SOFTWARE DEVELOPMENT OF REMOTE OPERATION SYSTEM FOR THE PIN TYPE FIXTURE OF CNC MILLING MACHINE

BY

DARMAWAN

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Kulliyyah of Engineering
International Islamic University
Malaysia

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ABSTRACT

The use of computer technology in manufacturing industries can improve manufacturing flexibility significantly, especially in manufacturing processes; many software applications have been utilized to improve machining performance, however none of them has discussed the abilities to perform direct machining. In this thesis, an integrated system for remote operation and monitoring of Computer Numerical Control (CNC) machines is put into consideration. The integrated system includes computerization, network technology and improved holding mechanism. The work proposed by this research is mainly on the software development for such integrated system. It uses Java three Dimensional (3D) programming and Virtual Reality Modeling Language (VRML) at the client side for visualization of machining environment. This research is aimed at developing a control system to remotely operate and monitor a self-reconfiguration fixture mechanism of a CNC milling machine through internet connection and integration of Personal Computer (PC)-based CNC controller, a server side, a client side and CNC milling. The performance of the developed system was evaluated by simulations using different types of common protocols such as Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). The developed software for the integrated system has been successfully tested on a CNC simulator, which is built based on Light-Emitting Diode (LED)s to represent of the pin type fixtures. By using TCP, the developed system requires 10.7 seconds to complete the close clamping, 7.9 seconds to release the clamping and can send 252 KB data when monitoring tool movement. On the other hand, the system only requires 3.9 seconds for close clamping, less than 1 second to release the clamping and it is able to deliver 463 KB when UDP protocol is implemented. UDP has been determined as the most suitable model for client-server architecture rather than TCP for real-time monitoring of the CNC milling, particularly for monitoring.

ملخص البحث

إستخدام تكنولوجيا الحاسوب في الصناعات يعمل على تحسين مرونة التصنيع بشكل ملحوظ ، وخاصة في سير عملية التصنيع. وقد تم إستخدام العديد من التطبيقات البرمجية لتحسين أداء الآلات، ومع ذلك لم يناقش أحد منهم قدرته على أداء الآلة المباشر. في هذه الأطروحة، قد وضع في الإعتبار نظام متكامل للتشغيل عن بعد ورصد مراقبة الكمبيوتر العددية (CNC) لمدخلات الآلات. النظام المتكامل يحتوى على حوسبة، تكنولوجيا الشبكة وتحسين آلية العقد. أساس العمل المقترح في هذا البحث يعمل على تطوير البرمجيات لنظام متكامل من هذا القبيل. فإنه يستخدم برنامج جافا ثلاثية الأبعاد (D3) ولغة نمذجة الواقع الافتراضية (VRML) في جانب العميل لرؤية بيئة الآلة. يهدف هذا البحث على تطوير نظام تحكم عن بعد لتشغيل ومراقبة إعادة تشكيل ذاتية لثبات آلي لآلة الطحن CNC من خلال الاتصال بشبكة الانترنت والتكامل من أجهزة الكمبيوتر الشخصية (PC) القائمة على وحدة تحكم CNC، جانب الخادم، جانب العميل و الطحنCNC. لقد تم تقييم أداء النظام بواسطة المحاكاة مستخداما أنواع مختلفة من البروتوكولات الشائعة مثل بروتوكول التحكم بالإرسال (TCP) وبروتوكول مخطط بيانات المستخدم (UDP). قد تم إختبار البرنامج المطور للنظام المتكامل بنجاح على جهاز محاكاة CNC والتي بنيت على أساس ضوء الصمام الثنائي(LED) لتمثيل دبوس ذو النوع الثابت. باستخدام الTCP، يتطلب النظام المتطور 10.7 ثانية لإغلاق المشبك، 7.9 ثانية لإطلاق سراح المشبك ويمكنة إرسال252 كيلو بايت من البيانات عند رصد حركة الأداة. من ناحية أخرى، فإن النظام لا يتطلب سوى 3.9 ثانية لإغلاق المشبك، وأقل من1جزء من الثانية للافراج عن المشبك ويمكنة إرسال463 كيلو بايت وذلك عند تنفيذ بروتوكول UDP . قد تم تحديد UDP كالنموذج الأكثر ملاءمة لخدمة العملاء بدلا من TCP لمراقبة الطحن CNC في الوقت الحقيقي، وخاصة للرصد.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

……..
Rini Akmeliawati
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

……..
Farhat Anwar
Internal Examiner

……..
Zahurin B. Samad
External Examiner

This dissertation was submitted to the Department of Mechatronics Engineering and is accepted as a fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering).

