

The Dynamic Measurement System Design for Stewart Platform by Using Digital Image Processing Method

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Abstract—In this study, the digital image processing method in the dynamic measurement system for Stewart platform is investigated. The measured signals of the platform based on the digital image processing method represent as the feedback signal of control system. In the study, the accuracy of control system is reasonable by capturing the image information of platform by using the digital image processing method and getting the detail of platform action directly.

Keywords—digital image process; Stewart Platform; sensor

I. INTRODUCTION

In recent years, the parallel link manipulators, namely, Stewart platform, have attracted much attention and many studies have been done on the dynamic analysis and/or controller design of the parallel link manipulators. The Stewart platform is a mechanical device with six extensible legs mounted on a level surface in three pairs, crossing over to three mounting points on a top plate. Devices placed on the top plate can be moved in the six degrees of freedom (6 DOF) in which it is possible for a freely-suspended body to move. These are the three linear movements x , y , z (lateral, longitudinal and vertical), and the three rotations pitch, roll, & yaw [1]. Because of its unique capability, the platforms have been employed in many control engineering applications such as simulator shakers, robotic manipulators, etc. [2, 3, 4]

Traditionally, the displacement sensor, namely, linear voltage differential transmitter (LVDT), is used to determine the length of the six extensible legs. The gyro compass are also widely been used to evaluate the dynamic of Stewart platform. In recent year, the Force/torque (F/T) sensors have widely been used in measuring inertia force of Stewart platform [5], monitoring forces of variable directions and intensity [6] and as a component of force feedback controller [7, 8]. In a sensor application, the friction, backlash and other nonlinearities at the passive spherical joints of the Stewart platform will affect the measurements in unpredictable ways.

Digital image processing is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing.

It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing.

Many of the techniques of digital image processing, or digital picture processing as it often was called, were developed in the 1960s at the Jet Propulsion Laboratory, Massachusetts Institute of Technology, Bell Laboratories, University of Maryland, and a few other research facilities, with application to satellite imagery, wire-photo standards conversion, medical imaging, videophone, character recognition, and photograph enhancement. The cost of processing was fairly high, however, with the computing equipment of that era. That changed in the 1970s, when digital image processing proliferated as cheaper computers and dedicated hardware became available. Images then could be processed in real time, for some dedicated problems such as television standards conversion. As general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and computer-intensive operations.

With the fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing and generally, is used because it is not only the most versatile method, but also the cheapest. In this research, the digital camera is used to replace the traditional sensor due to its Advantages by using the image processing method to determine the motion of the platform dynamic.

The remainder of this article is organized as follows: The basic methodologies of the digital image processing which used in this research are discussed in Section 2. In Section 3 shows some experimental results on a realistic Stewart platform by using proposed method. Finally, some conclusions are made in Section 4.

II. MAIN METHODOLOGIES

The charge-coupled device (CCD) is a device for the movement of electrical charge, usually from within the device to an area where the charge can be manipulated, for example conversion into a digital value. Often the device is integrated with an image sensor, such as a photoelectric device to produce

the charge that is being read, thus making the CCD a major technology for digital imaging. Although CCDs are not the only technology to allow for light detection, CCDs are widely used in professional, medical, and scientific applications where high-quality image data are required.

The RGB format images capture from the Stewart platform by CCDs are transfer into YUV format. The YUV is a color space typically used as part of a color image pipeline. It encodes a color image or video taking human perception into account, allowing reduced bandwidth for chrominance components, thereby typically enabling transmission errors or compression artifacts to be more efficiently masked by the human perception than using a "direct" RGB-representation. In this research, the algorithms of RGB formatted image transfer into YUV formatted image as follows:

Define

$$R, G, B, Y \in [0, 1].$$

$$U \in [-0.436, 0.436]$$

and

$$V \in [-0.615, 0.615]$$

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

The YUV model defines a color space in terms of one luminance (Y) and two chrominance (UV) components. The platform dynamic is determined by the luminance component as the marker position with cyber action system. The coordinate of the platform is shown in Fig 1.

The 6 DOF of the platform are calculated as follows:

Step 1. Find the center O_0 of the platform and calculate the displacement of X, Y, and Z axis.

$$O_0 = \left(\frac{x_2 + x_3}{2}, \frac{y_2 + y_3}{2}, \frac{z_2 + z_3}{2} \right) = (x_i, y_i, z_i) \quad (2)$$

where

$$x_i = \frac{x_2 + x_3}{2}, y_i = \frac{y_2 + y_3}{2}, \text{ and } z_i = \frac{z_2 + z_3}{2} \quad (3)$$

Step 2. Find the center O_1 of the marker position A to B and the center O_2 of the marker position A to C. Calculate the angles of α , β , and γ , respectively.

