DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

Signature: ………………..
Author: LEE SEK ENN
Date: ………………..

To my beloved mother and father

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ABSTRACT

This project address the usage of electric linear actuators on the application of visual inspection such as 3D image processing. Visual inspection such as photogrammetry were widely used since mid-1980 due to its automated operation that can eliminate the error occurs by inspection using traditional method, which is the inspection of products with simple measuring devices. However, visual inspection that carried out in industrial application without stop the production line would be beneficial due to minimizing loss in terms of costs and time. A model of linear electric actuators is presented to illustrate the potential of performance in obtain same speed with the inspected object that travelled on conveyor belt. Constant velocity is requested and method of obtaining was being controlled by AC servo motor controller that are presented in this project. Fully automatically operation is likely to perform. However, this cannot be carried out due to incompatibility of equipment. For the next research, it is highly recommended to check the compatibility between the equipment.

ABSTRAK

Projek ini menujukan penggunaan penggerak elektrik linear dalam aplikasi pemeriksaan visual seperti pemprosesan imej 3D. Pemeriksaan visual ini amat popular pada pertengahan 1980-an atas operasi penggunaan yang automatik di mana boleh meningkatkan prestasi dalam proses pemeriksaan. Pemeriksaan visual yang boleh dijalankan tanpa perlu menghentikan proses pengeluaran akan memberikan manfaat dari segi masa dan kos. Sebuah model penggerak elektrik linear disediakan untuk menguji prestasi dalam menyesuaikan kelajuan penggerak dengan objek yang diperiksa yang terletak di atas ‘conveyor belt’. Objektif projek ini adalah untuk mendapatkan halaju yang tetap dengan menggunakan ‘AC servo motor controller’. Operasi yang automatik amat digalakkan tetapi untuk kajian ini, operasi secara automatik tidak dapat dilaksanakan atas sebab kegagalan dari segi peralatan. Oleh itu, pemeriksaan terhadap fungsi dan operasi peralatan tidak patut diringankan untuk kajian seterusnya.

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rpm	=	Revolution per minute
W	=	Watt
Hz	=	Hertz
mm	=	Millimeter
cm	=	Centimeter
MB	=	Mega Byte
a	=	Acceleration, mm/s^2
ms	=	Acceleration, ms
s	=	Second
$x10^{STM}\mu m$	=	Pulse per revolution

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CHAPTER 1

INTRODUCTION

1.1 Background

Products quality and delivery reliability are the key factor success in manufacturing industry (Colledani et al., 2014). In order to deliver high quality products, inspection is very important but traditional approach like labour- intensive methods results in increasing manufacturing lead time and production cost, as well as delay in detecting an out of control limit (Fundamentals, Inspection, & Machine, n.d.). However there is another kind of visual inspection approach that mainly deal with surface quality, maximum defect size and detection of defects on surfaces, such as crack, corrosion, damaged part on a components assembly (Li & Gu, 2004). Besides, optical visual inspection can executed very fast with no human interference and constant, which are significant advantages of achieving production monitoring (Kosmopoulos & Varvarigou, 2001). So photogrammetric measurement (as a part of visual inspection) regarded as accepted 3D measurements tools that has been a possibility for quality control with direct input of image information into computers (Clarke et al., n.d.). Somehow, development of fully automatic photogrammetric measurement would be more benefit to in- line industrial inspection. Thus, motorized linear slide that allow image capturing device move spontaneously with the conveyor belt is introduced to accomplish the objective of this project. Control mechanism is access through Ac Servo Motor Controller. Manual dimensioning and tracing work can be replace by capture surfaces of design models (Mat et al., 2009).

1.2 Problem Statement

To speed up production rate and improve product quality, products inspection has to be carried out with higher accuracy at shorter duration of time. Thus, non–contacting 3D modeling reconstruction such as photogrammetry appear to be a good avenue (Uffenkamp, n.d.). However, in a continuous manufacturing process, a product is being delivered in a continuous manner. Dealing with a moving target causes a motion effect (i.e. Blurring) on the acquired images (Zappa et al., 2014). Therefore, a controllable electric linear actuator that can move simultaneously with the conveyer belt is necessary. By doing so, camera mounted on the electric linear actuator can move at the same speed as the rate of product that being delivered on the conveyer belt. Hence, blurring of image eliminated.

1.3 Objectives

i) To optimize the AC Servo Motor controller of motorized linear actuator for image base 3D modeling application
ii) To design varies mechanisms of controlling the speed, timing and positioning linear slider of image capturing device of photogrammetry.
iii) To access the performance of each control mechanisms.

