EMBEDDED INSTRUMENTATION SYSTEM FOR OPTICAL TOMOGRAPHY BASED ON IMAGE SENSORS

MOHD AMIR HAMZAH BIN AB GHANI

UNIVERSITI TEKNOLOGI MALAYSIA

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MOHD AMIR HAMZAH BIN AB. GHANI

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To my beloved family, friends

and lecturers who have guided

and inspired me along the journey.

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ABSTRACT

Tomography technique was used widely for its visualisation by section ability. The technique that is popularly used in process industry has high efficiency and is able to improve manufacturing sector. Optical tomography can capture images of objects moving in high speed is a convenience and commonly used in process industry particularly in chemical process. Optical tomography system can be embedded with a controlling unit capable of giving instructions in which to operate the optical sensors. The embedded controlling unit helps reduce processing time of data collection and can be conveniently placed in a minimal working space environment. The main component for the embedded optical tomographic system is the Charge Coupled Device (CCD) used as an image sensor. The SONY ILX551A CCD sensor that has 2048 effective pixels was placed outside of a pipe on an octagon shape Perspex due to its non-intrusive nature. There are four projections used for the tomography system with a single CCD sensor placed at each end of the projection. The CCD sensors are controlled by an embedded system including an ATMEGA1284P microcontroller that produces driving signals needed to turn on the four CCDs in the system. The microcontroller Timer function generates the signal according to the sequence needed by the CCD sensors. The speed of the data produced correlates with the speed of the timing signals sent out from the microcontroller. The experimental result recorded was based on the four conditions: when the sensors were fully open, fully closed, half open and when an object is present. The image of when an object present condition was produced through image processing method. Hence, the embedded instrumentation system for optical tomography based on image sensors manages to obtain data accordingly to the sensors detection.

ABSTRAK

Teknik tomografi telah digunakan secara meluas kerana kemampuannya untuk visualisasi secara seksyen. Teknik yang digunakan oleh pemaju dalam industri pemprosesan mempunyai kecekapan yang tinggi dan mampu meningkatkan sektor pembuatan. Tomografi optik dapat menangkap gambar objek yang bergerak dalam kelajuan yang tinggi dengan mudah dan banyak digunakan dalam industri pemprosesan terutama dalam bidang proses kimia. Sistem tomografi optik boleh diasimilasikan dengan unit pengendali yang mampu memberi arahan untuk mengoperasikan sensor optik. Unit kawalan tertanam membantu mengurangkan masa pemprosesan pengumpulan data dan boleh dipasang dengan mudah di dalam persekitaran ruang kerja yang minimum. Komponen utama sistem tomografi optik yang tertanam adalah Peranti Ditambah Caj (CCD) yang digunakan sebagai penderia imej. SONY ILX551A penderia CCD yang mempunyai 2048 piksel berkesan ditempatkan di luar paip yang berbentuk oktagon Perspex oleh kerana sifat non-intrusif. Ada empat unjuran yang digunakan untuk sistem tomografi dengan satu penderia CCD diletakkan di setiap hujung unjuran. Penderia CCD dikendalikan oleh sistem terbenam termasuk pengawal mikro ATMEGA1284P yang menghasilkan isyarat memandu diperlukan untuk menghidupkan empat CCD dalam sistem. Fungsi pemasa pada mikropengawal menjana isyarat mengikut turutan yang diperlukan oleh penderia CCD. Kelajuan data yang dihasilkan bergantung kepada kelajuan isyarat masa yang dihantar keluar dari pengawal mikro. Hasil eksperimen dicatatkan adalah berdasarkan empat syarat: apabila sensor terbuka sepenuhnya, ditutup sepenuhnya, separuh terbuka dan ketika objek hadir. Imej apabila keadaan objek yang hadir telah dihasilkan melalui kaedah pemprosesan imej. Oleh itu, sistem instrumentasi yang tertanam untuk tomografi optik berdasarkan penderia imej mampu mendapatkan data yang dikehendaki untuk pengesanan penderia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CLK	-	Clock Signal
CCD	-	Charge-coupled Device
DAQ	-	Data Acquisition System
DAS	-	Data Acquisition System
DC	-	Direct Current
EEPROM	-	Electrical Erasable Programmable Read-Only Memory
ECT	-	Electrical Capacitance Tomography
LED	-	Light Emitting Diode
MCU	-	MicroController Unit
MPU	-	MicroProcessor Unit
OFPT	-	Optical Fibre Process Tomography
P1	-	Projection One
P2	-	Projection Two
P3	-	Projection Three
P4	-	Projection Four
PC	-	Personal Computer
PIC	-	Peripheral Interface Controller
PWM	-	Pulse Width Modulation
ROG	-	Read Out Gate

LIST OF SYMBOLS

α	-	linear coefficient
cm	-	centimeter
f_0	-	Focal length
I	-	Current
I	-	Intensity
kHz	-	kiloHertz
ln	-	natural log
m	-	meter
mA	-	milliampere
mm	-	millimeter
MHz	-	megaHertz
n_t	-	transmitted refractive index
n_i	-	incidence refractive index
R	-	Resistor
V	-	Voltage

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The word tomography was derived from word tomos which means volume in Greek and graphein which means to write. It is also described as the idea of ‘a section’ or ‘a slice’. Therefore tomography is imaging by sections or in other word, sectioning. The method is well known and widely used in archaeology, biology, radiology, geophysics and other sciences. Tomography is also an important techniques used even in the nuclear fields (Itami *et al*, 2001).

