Using Image Processing as a Measuring Device in Close Loop Control System and System Behavior Analysis

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Abstract: In this paper, the common principles of digital image processing are investigated. By using these principles, one can deploy simple devices such as a PC or webcam to establish a system based on Image processing techniques in order to test different algorithms. The use of color software filters increases the need for processing power of image processor, but based on the ease of a capability and inexpensiveness of modern computers can reduce the total system expenses. Further in this research, several image processing systems in which cameras are used as feedback sensor in close loop control systems. These cameras can aid in obtaining kinematic parameters such as speed and position. In some cases the use of this method, due to its system physical status can be the best method. In some other situation this method could be used alongside of other choices. The chief advantage of this technique is that the instrumentation tools can not affect the case under study.

Key-Words: Image processing, Vision feedback, Tracking systems, Adaptive control, pattern recognition

1 Introduction

Nowadays, image processing has found various applications in industry and in some cases it can be used as the only data collecting technique.
A variety of image processing has 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 control several actuators. Also be 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.

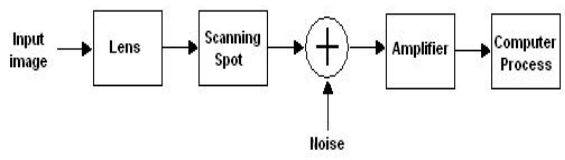

Fig1. The elements of an image processing system

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 fureig1 that is directly under the users' control [4].
In simple systems a webcam can be used as sensing unit for image capturing. These cameras are of CMOS and CCD type. CCD sensors show a higher quality image than other type. Images can be processed by Digital Signal Processor (DSP) or personal computer (PC). The choice depends on the availability and the needed processing speed.

In this paper some of the image processing system which were developed by the authors will be described.
The first system, by using image processing techniques kinematic parameters of a passive bipedal walking is determined. In the second system, a puzzle solver robot which employs machine vision for positioning robot TCP is described. Also the numerical pattern recognition

is explained in this section. The third system introduces a laser tracking system in which a camera is used as a sensor for recognition of target position.
The fourth and the last case describe a prototype test crane which has employed a machine vision system to determine free load status in mid air. This system provided one of the most accurate techniques in position finding of material.

2 Image Matrixes

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).

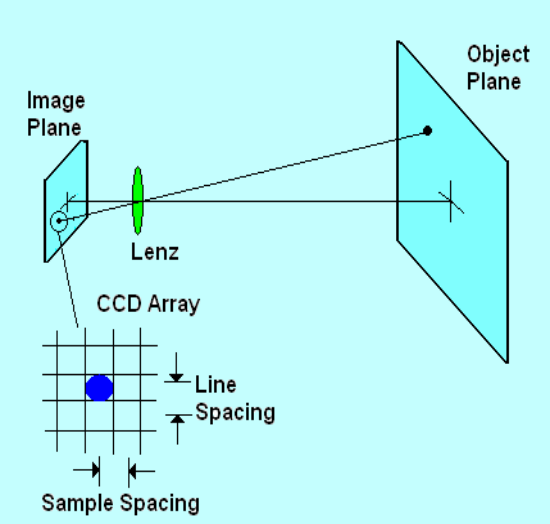

Fig2. Image formation

The voltage of each image plane element is converted to a binary code by an ADC and then transferred to 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.
In case of the use of a PC as processor equipped with Microsoft windows as OS, using Video For Windows (VFW) programming technique is A recomended. This technique makes a simple communication with all image capturing devices.

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.

3. Color separation 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. Different digital image saving methods are developed among them, RGB color space have more application in color image processing.
In this system the search space is determined by R, G, and B axis. 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. For example to identify the yellow color the amount of the R and G must be more than 200 and amount of B must be less than 150.
The color space of these Conditions is shown in Figure3.