……..
Md. Raisuddin Khan
Head, Department of Mechatronics

This dissertation was submitted to the Kulliyyah of Engineering and is accepted as a fulfilment of the requirement for degree of Master of Science (Mechatronics Engineering).

……..
Md. Noor B Salleh
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Darmawan

Signature ……...…… Date ……...……

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Affirmed by Darmawan

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Signature Date

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All praise to Almighty Allah (SWT) for His endless blessing and granting me patience to complete my thesis and master degree and salutation upon the Prophet Muhammad SAW.

I wish to thank my family for their help and support. Special thanks, I send to my my mother, my father and my wife as an example of hard work and inspiration. I have always been overwhelmed by their wise advices, care, kindness, and love. There are no words that can show my gratitude to them, for all my family thank you so much.

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Finally, I would like to thank everybody who was important to the successful realization of this thesis, as well as expressing my apology that I could not mention the names personally one by one.

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LIST OF ABBREVIATIONS

3D	Three Dimensional
API	Application Programming Interface
ASP	Active Server Pages
AVML	Advance in Visual Methods for Linguistics
CAD	Computer-Aided Design
CAM	Computer Automated Manufacturing
CCW	Counter Clock Wise
CM	Communication Media
CNC	Computer Numerical Control
CORBA	Common Object Request Broker Architecture
CPD	Collaborative Product Design
CPU	Central Processing Unit
CW	Clock Wise
DAG	Directed Acyclic Graph
DAQ	Data Acquisition System
DCOM	Distributed Component Object Model
DHTML	Dynamic HTML
EAI	External Authoring Interface
EMC	Enhanced Machine Controller
EMC2	Enhance Machine Controller 2
FDM	Fused Deposition Modeling
GA	Genetic Algorithms
GPU	Graphic Processing Unit
GUI	Graphic User Interface
HAL	Hardware Abstraction Layer
HTML	Hypertext Markup Language
IDE	Integrated Development Environment
IGES	Initial Graphics Exchange Specification
IP	Internet Protocol
JDBC	Java Database Connectivity API
JDBC	JavaservletthroughJavaDatabaseConnectivity
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
MuMaTe	Multiple Manipulators for Training and Education
NC	Numerical Control
NGM	next-generation manufacturing
NI	NationalInstrument
ODL	object definition language
OML	objects to manipulation language
OODBMS	specific object-oriented database management system
PC	Personal Computer
PHP	PHP:Hypertext Preprocessor

PSO	Particle Swarm Optimization
RAM	Random Access Memory
RDP	Remote Desktop Protocol
RMI	Remote Method Invocation
RP	Rapid Prototyping
SCTP	Stream Control Transmission Protocol
SDAI	Standard Data Access Interface
SDRC	Structural Dynamics Research Corporation
SFF	Solid Freeform Fabrication
SP	service provider
SQL	Structure Query Language
SR	service receiver
SSL	Secure Socket Layer
STEP	Standard for the Exchange of Product Model Data
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TLS	Transport Layer Security
UDC	User Defines Commands
UDP	User Datagram Protocol
URLs	UniformResourceLocators
VIs	Virtual Instrument
VM	virtualManufacturing
VRCE	VirtualReality-BasedCollaborativeEnvironment
VRML	Virtual Reality Modeling Language
WAN	Wide Area Network
WOO-DB	Web-based Object Oriented-DataBase
XML	Extensible Markup Language

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The current trend in manufacturing tends to produce a large variety of products with small batch sizes. This condition requires an effective usage of manufacturing facilities. Sharing and distributing manufacturing tools through a remote operation is a way to optimize the usage of manufacturing facilities (Afzeri, Muhida, R., Darmawan, andBerahim, A.N.,2008). Remote operation that performs an automatic setup for a variety of work-pieces is an alternative solution. Remote operation of manufacturing facilities can reduce the timeprocess and minimize human operator involvement in machining processes. The shop floor does not need to be attended continuously; beside, human operators can operate and monitor the facilities from proximity place. Therefore, applying remote operation in modern manufacturing processes can possibly decrease machining cost.