Several techniques or methods have been discovered and reinvented in the field of industrial process tomography. Each technique has its own advantages and limitations and it is difficult to select the most practical application as each technique is unique in its own way. With the right combination of application, it could provide good productivity and quality result. (Bogolubov *et al*, 2005; Zeni *et al*, 2000).

It is largely used in manufacturing science and material processing for it non-contact properties and it helps reduce measurement error (Xu *et al*, 2011; Zeng *et al*, 2010; Luo *et al*, 208; Wang *et al*, 2014). The technique is capable resolving the measurement precision problem (Zhao *et al*, 2013a; Zhao *et al*, 2013b; Zhao et al, 2012b) and popularly used in biomedical imaging system (Chang *et al*, 2013; Chaudhari *et al*, 2005). The optical system in biomedical aim to increase acquisition speed and be non-intrusive (Stifter *et al*, 2008; Bezerra *et al*, 2009). The application of tomography in biomedical can even imaging the blood vessel (Ko *et al*, 2005).

The tomography method was also used in army industry science and air flight (Han *et al*, 2014). For process industry especially in chemical process, optical tomography has been used in many latest equipment with optical fibre being one of it (Ramli *et al*, 1999). Various tools or system are being produced at all time to improve the measurement process. It becomes important as optical tomographic image can help to capture image that are hard to see with our bare eyes, thus improving productivity and reducing wastage. The benefits are useful to everyone involved in the process industry.

The system of optical tomographic instrumentation based on the charge-coupled device (CCD) linear image sensor has the ability to fully measure the cross section of the pipe. In addition, the optical tomographic system is known as safe and non-intrusive (Zhang *et al*, 2008). The optical tomography is also useful for investigating and monitoring flow of solid or gas (Mohd Zain *et al*, 2010). Direct contact of the transducer and the measurand are not necessary. The efficiency of the technique is high and has the possibility to improve manufacturing sector especially in the chemical industries. The technique is also able to provide measurements via on-line.

1.2 Project Background

In order to get a better understanding of some chemical process, an approach that is more subtle is required. Process tomography is a medium used as a visualizer to look into the interior section of industrial processes. The images of tomography will give valuable information of the process. It will give insight knowledge that is good and beneficial for on-line monitoring and equipment designs. (Peyton *et al*, 1996; Wang *et al*, 1999).

Current work in finding new investigative techniques has given more attention on the use of tomography to three-dimensional and cross-sectional images of internal multi-phase flow behaviour process flow (Simon *et al*, 1994). The tomographic system mostly composes of an array of sensors, a signal conditioning system, data acquisition system, and a display system (Green *et al*, 1998). Whereby, the collected data are processed by using an algorithm that will reconstruct it and produce images (Xie *et al*, 1989).

Optical approach is by nature non-intrusive and considered as safe due to the fact that the transducer does not need direct physical contact with the measurand. The technique known to has high efficiency (Kostov *et al*, 2000) and could enhance manufacturing especially in the chemical industries (Leutwyler *et al*, 1994). For processes that handle transparent fluids and where optical access is possible, this technique can offer images in high-resolution state (Beck *et al*, 1995). The optical tomography technique also capable of performing on-line measurements due to its direct optical characteristic (Black et al, 1996).

1.3 Problem Statement

Various tools and methods for optical tomography had been done especially in process industry. The methods used are being improved from time to time in order to optimize the efficiency and accuracy of the system.

Any tomography system contains few limitations that can be overcome or improved in the future work. The technology is always expanding and improving as we know it. Often a microcontroller is used in the system to control the flow of the process and data transfer. An improved and fast microcontroller can be used to obtain an efficient result and fast, regardless of what type of microcontroller used, especially in the data acquisition process. Faster PC is available now rather than in previous project to cut short processing time (Mariani, 2004).

1.4 Research Objectives

1. To design and to develop an embedded tomographic instrumentation system that is based on charge-coupled device (or better known as CCD) linear image sensor.
2. To evaluate performance of the developed system in terms of capabilities and adaptabilities of the microcontroller used to handle the image sensors.

1.5 Research Scope and Limitation

In order to achieve the objectives of this project, the scope of the project are:-

i Study the programmable microcontroller used for the system which is ATMEL ATMEGA1284P microcontroller, a high performance, low power 8 bit microcontroller.

ii Generate driving signals based on ATMEL ATMEGA1284P microcontroller to activate the CCD Sony ILX 551A a linear image sensor, which is capable of capturing an image of 2048 pixels.

iii Develop timing signals to acquire and to capture CCD raw data using ATMEGA on-chip Timer.

iv Develop a complete embedded instrumentation system for four-projection optical tomography system that is suitable for solid in air environment.

1.6 Organization of the Thesis

Chapter 1 of this thesis explains the background of process tomography. The background of the project, problem statement, objectives and the scopes of the project are defined. The development of the project is based on the subject discussed in this chapter as well as introduction to tomography. Chapter 2 discusses the previous works and researches done on tomography field with emphasize on embedded system used. Many types of different sensors and control system used in optical tomography are highlighted. Chapter 3 describes the mathematical modelling models of the system based on three types of models – measurement section, light source and particle. Through modelling, the size is calculated and the whole system functionality takes shape. Chapter 4 describes the overall set up of the system, testing tools, lighting system used, the CCD testing, microcontroller system. Step by step process was discussed from software development of the controller board, CCD driver board to hardware testing. Chapter 5 describes in details the output result of the embedded system from four projections in four different types of condition.Chapter 6 discussed the conclusion of the project and recommendation for future works.

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