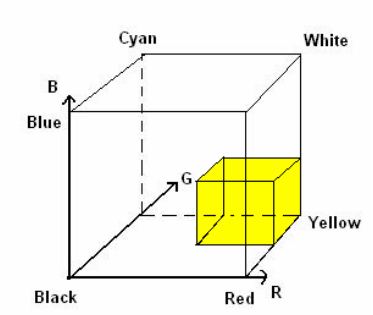

Fig6. Rectangular color space

After separation of desired colored nodes, for noise effect reduction a low pass filter 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 deffrentiate a model of pixel sequences. Further, some different projects are described.

4 Determination of Kinematic Parameters of a Passive Bipedal Walking Robot

In this project, the kinematic parameters of a bipedal robot were determined. These parameters were also obtained trough simulation techniques. Then, the results were compared with experimental results[5].

The physical characteristics of the fabricated biped are shown in Figure3. This robot is designed and manufactured based on the McGeer Biped which was first designed and manufactured in Cornell University in the USA [6], [7].

Fig.3: Passive Biped Walker of the University of Guilan

Figure 3 shows the schematic of the bipedal robot The plane coordinate is divided to 3 geometrical zones and also 2 color zones. All zones should be distinguished from each other. The geometrical and color zones, is shown in Figure 3.
The amounts of the position areas are given to the image process program. According to the separating method of the position areas and colored areas, it is assured that the obtained point is unique.

As the relation of the distance between the planes - where the nodes are inside them – and the mean distance of them to camera is very close , all the nodes can be assumed in the same plane. It is due to the effect of immeasurable factors on the transfer function of the pixel positions to the real positions. Nodes position accuracy depends on camera resolution and distance between image plane (CCD array) and object plane. Nodes appear like color area in image and center of that area is node position.

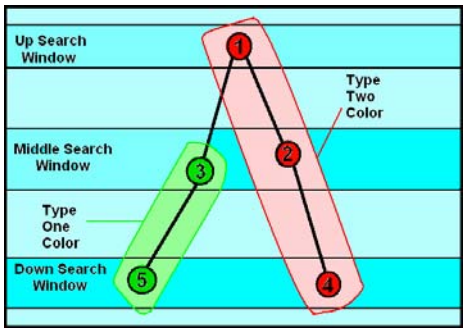

Fig.8: Geometric and color zone

In cases where the mid-legs is covered by the leg that is faced to the camera - which prevents it to ind the nodes- Linear Regression method is used to obtain closest datum to the unknown data. For obtaining angular velocity and acceleration the following formulation (5 points differential) is used. To write the program, Delphi 7.0 is used. The GUI program is shown in Figure 9.

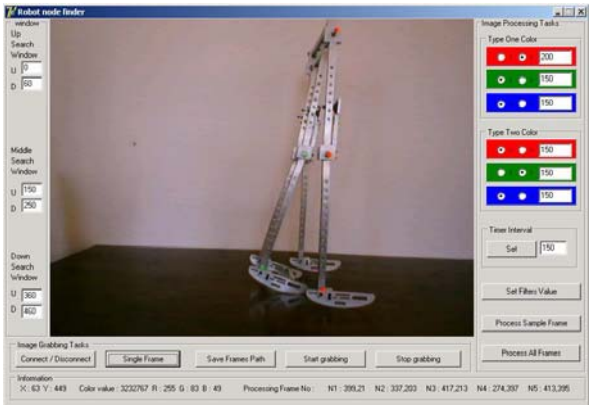

Fig.11: The Program GUI designed by Delphi 7.0

5 The Puzzle Solver Robot

The robot introduced in this section is designed to solve numeral puzzles. Its control is totally by computer and has vision capability which leads its arm to certain places. In the control loop of the arm for identifying the top of the arm, image processing technique is used. Because of its polar movement on the plane, the design of the robot is considered an optimized one. The control orders are given to robot by a parallel port which obtains image from a camera through USB port. For numerical recognition a simple algorithm with the capability of learning new patterns is used. Noting that different conditions have not been given to the robot, therefore the robot is highly considered intelligent. Some of the robot characteristics include recognizing numbers by camera, 3 degree of freedom, polar movement of the plane, locating the arm of robot with the use

of camera, and capability of learning simple numerical pattern.
Such a system can be helpful as a benchmark in testing and performing image processing algorithms. An arm with 3 degrees of freedom as effector and a webcam as vision sensor has been used in the system. Processing of images should be done using a personal computer [8].