1.4 Scope

The scope of this project is to design a controller that can be used to control the speed of a motorized linear actuator that move spontaneously with the conveyer belt. The efficiency and the performance of the motorized linear actuator with implementation of control methodology will be assessed. Ac Servo Motor controller using MR configurator software are the focus of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Research Background

Standard method for complex 3D measurement tasks need to have object with a high number of object points. Close range photogrammetry offered potential measurement with convergent multi- image configurations (Luhmann, 2010). Inspection of incoming parts with no human interface can be done but this required at the finished assemblies and photogrammetry is usually done when the products is in static condition. To make it in time inspection at the early stage without stopping the production line, actuators to run corresponding with the conveyor belt is designed for the visual inspection. However highly precision position and speed controls are needed especially in motion control equipment (Rashidi et al., 2015). Types of actuators are compared of its function and advantages in application. .Furthermore, controller should have design with load/ friction compensation, disturbance rejection against parameter variations in addition to accuracy (Rashidi et al., 2015). Basically the objective of controller is to make system to reach the optimum position.

2.2 Overview of Inspection System

Products quality and delivery reliability are key factors for success in manufacturing industry (Colledani et al., 2014). Challenge faced such as delivering the required production rate of high quality products by minimizing resources in terms of human power and mechanical power (F. Puente Leo, 2006). Usually traditional approach of inspection method uses measurement such as ruler, calipers, and meter ruler and so on. Therefore manufacturers look for reliable and consistent automated visual inspection of their products to reduce manual involvement in inspection. Not only this, labor intensive methods will result in increase of manufacturing lead time and production cost, as well as significant delay in detecting the defects (Fundamentals et al., n.d.).

Basically, finish inspection and in-line inspection are the two main inspection performed by machining industries. Finish inspection can only performed the work at the end of the machining process in a special quality room where in- line inspection is performed at the production line (Ayub et al., 2014).

The advantages of in-line inspection are the identification deviations from the nominal values, detection absence of vital parts of properties and detection products out of tolerance at the early stage in manufacturing process to prevent from further machining, handling, assembly, etc. In addition, information on deviations from target values may be fed back to process (Ayub et al., 2014).

Among those inspection processes, visual inspection is another kind of inspection approach that mainly deals with surface quality and maximum defect size. Defects on surfaces, such as cracks, corrosion, damaged part on a component assembly also part of visual inspection (Li & Gu, 2004). In the meantime, there are quite of areas visual inspection have extended to. For an example, areas of robot guidance, inspection of incoming parts or finished assemblies in application of inspection, part identification, guidance and control (Ayub et al., 2014). Significant advantages of an optical visual inspection are it can executed very fast with no human interference and constant, thus 100% monitoring of the production can be achieved (Kosmopoulos & Varvarigou, 2001). Lest not, direct input of image information into computers is the development of fully automated photogrammetric measurement (as a part of visual inspection). This discover been a possibility for quality control which would be benefit in industrial inspection (Clarke et al., n.d.).

In many successful and diverse applications, photogrammetry can be regarded as fully accepted 3D measurements tools. Field of industry, biomechanics, chemistry, biology, archeology, architecture, automotive and aerospace engineering, as well as accident reconstruction have practiced photogrammetry (Jiang et al., 2008). According to Satorres Martínez et al., (2009), different types of defects are detected based on the design of algorithms which are more towards its geometry and dimensions. Large variety of industrial application areas also apply photogrammetric system, including;

- Automotive manufacturing, for car body deformation measurement, control of supplier parts, adjustment of tooling and rigs, establishment of control point networks, crash testing, etc.;
- Aerospace industry, for measurement and adjustment of mounting rigs, antenna measurement, part-to-part alignment, etc.;
- Wind energy systems for deformation measurements and production control;
- Engineering and construction, for measurement of water dams, tanks, plant facilities, etc.

2.3 Photogrammetry

By using camera, digital representing of real object in form of point cloud is a technique of photogrammetry (Daaam, 2010). In other word, reliable information about the properties of surfaces and objects is able to obtain through photogrammetry without physical contact with the objects. The name “photogrammetry” is derived from three Greek words *phos* or *phot* which means light, *gramma* means letter or something drawn, and *metrein* is the noun of measure (Schenk, 2005).

Fundamental principle of photogrammetry is triangulation. Used images can be divided into stereo photogrammetry and single image photogrammetry. “Lines of sight” can developed from each camera to points of object by overlapping two or more images from at least two locations and 3D structure of object reconstructed is defined as stereo photogrammetry. Stereo photogrammetry is excellent to obtain three dimensional information for the objects from registered images that are two dimensional which can be done by intersection of these lines of sight mathematically from the three dimensional coordinates of the points of interest ("Geodetic Systems, Inc," n.d.). Second type would be monoscopic photogrammetry (also called as single image photogrammetry) where information of objects is presented by using mono-plotting methods (Marinov, 2003).