$$O_1 = (x_j, y_j, z_j) = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}, \frac{z_1 + z_2}{2} \right), \quad (4)$$

$$O_2 = (x_k, y_k, z_k) = \left(\frac{x_1 + x_3}{2}, \frac{y_1 + y_3}{2}, \frac{z_1 + z_3}{2} \right). \quad (5)$$

Such that

$$\gamma = \tan^{-1} \left(\frac{z_i - z_j}{y_i - y_j} \right) = \tan^{-1} \left(\frac{z_3 - z_1}{y_3 - y_1} \right) \quad (6a)$$

$$\beta = \tan^{-1} \left(\frac{z_i - z_k}{x_i - x_k} \right) = \tan^{-1} \left(\frac{z_2 - z_1}{x_2 - x_1} \right) \quad (6b)$$

$$\alpha = \tan^{-1} \left(\frac{x_i - x_j}{y_i - y_j} \right) = \tan^{-1} \left(\frac{x_3 - x_1}{y_3 - y_1} \right) \quad (6c)$$

The marker positions are captured by using three CCDs from fixed X, Y, and Z axis.

III. EXPERIMENTAL RESULTS

The equipment used in the experiment consists of three CCDs form Logic Inc., Taiwan, Borland C++ builder 6, and the software of Microsoft DirectX9.0 SDK, namely GraphEdit. The frame size is 352×288 with 30 frames per second in YUV420 formatted. The pictures captures from three CCDs are synchronizing by GraphEdit and then find the marker positions. The graphical user interface (GUI) is shown as Fig 2.

In Fig 2, the three frame of Stewart platform shown below in the graphical user interface are x axis, y axis, and z axis, respectively. The three white points in the edge of the Stewart platform are marker positions. Those RGB based frames are transfer into YUV formatted by using equation (1) and then the motion of the platform are calculate by using equations (2)-(6). The real time output is shown as Fig 3. In the Fig3, the input signals of the x, y, and z axis are sine wave, respectively. The image processing output signals of the platform and the input commands are almost identical

The non-cyclical movement of the ship will be used as input signal. The sea trial data of the rolling angle from a small yacht and the Stewart platform output are shown as Fig 4 and Fig 5, respectively. The pitching angle of the same yacht and the Stewart platform output are shown as Fig 6 and Fig 7,

respectively. The image processing output signals of the platform and the input commands are almost identical.

IV. CONCLUSION

In this paper, the dynamic measurement system of Stewart platform based on image processing method has been proposed. The traditional sensor of the platform has been replaced by the proposed method and significantly improves the system performance. Based on the experiment results shown as above, the proposed image processing method has the potential to become one of the candidates of the Stewart platform sensor.

The advantage of the proposed method is more cheaply than traditional sensor, i.e., gyro. However, the image processing based sensor could not properly measure the torque on the platform. The disadvantage just mention restricts the possibility which be apply to the platform control system.

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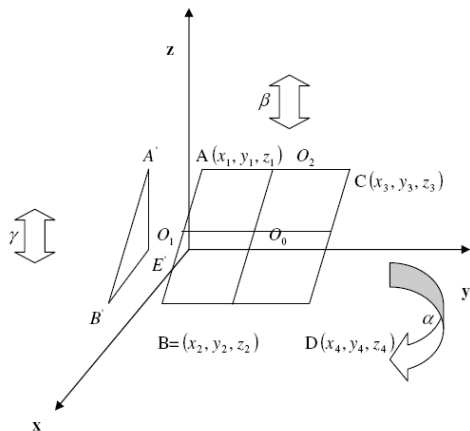


Figure 1. The coordinate of the platform.

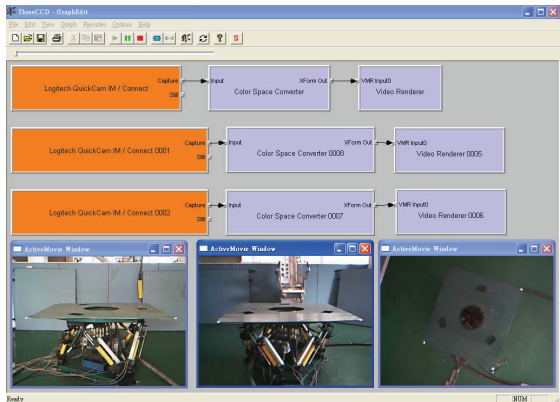


Figure 2. The graphical user interface.

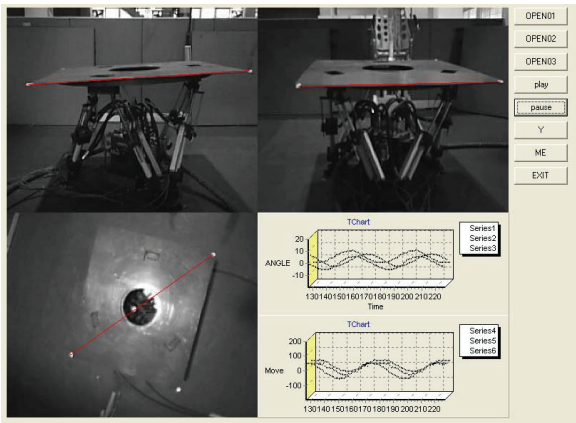


Figure 3. The real time output of the proposed algorithm.

