Design of a Vision System as a Coordinate Measurement Sensor In a 2D Gantry Crane Control System

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***Abstract*- 2D crane conveying system is a suitable example for applying the control theories. As precise instrument tools are usually conveyed with this kind of cranes, it is essential to control the vibrations during the motion. This paper deals with the control of the crane's angle during the motion.Basically, the goal of the paper is find the exact position of the load. Since the load is hanged by a flexible rope, using angles sensor can not be accurate. Hence, the use of a camera can provide the simplest technique for this purpose.**

I. INTRODUCTION

Nowadays, the image processing has found various applications in industry and in some cases it can be used as the sole data collecting technique.
A variety of image processing systems have been developed so far such as human motion capture and analysis[1], tracking system[2], human-computer interaction system[3], and etc.

Nearly all of them employ a camera for acquiring data which is used to send the proper command to several actuators.
They are used in extraction of necessary parameters and use the picture frames saved in certain processing action.

The main component of an image processing system is shown in Figure1.

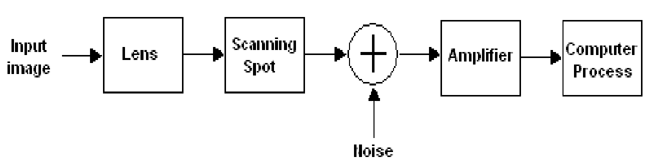

Fig1. The elements of an image processing system

Transfer function of each component can be modeled analytically, determined experimentally, or taken from manufacturers' specifications.

The lenses, for example, can be assumed diffraction limited. The computer operation may or may not be linear, but this is the only subsystem in Figure1 that is directly under the user's control [4].

Tracking moving objects over time is a complex problem in computer vision and has been an important research subject over the last few years [5], [6], [7]. Impressive tracking systems have been developed for some specific applications [8], [9].

II. IMAGE MATRIX

Image capture sensor is formed from some light sensitive elements. The voltage of each element is proportional to the intensity of radiation light.
The image forms on the sensor plane by variating light propagation tools such as convergent lenses (Figure2).

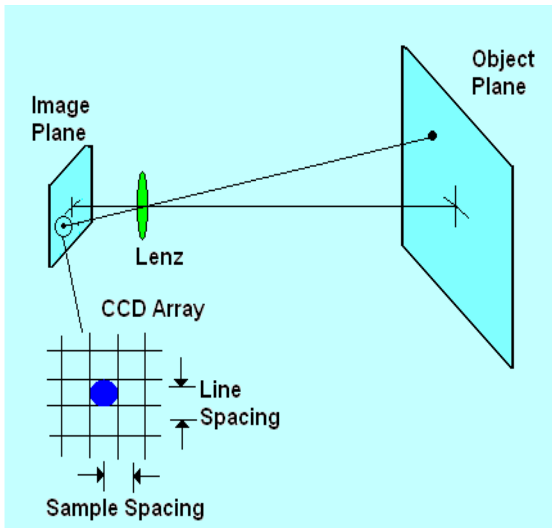

Fig2. Image formation

The voltage of each image plane element is converted to a binary code by an ADC(Analog to Digital Converter) and then transferred to the main processor by a communication cable.
The communication protocol is chosen from different S-video, IEEE1394, RS170, or USB type. Based on their application, each of them have their own advantages or drawbacks.

At the end, the expected images as RGB or CMYK format and as a 3D matrix which its elements are image pixels color value will be formed.

III. Color Sepration Filters And Noise Effect Reduction

Separating a particular color or color node is common need in various color image processing systems. In most cases in order to separate and pass a particular color, colored filters are used. A less expensive and more flexible solution is the utilization of software filters specially when using webcam as image capturing sensor.

In this system the search space is determined by R, G, and B axes. Each of the amounts of R, G and B for a singular pixel can be in the range of 0 and 255. For separating of a particular color the amount of B, G, and R is compared to a desired value. The color space is shown in Figure3.