Remote operation for many new Computer Numerical Control (CNC) machines is possible to be constructed by using common information, computer technology andparticular equipment. The internet allows a CNC machine to be remotely operated and monitored. This capability may increase productivity and profitability as it can minimize machine idle time, setup and training costs. Remote operation and monitoring system involves a remote host, servers, and controlled objects that are seamlessly integrated into a common network by using a standard Local Area Network (LAN), switch hub and Transmission Control Protocol/Internet Protocol (TCP/IP).

Thevarietyofwork-piecesdepends on customerdemand. This may result in work-pieces with complex geometry with variations, thus, they cannot be clamped with the use of a single fixture. The cost of process production will increase. Therefore, the design of a flexible fixture by using the pin type as shown in Figure 1.1, is required to obtain a suitable clamping (Afzeri et al., 2008). This type of fixturemay result in unit cost reduction, higher product quality and shorter lead-time. The outcome of this research providesa new mechanism that allows users from any other places to operate and monitor fixture processes via internet connection.

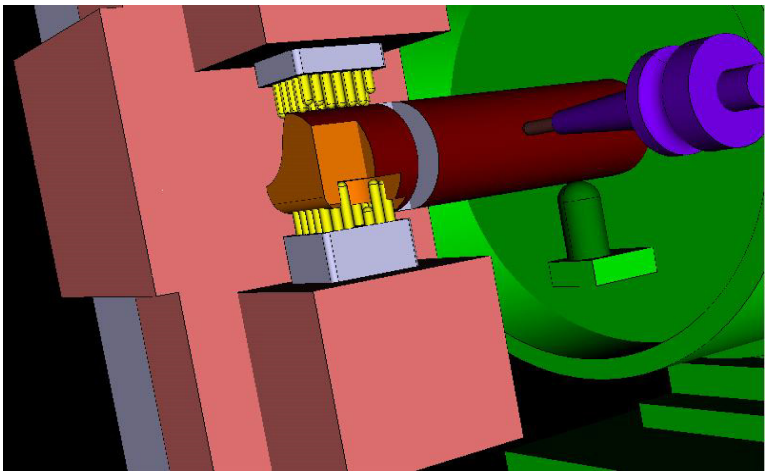

Figure 1.1: Virtual simulation of pin type fixture

There are many studies on machie operation and monitoring, such as those are conducted bySormaz, D.N. (2001)and Qiu Z.M(2001). Theyconcentrateonthe operation and monitoring machining processes, but there is hardly any work which considers performinga machining process by remote operation completely.Motivated by this fact, this research is carried out. In this research, remote application to drive pin type fixture for automatic setup on a variety of work-piece, is proposed as a new mechanism. Nukhae (2008) presented an analyzingof the designed work-piece by

using Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) algorithms. It determines the optimum clamping based on the minimum deformation of the designed work-piece.

Customizing an existing system to improve its function is a prevalent way to reduce time and construction cost. A CNC milling machine that is controlled by a PC-based CNC controller is applicable to laboratory use. Itcan be customized to do particular tasks. The advantage of using PC-based CNC controller to drive the CNC milling machine is that it can easily bring the machine into an online system for remote operation as most of PCs are equipped with a communication interface, such as Ethernet card. In addition, all functions in the PC can be used to support the operations, such as Graphic User Interface (GUI) as shown in Figure 1.2.This allows users to monitor the machine better than a conventional CNC machine controller. Besides, thestorage capacityallowsthe users to store many Numerical Control (NC) codes.