On the basic, photogrammetry also divided into two categories: aerial and terrestrial photogrammetry. Images such as topographic maps and land use details acquired via overhead shots from an aircraft are known as aerial photogrammetry (Fig. 2.1). Terrestrial photogrammetry is further defined as close range photogrammetry (Fig. 2.2), an approach where camera generally pointing towards the center of the object with highly convergent camera orientations when the object size and the camera distance are both less than 100m (Jiang et al., 2008).

Figure 2.1: Aerial photogrammetry.
(Source: Marinov, 2003)

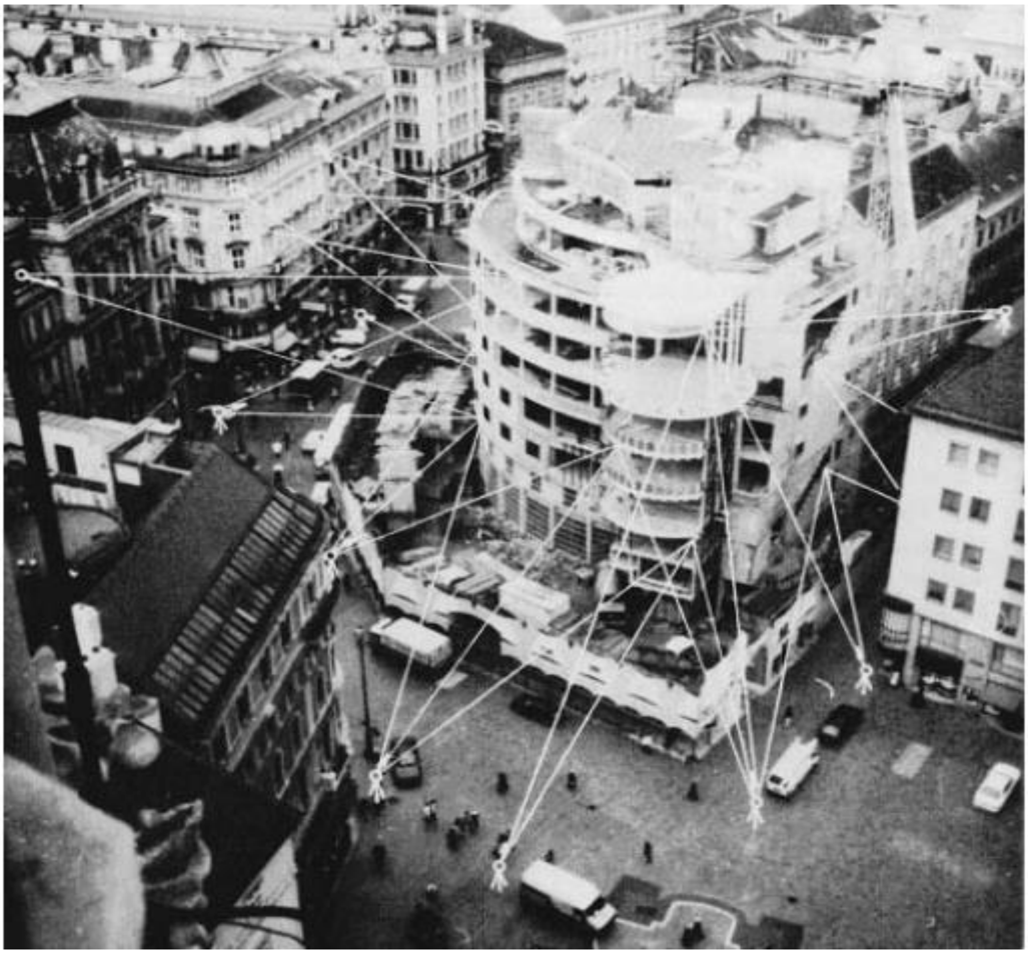

Figure 2.2: Close range photogrammetry.
(Source: Marinov, 2003)

2.3.1 Close range Photogrammetry

Close range photogrammetry become technically and economical successful in the mid-1980s due to its first breakthrough in automated and high accurate 3D measurements. Large volume objects with high number of object points can be obtained based on the convergent multi-image configurations, digital comparators and digital image processing of the scanned imagery as close range photogrammetry offered the potential of measurement precision to 1: 500,000. By this, performance of photogrammetry could be become standard method for complex 3D measurement tasks (Luhmann, 2010).

