-Based Maintenance
CMMS	Computerized Maintenance Management System
CPP	Correct Prediction Percentage
CPRI	Common Public Radio Interface
EM	Error Mean
ESD	Error Standard Deviation
FIS	Fuzzy Inference System
FLC	Fuzzy logic controller
FPC	Flexible Printed Circuit
HMS	Health Management System
HVM	High Volume Manufacturing
LCL	Lower Control Limit
MSE	Mean Square Error
OEE	Overall Equipment Effectiveness or Efficiency
OTN	Optical Transport Network
PHM	Prognostic and Health Management
PM	Preventive Maintenance
PON	Passive Optical Network
PSO	Particle Swarm Optimization
RMS	Root Mean Square
RMSE	Root Mean Square Error
RUL	Remaining Useful Lifetime

SDH	Synchronous Digital Hierarchy
SOH	State of Health
SONET	Synchronous Optical Networking
SPC	Statistical Process Control
SVR	Support Vector Regression
TPM	Total Productivity Maintenance
TTM	Transceiver Testing Machine
TTM-CS	Transceiver Testing Machine Control System
UCL	Upper Control Limit

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CHAPTER 1

INTRODUCTION

1.1 Introduction of Industrial Revolution

Smart factory is an intelligent manufacturing approach for industrial revolution. This promises an enhancement of advance manufacturing process in handling a big data and integration. In recent years, various ideas have been produced among the world to evolve traditional manufacturing environments into intelligent manufacturing.

In Germany, "Industry 4.0" strategy; and “Industrial Internet" has been introduced by United States. Meanwhile, Japan introduced "Manufacturing White Book Year 2014" and China coined in “Made in China 2025" (Xiaoya, *et* al., 2017).

There are many equipment used in manufacturing industries for production line operations. Every single equipment has its own functions and capabilities to meet the production line testing requirement. All the equipment can be used either standalone with manual operate or automated with embedded software and attached to machines.

Most of the manufacturing companies have spent a lot of money for maintaining the performance of machines by doing monitoring and scheduling for maintenance work. The periodic maintenance works are very important to make sure all the machines operate in good condition to meet the production expectation (Khac, *et* al., 2014).

Product quality is very critical in manufacturing company and the same time to full fill customer's demand. They are not only concern about capability of the company to deliver their needs but also in term of quality for every testing process that have been done in production lines. They are requesting a data log from each operations involved. These will tense manufacturing company to make sure all the quality of each process flow should be well monitored and certified.

The complexity of modern manufacturing system in industry is growing fast and corresponded with the increasing of faults that influence the reliability and system effectiveness. This makes fault diagnostics is very important (Cai., *et* al., 2016).

1.2 Problem Background

Time is very important for all industries especially in manufacturing industry. On-time delivery to support a high customer's demand is always being critical. This goes the same to Finisar Company. As the number one company in fiber optic technology, they always focus on "Test Time Reduction". Besides that, to support a huge demand from customer, they need to prepare a good testing control capabilities to test the Transceivers. Transceivers is the main product being produced by Finisar Company.

The transceivers built in Finisar will go through assemble process and test through production process flow. All the machine used in production must always be in a good health condition. This is to make sure quality of transceivers is monitored and meet customer's satisfaction. Improper maintenance triggering process for Transceiver Testing Machine (TTM) might increase downtime of each machines. A good Preventive Maintenance (PM) scheduling control can help company to reduce the downtime.

In Finisar, TTM have been used to perform several type of testing for transceivers. Transceivers is a device that contained transmitter and receiver with a common circuitry in a single housing. "Transceiver Testing Machine (TTM)" was built with various type of instrument, circuit board and fiber cable. There are multiple approach for this company to control and monitor the health status of each machine. Finisar Company was implementing maintenance scheduling for each TTM every 24 hours, 48 hours or 72 hours. This maintenance task was implemented without knowing the current health status of each machines.

Besides Finisar, there are other companies that face the same issue on designing the maintenance schedule for production line. As an example the case study for a semiconductor company situated in Penang. The company has been established since 1994 and leading technologies in manufacturing Flexible Printed Circuit (FPC). Their main service and support are circuit design, fabrication and mass production. The manufacturing operation for FPC can be divided into four clusters and each clusters has its own section.

The problems of that company is the lacking of manpower resources. They have only 8 technicians for maintenance the 109 machines. The same technician will also responsible for maintenance of company's air conditioner and lamps. Usually, a major breakdown case will take more than 2 hours to complete and less than 2 hours for minor case. The numbers of maintenance support is not enough to handle all the issues and this will increase the idling time for production operation. This were contributed by improper scheduling maintenance even the maintenance scheduling is early predetermined. As a solution, they proposed a proper scheduling based on machine requirements and historical data (Hasnida, *et* al., 2012).

Other than that, automotive company also has the same issue in maintenance scheduling. Based on case study from Patricia, *et* al., 2017, the Preventive maintenance scheduling is performed manually by a planner. The existing method is supported by Computerized Maintenance Management System (CMMS) as a scheduling tool.