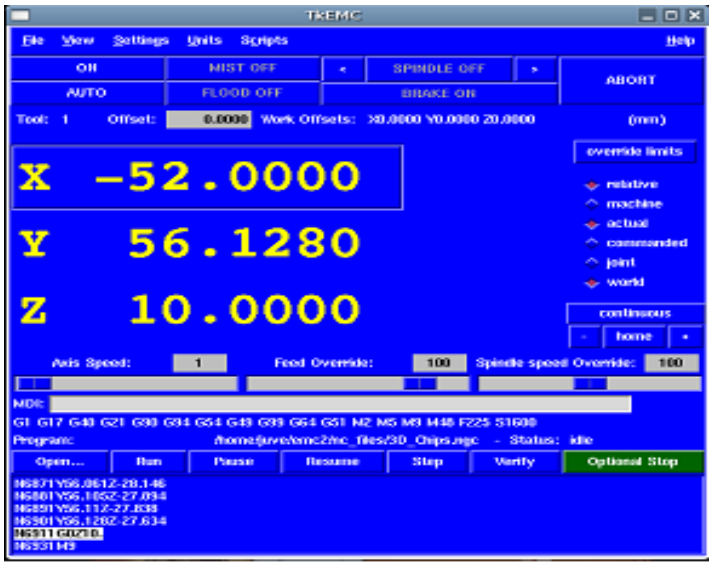

Figure 1.2: One of Graphic User Interfaces (GUI) of PC Based CNC controller

This research is intendedtomerge the computer technology into mechatronics and manufacturing disciplines.Thisis to allow an innovation in the manufacturing field. Acollaboration in cross-disciplines, such as manufacturing and mechatronics engineering as well as computer that science canprovide great improvement in the system concerned.

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

The importance and usefulness of internet communication for manufacturing systems for improving the facility of manufacturing industry by direct access to shop facility has not been explored (Zhuang, Y., Chen, L.,and Venter, R.,2000). Some studies have been conducted on operating and monitoring of CNC machines. However, none of them has discussed the abilities to perform direct machining; most of the works have been based on manual operation. Manual setup of the holding attachment results in a non-optimal process, as it is time consuming, lack of safety and precision. In addition,it is limited, because it has to be conducted at the shop floor site.

The most common problem in remote system is related to the speed of the system. This is commonly found in shop facility, which uses a camera-based monitoring system (Lal S.P and Onwobolu G.C., 2007). This system requires a very large data size, thus, it could not be a real-time as the image transferred and viewed by the user is slow.

To solve the above problem, several attempts are taken in this research to develop a new way to set up CNC machines, which are equipped with pin type fixtures by using remote operation. Furthermore, an effort is done to introduce a mechanism to monitoring a CNC milling machine through a Java 3D application at a

client side to visualize a machine environment. So, the problem with a real-time monitoring system can be solved.

1.3 RESEARCH OBJECTIVES

The objectives of this research are:

1. To develop software for an online controller to drive the electrical system of a pin type fixture of CNC milling machine.
2. To develop an integrated software that remotely monitors and operatesa CNC machine system through commanding the proposed controller.
3. To implementthe developed software on a self-reconfigurable fixture mechanism.
4. To evaluate the performance of the developed software on remote monitor and operation system.

1.4 RESEARCH METHODOLOGY

In this sub chapter, the flowchart of the research process is shown in Figure 1.3.