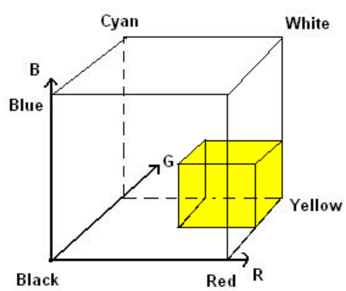

Fig3. Rectangular color space

After separation of desired colored nodes, for noise effect reduction a low pass filter (LPF)can be used. Matrix coefficients for such a filter are calculated as a moving average filter as follows:

$$\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix} = \text{LPF Mask}$$

After separation of needed pixels and elimination of noise, the necessary recognition algorithm is used. This algorithm can be used to easily determine the pixel coordinates or can be employed to differentiate a model of pixel sequences.

IV. System's Equations Of Motion

One of the main factors in designing a crane system is "the capability to convey a work piece from one point to another in the minimum time". Its main goal is to optimize the conveying time between two known points in a 2D plane according to control the angle of cable and vibrations. To maximize the crane's efficiency (Covering the path in the minimum time) lots of methods are presented.

Most of cranes have similar dynamics. In figure (4) a model of a gantry crane is shown which **M** is the crane's conveyor mass, **m** is the load mass , **L** is the cable length , **g** is gravity acceleration (9.81 kg/m^2), **F** is exerted force to vehicle , **y** is the position of conveyor and **θ(t)** is the oscillation angle.

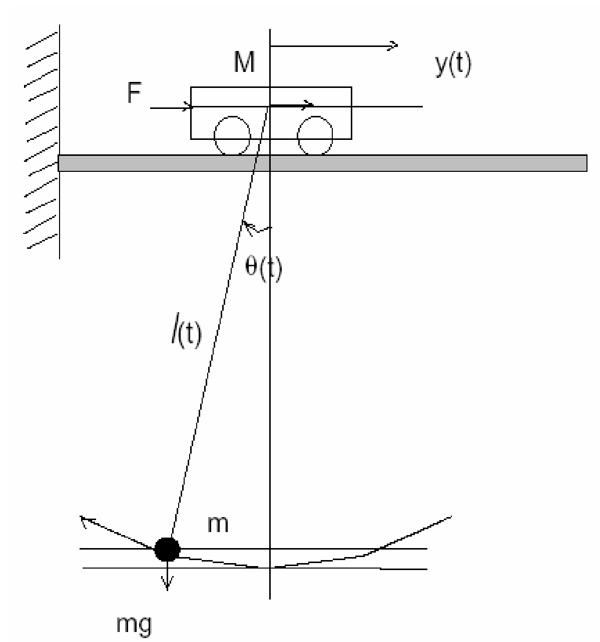

Fig4. A gantry schematic diagram

For obtaining the dynamic equations, following assumptions are considered:

1. Ignoring the non-linear and dynamic effects of motor
2. Ignoring the effect of friction for conveyor mass
3. Ignoring the attenuation of wind

Using these assumptions, motion equation will be obtained:

$$\ddot{y}(t)\,Cos\theta(t) - l(t)\,\ddot{\theta}(t) - g\,Sin\theta(t) - 2\dot{l}(t)\,\dot{\theta}(t) = 0 \quad (1)$$

If the oscillation angle be small enough it can convert to a linear system:

$$Sin(\theta) \approx 0 \qquad Cos(\theta) \approx 1 \quad (2)$$

By ignoring the higher degrees of power and assuming the dependence of cable length to time $l = l\ (t)$, equations *(1)* and *(2)* can be transformed to equations *(3)*and *(4):*

$$(M+m)\ddot{y}(t) - m\ddot{l}(t)\theta(t) - 2m\dot{l}(t)\dot{\theta}(t) - ml(t)\ddot{\theta}(t) = F(t)$$

(3)

$$\ddot{y}(t) - l(t)\,\ddot{\theta}(t) - g\,\theta(t) - 2\dot{l}(t)\,\dot{\theta}(t) = 0$$

(4)

If $\mathbf{M \times l\,(t) \neq 0,\ t \in [0, t_f]}$, and t_f be the final time , the state equation will be obtained

$$\dot{X}(t) = A(t)\,X(t) + B(t)\,F(t) \qquad (5)$$

In which the X (t) is the state vector as below:

$$X(t) = [\;x(t) \quad \dot{x}(t) \quad \theta(t) \quad \dot{\theta}(t)\;] \qquad (6)$$

And **F** (motor force), is the input of the system.