However, the maintenance scheduling is a time-consuming task. This is due to the higher numbers of planned task to handle with an available resources needs.

The example of resources needed are technical knowledge and skills, availability of spare parts and downtime. The company operates in 24 hours basis and planner initiated a weekly scheduling for production lines. However, the planners rescheduled the tasks to use the unplanned downtime daily since no allocation time for daily preventive maintenance works except for weekend basis. In this case, the maintenance scheduling need a method to allocate the maintenance tasks to the resources.

In conclusion, the problem of maintenance scheduling could happen in among all industries field including Finisar. Basically, each company requires a proper maintenance scheduling to resolve the problem of resources availability and downtime. The gap is still exist even they already have the maintenance scheduling planned in the earlier stages. Looking into those related problem, the maintenance task can be triggered properly by integrating the existing control scheduling with computer intelligent technique which is explained in details in Chapter 2. Those techniques have been used to estimate the health of equipment or machine whether it is necessary to perform a maintenance task or not.

1.3 Problem Statement

The purpose of this study is to propose an enhancement of the existing maintenance triggering process. Currently, technician needs to perform maintenance for each machine by using a default Maintenance Expiry Time setting as a triggering reference. The maintenance task has been performed without knowing the real health status of each machines. There are several problems found in the process of performing maintenance:

i. Maintenance task will consume idle time for each machine while waiting technicians to perform the maintenance

ii. Complexity of the machine's configuration will requires more time to complete the maintenance task and this will increase the machine's downtime.

iii. More manpower is needed to perform the maintenance task for thousand numbers of machine

Currently, test data for all "Transceiver Testing Machine (TTM)" in Finisar Company has been stored in Finisar servers. The configuration setting for each machines are controlled via web based called "Transceiver Testing Machine Control System (TTM-CS)". Most of the transceiver testing has been testing using "Automated Test Equipment (ATE)" software as an official software in Finisar.

This software will query machine's information from TTM-CS during production testing operation. Basically, this transaction gives a capability for ATE software to determine machine's identity and historical information such as product type, product part number, machine's configuration, machine's activities, machine's status, and so on.

Reliability for each machine is monitored strictly by analyzing the output result from a completed maintenance task. The maintenance for "Transceiver Testing Machine (TTM)" has been performed by using a golden unit as a testing unit on a machines. This is to make sure machine performance meets a controlled parameters value.

Currently, TTM will trigger maintenance dependings on production transceiver testing results or maintenance expiry time settings. The expiry time setting has been configured by an expert. Normally, the expert will set expiry time either every 24 hours, 48 hours or 72 hours. The performed maintenance task involved a process of validating machine's health by checking a certain control parameters.

These settings are fixed depending on quantity of sharing machine in one setup. Table 1.1 below shows the list of setting.

Table 1.1 : Maintenance Expiry Time Setting

TTM Configuration	Maintenance Expiry Time
Standalone Machine	24 hours
Sharing 2 Machines	48 hours
Sharing 3 Machines	72 hours

Figure 1.1 below shows a process flow of maintenance triggering process for TTM. Each TTM gets its Expiry Time settings from Transceiver Testing Machine Control System (TTM-CS). TTM-CS will provide Maintenance Expiry Time and previous Maintenance Timestamp. The Maintenance Timestamp is a time of a previous passed maintenance task. Every TTM will have a different timestamp. ATE software will calculate a time difference between current time and previous Maintenance Timestamp.