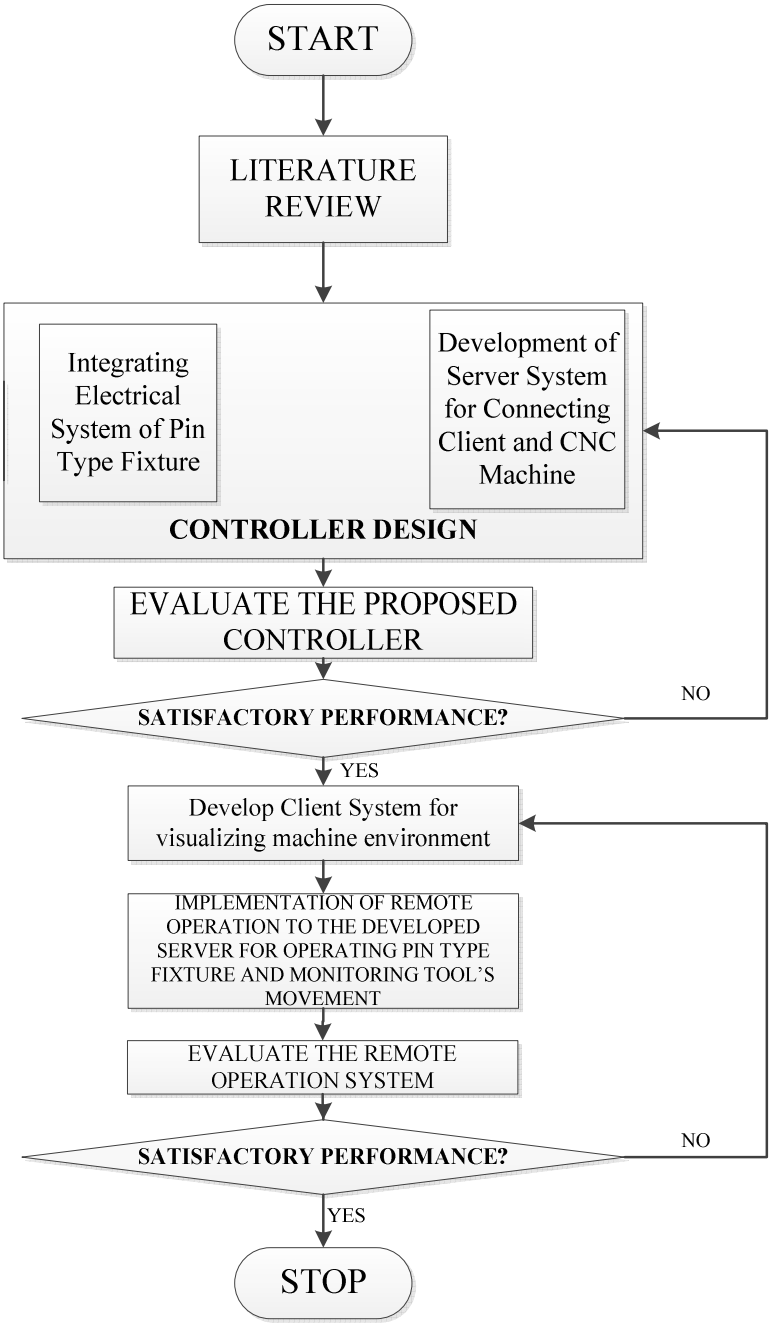

Figure 1.3: The flowchart for the Research Methodology

1.5 SCOPE OF RESEARCH

This research covers the design of a 3D virtual simulation from the client side by using the Java 3D programming language for visualizing the machine environment. This research also encompasses the design of software for an online controller in the server side for driving an electrical system of the pin type fixture. Itcustomizes PC-based CNC controller for controlling four axes as found at a milling machine which supports data for the server side.

The software application provides a space for users to operate the pin type fixture for completing the clamping process through internet connection and to monitor the cutting tool movement. The Java 3D program will be executed from the client side by using its compiler. Data for simulation of machine environment are supported by developing server that is connected to the CNC milling machine equipped by the pin type fixture through data-acquisition card.

From the server side, this research is limited ondeveloping software application by using LABVIEW graphical programming to handle any request from client.Some functions are also constructed to extract the pin configuration files by using MATLAB script programming language. The function will be operated by LABVIEW Virtual Instruments.

The client-server architecture is developed to establish data communication at this remote system. Firstly, the code following the TCP protocol which is constructed by socket programming is employed to allow communication between the client and the server side. Secondly, another code by using the UDP protocol as a comparison to the TCP protocol is also applied to obtain optimal and efficient communication.

LEDs are used to represent the pin type fixture. They are arranged, so that their positions are related to the pins in visualization on the client side. In this research,

LEDs are considered as switches for enabling hydraulic systems whichdrive the real pins. To evaluate the performance of software, pin configuration files are extracted by using the developed software as of the result is indicated through the lighting LEDs. Each of the LED is connected to the online controller through a digital output interface of data-acquisition card.

1.6 DISSERTATION OUTLINE

The dissertation consists of five chapters. In Chapter One, the introduction as the internet based manufacturing system is presented. This chapter presents the background, problem statement, research objectives, research methodology, scope of the research and dissertation outline.

Chapter Two presents the literature review on computer technology contributions in manufacturing systems.This includes by Virtual Reality Modeling Language (VRML) modeling, Computer-Aided Design (CAD)-based product modeling and data exchange, simple client-server architecture, remote operation of manufacturing equipment, virtual simulation of manufacturing environment, and pin type fixtures. This chapter also presents the theoretical background of tools and constructors that are employed in developing an internet-based of CNC milling machine. Previous works conducted by some researchers on the related topics are explored and elaborated.

Chapter Three explains the research methodology which includes the development of client side through constructing Java program to create virtual model simulation, and the communication system with the database server and the server side. This chapter also presents the process of developing software applications at the server side that includes the building of the database server, the development of

LABVIEW-based program for handling requests from client. Remote Desktop Protocol is also discussed to show its contribution to this research. Mechanism for measuring system performance is explained.

Chapter Four discusses the result of analysis of the remote operation system according to time delay and accuracy of the sensors system.

Chapter Five summarizes the entire work explained in previous chapters. Conclusion and future works are also presented in this chapter.