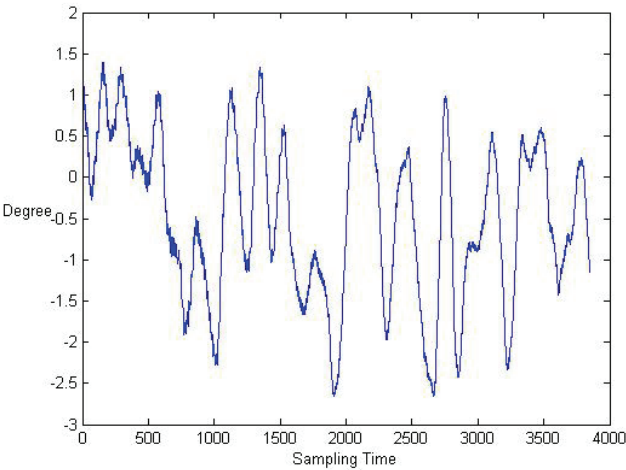


Figure 4. The rolling data of a small yacht.

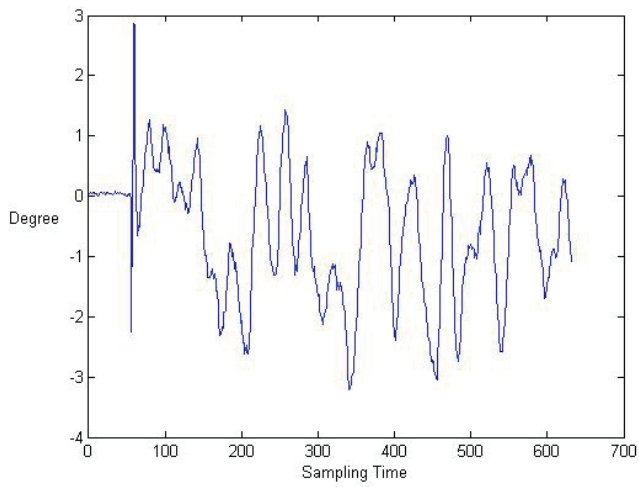


Figure 5. The rolling output based on proposed measurement method.

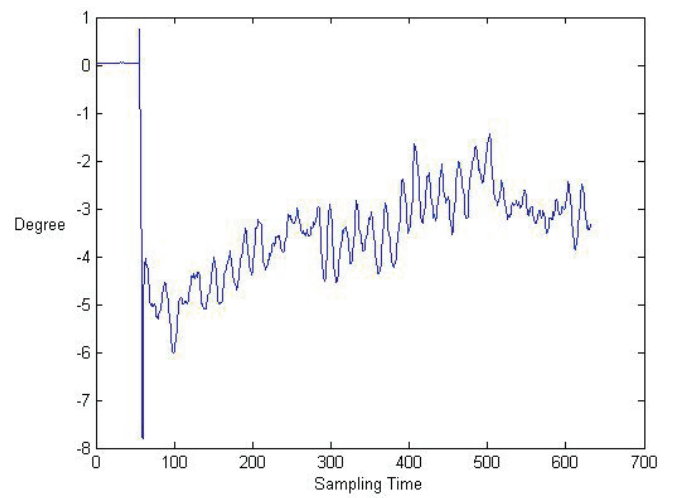


Figure 7. The pitch output based on proposed measurement method.

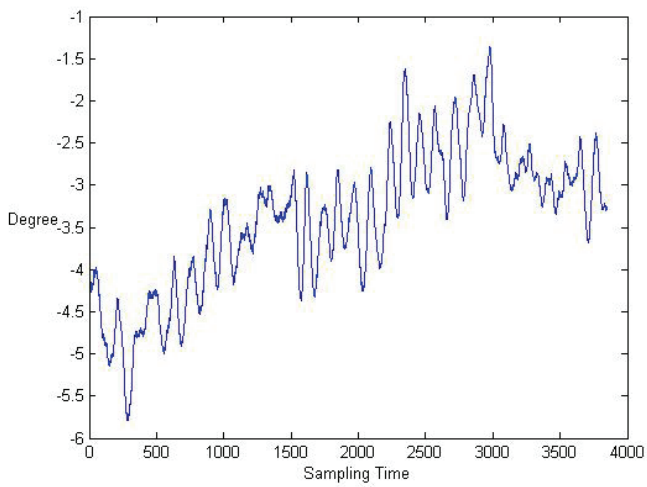


Figure 6. The pitching data of a small yacht.