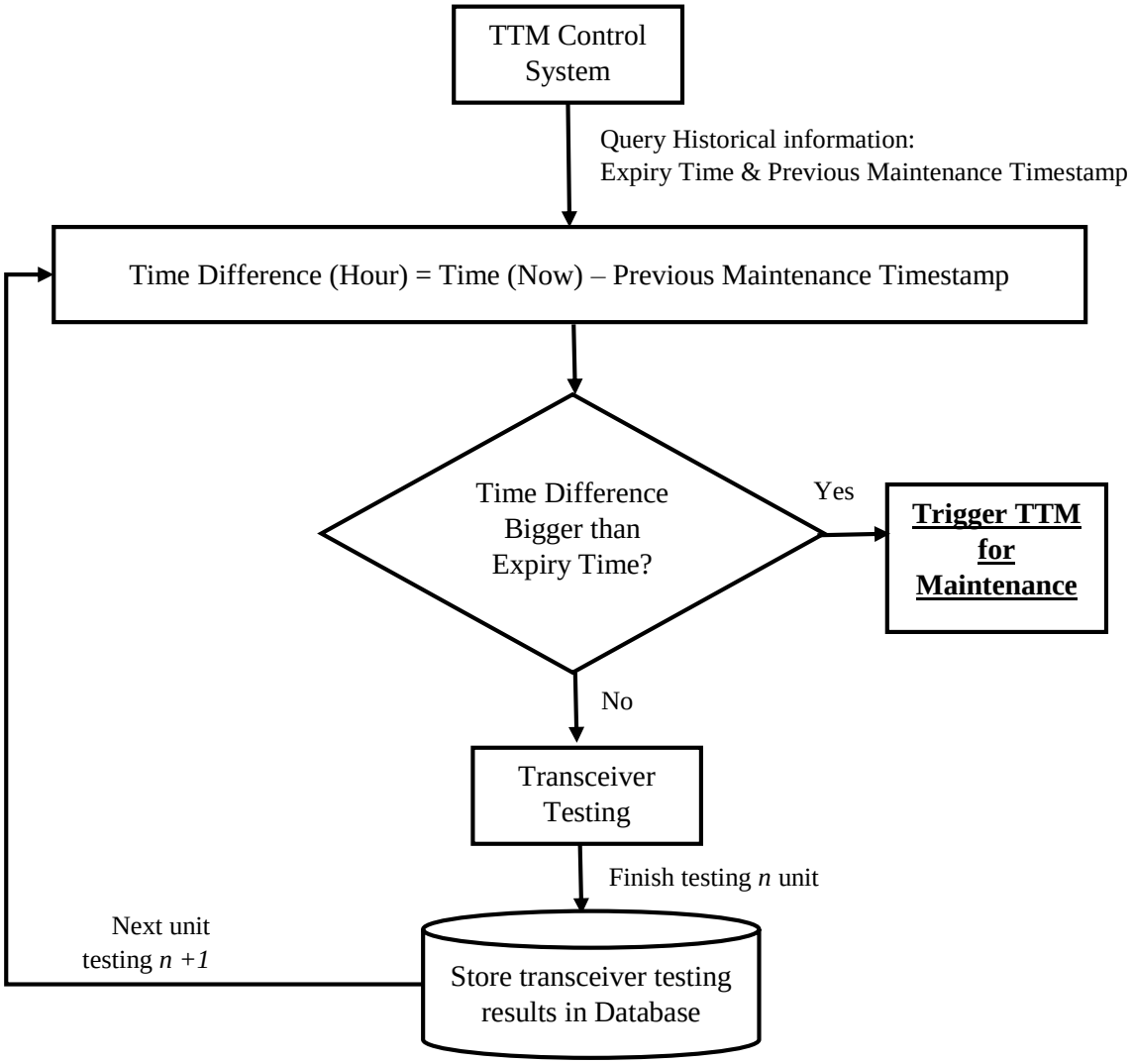

Figure 1.1 : Process of TTM Maintenance Triggering Process

Then, the time difference will be compared with the Maintenance Expiry Time setting. If the time difference is more than Expiry Time, then ATE will trigger operator to perform maintenance. While the time difference is less than Expiry Time, then ATE will continue with the n unit of product testing.

Once the testing of the "n" unit is done, testing results will be saved in database. At this point, ATE will calculate again the time difference between current timestamp and previous maintenance timestamp before continue for the "n+1" unit of transceivers

to be tested. This process will continue until the time difference is more than Expiry Time.

By introducing the new model for this process, the model learns the behavior of each machine and estimate the health status of each machine before performing a maintenance task. The enhanced system will consider the health status for triggering maintenance task instead of just using default Maintenance Expiry Time setting. This proposed model will be validated by comparing the training results with a real time production test data.

1.4 Aim and Objectives

The aim of this study is to propose a prediction model that can be used for an enhancement of the existing machine's maintenance triggering process using "Adaptive Neuro Fuzzy Inference System (ANFIS)". The results are used as a basis for the proposal to integrate with the existing process in Finisar company.

The above aim was accomplished by fulfilling the following research objectives:

1. To investigate the factors that influence the health status of Transceiver Testing Machine (TTM) for maintenance triggering process.

2. To propose new ANFIS model to estimate health status of Transceiver Testing Machine (TTM).

3. To validate proposed ANFIS model using production historical test data

1.5 Scope

In this research, the scope or boundary are defined as below:

1. This research focused on estimating health status for Transceiver Testing Machine (TTM) in Finisar production line.

2. This research focused on the proposed ANFIS model to be implemented in existing maintenance triggering process.

3. This research neglected loading time and downtime parameters as input for ANFIS model.

4. This research used Gaussian as a membership function in ANFIS model development.

5. This research focused on studying the TTM's production historical data from the same transceivers data rate family.

6. This research focused on validating proposed model using production historical test data.

1.6 Research Organization

This research consist of five chapters. In Chapter 1, it was discussed about the overview of industrial revolution among the world, problem background, problem statements, aim and objectives and scope.

Chapter 2 is a Literature Review of existing techniques and relates case studies can be used for estimating health status of Transceiver Testing Machine (TTM). The various approach compared to determine gap and strength among them.

Chapter 3 is Research Methodology, described a methodology used in this research which contain general research framework, and process sequence to complete this research.

Chapter 4 illustrated experimental result of the proposed ANFIS model with expected result outcome.

Chapter 5 is the final chapter which contains conclusion and future work.

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