2.3.2 Technical Issues of Photogrammetry

To form an efficient and economic system, number of technical components required to succeed use of photogrammetry in industry. Therefore, components and related technical issues summaries as the following list:

- Imaging sensor: resolution (number of pixels), acquisition and data transfer speed, camera stability, synchronization and etc.;
- Targeting and illumination: interested object featured, target shape and size, and measurement volume;
- Image configuration: number of camera stations, desired measurement accuracy, redundancy, robustness, self- calibration ability, and self- control of orientation and calibration;
- Image processing: automation of target recognition and identification, sub-pixel measurement of target center, multi-image, matching approaches, and feature tracking;
- 3D reconstruction: 3D coordinates determination method (e.g. spatial intersection, bundle adjustment) and error statistics;
- Data interfaces: integration into CAD/ CAM environments, machine and data interfaces and etc.;
- Verification of accuracy: reference bodies, reference data, standards and guidelines and acceptance tests.

Setup of complex tasks is illustrated in above lists for an appropriate design, operation of close-range industrial photogrammetry systems. Besides, basic camera concepts, system designs and measurement tasks for industrial photogrammetry also presented. An overview of recent technology and applications provided rather than comprehensive coverage due to large variety of applications and system configurations is discussed (Luhmann, 2010).

2.3.3 Photogrammetric Cameras

Cameras with stable interior orientation and high accuracy are demanded to reduce need of periodic or on-the-job calibration, and technical possibility for simultaneous camera calibration. Besides the classical ‘metric camera’, rarely few cameras are mainly for photogrammetry application. However, limitation of ‘metric camera’ is it only is used in conjunction with the desired accuracy level of camera. Photogrammetric cameras (Fig. 2.3 and Fig. 2.4) are designed for high- accuracy industrial metrology. In the meantime, the integrated processors enable 3D measurements in off-line (1 camera) or on-line (2 camera) mode (Luhmann, 2010).

(a) Metric camera GSI INCA 3 (3500 × 2350 pixels). (b) Metric video camera AXIOS 3D SingleCam (776 × 582 pixels).

Figure 2.3: Examples of photogrammetric cameras.
(Source: Luhmann, 2010).

(a) Metric stereo camera AXIOS 3D CamBarB2 (1392 × 1040 pixels). (b) Four-camera head AICON DPS (1300 × 1000 pixels).

Figure 2.4: Examples of photogrammetric multi- camera systems.
(Source: Luhmann, 2010).

2.3.4 SLR Cameras

High- resolution digital SLR cameras with sensors between 10 and 60 Megapixel are designed for fast and simple photogrammetric work because of its range of exchangeable lenses, high capacity storage devices and powerful batteries. Somehow, camera calibration is an important step in the complete process chain as their mechanical stability is usually poor and with changing interior orientation (Luhmann, 2010). Classical small format (35mm SLR) are offered by companies such as Nikon, Canon and Sony are mainly used for off-line applications. The two sample cameras are shown in Fig. 2.5.

(a) Nikon D3x (6048 × 4032 pixels).

(b) Hasselblad H4D-60 (8956 × 6708 pixels).

Figure 2.5: Examples of digital SLR cameras.
(Source: Luhmann, 2010)

2.3.5 Camera Calibration

Since accuracy is directly related to sensor quality and correct modeling of interior orientation, camera calibration is an essential of photogrammetric systems in industrial application (Luhmann, 2010). Somehow, there would be some difficulties faced in calibration as stated in following cases:

- Camera geometry unstable during image acquisition (e.g. gravity effects)
- Geometric configuration of images does not allow bundle adjustment with self-calibration (e.g. due to weak intersection angle or lack of camera rotation)

- Objects does not provide enough information (e.g. points, distances) for calibration

Besides, three or more control points as the datum of object can be introduces as well as introducing shape constraints in photogrammetric orientation (Luhmann, 2010). Otherwise, image-wise of the camera will be calibrated if the mechanical instability of the camera is worse than the required accuracy level. As long as the imaging configuration consists of enough well distributed images, the position of perspective center is usually adjusted for each image while the distortion values are kept constant for all images as to enhance the accuracy. Furthermore, precision of camera calibration can be determined from precision of image and object points, or by standard deviations of camera parameters (Luhmann, 2010).

2.3.6 Accuracy and Verification

Two most important practical considerations are the specified accuracy of an industrial measurement system and the achieved accuracy within a real project. Final accuracy figures can be manipulated simply by increasing the number of observations in many photogrammetric applications. Furthermore, photogrammetric measured distances are compared to their calibrated nominal length for the accuracy test. Further developments of high precision industrial close range photogrammetry is challenging in industrial photogrammetry (Luhmann, 2010).

2.4 Automated Inspection on Moving Conveyor

Nowadays, manufacturing is very high competitive with automation in quality control processes (Kosmopoulos & Varvarigou, 2001; Leones et al., 2005). This included on the moving conveyor, some sort of automated visual processing and classification of items placed are required in many industrial applications. An overview of the typical setup is shown in Fig. 2.6 which camera located above conveyer belt which view the items orthographically. Classification of items placed are done by the item separator that placed before the camera so the incoming items are