V. PC INTERFACE

As explained in the previous section, totally two DC motors must be controlled. A computer is utilized for image processing and control of the robot. The control commands are issued through a printer port of the controlling computer.
The computer takes images by a web camera through USB.
Based on the designed control algorithm, the necessary commands trough parallel port is passed to the interface.
The two controllers of DC motors provide left and right motor rotation. A powerful push-pull movement for controlling motors is provided.

VI. COMPUTER PROGRAMMING

The crane system control program is in Delphi with a total of 1300 lines of programs. The Program's GUI is shown in Figure 3.

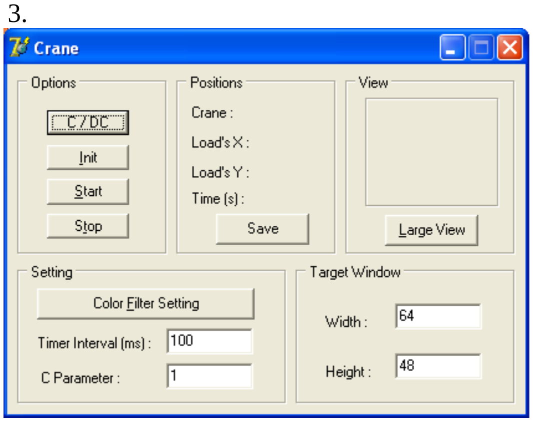

Fig3. The Program GUI designed by Delphi 7.0

A. Device Driver

This section consists of sub-programs written in assembly language for hardware control and access to the parallel port.
Note is made that Delphi has an internal assembler. So, there is no need to link the main program to other control sections.

B. Image Capturing and Processing

To capture images Video for Windows (VFW) technique is used.
The Tscap32 component is used to get data from camera driver through VFW. This is a free component on the internet.
The images are given as 640x480 matrix in RGB format and pass to image processing section.

Here the windowing technique has been used for reducing the time of image processing. The source code in Delphi is shown below. This procedure execute every 0.1 sec by a timer event.

VII. CONCLUSIONS

In this paper an instrumentation systems for analysis of different behaviors which employed vision techniques, were presented. In many situations, which we need to determine kinematic parameters of a system, especially position parameter, image processing can provide one of the best alternative. Improvement methods for noise elimination in which the increase of processing power for computing systems is presented, can provide powerful and efficient tools for researchers in various field of science and technology. The use of these techniques not only results in achieving better results but will help to save time and money in total.

REFERENCES

[1] J.K. Aggarwal, Q. Cai, "Human motion analysis: a review", ComputerVision and Image Understanding 73 (3) (1999) 428–440.

[2] M. Alitavoli ,Salar. Basiri, Saeed. Basiri, " Image Processing Based Tracking System ", WSEAS TRANSACTIONS on SIGNAL PROCESSING, Issue 12, Volume 2, December 2006, pp.1558-1662

[3] Robert Ward, " An analysis of facial movement tracking in ordinary human–computer interaction"
Interacting with Computers 16 (2004) 879–896

[4] Kenneth R. Castleman, Digital Image Processing, Prentice Hall, New Jersey, 1996

[5] Lowe, D.G., "Robust model-based motion tracking through the integration of search and estimation,"
International Journal of Computer Vision, vol.8:2, pp. 113-122, 1992.

[6] Coombs, D., and Brown, C., "Real-time smooth pursuit tracking for a moving binocular robot," *Proc. IEEE*, pp.
23-28, 1992.

[7] Huttenlocher, D.P., Noh, J.J., and Rucklidge, W.J., "Tracking non-rigid objects in complex scenes," *Proc. IEEE*,
pp. 93-101, 1993.

[8] Dickmanns, E.D., Graefe, V., "Applications of dynamic monocular machine vision," *Machine Vision and Applications*, pp. 241-261, vol. 1, 1988.

[9] Frau, J., Casas, S., Balcells, Ll., "A dedicated pipeline processor for target tracking applications," *Proc. IEEE International Conference on Robotics and Automation*, pp. 599-604, 1992.