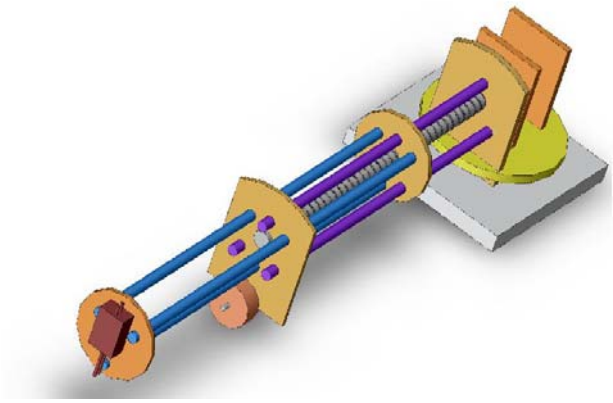

Fig6. Puzzle Solver Robot Schematic

The robot's control program is written by Delphi7 with a total of 1600 lines of programs.

5.1 Number recognition

After distinguishing the number from the background, the next step is to recognize them.
A novel algorithm is used to recognize numbers using Figure 9 (this is 3 in Persian form), this algorithm is described.

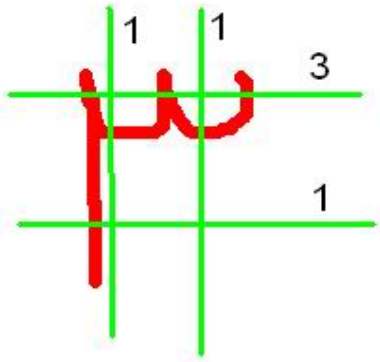

Fig9. Number Recognition Method

As observed in fig.6 the numbers of lines forming a number in different coordinate positions in the number plane are different. This is the key for number recognition in this algorithm. For example for number 3, the number of upper limes are 3, one lines on the bottom, one line on the left and one line on the right is used.

5.2 Controller

In figure11 a schematic diagram of image processing based close loop controller is illustrated.

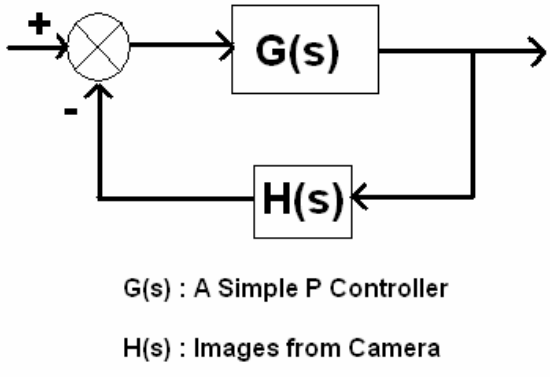

Fig11. Image processing based close loop controller

After number recognition and puzzle solving, all the action that the robot must do in order to organize the puzzle will be determined.

Based on the coordinate of each numbers in the system, this procedure is prepared in the form of a G-code like commands. So, the controller loop based on coordinates will change the position of cell. The plane is swiped once to finalize TCP. Due to the different between the TCP color and its background, its position will be determined. Now the robot is ready to optimize the movement by considering the TCP point and the intended position. To do this, Firstly radius and then angle of the arm will increase or decrease to become equal to the optimum values of radius and angle.

6 Tracking System

Image processing based tracking systems equipped with powerful computing systems have gained vast applications nowadays. In this section, an image processing based tracking system and its algorithms is described.
Tracking moving objects over time is a complex problem in computer vision and has been an important research subject over the last few years [9], [10], [11]. Impressive tracking systems have been developed for some specific applications [12], [13]. In case of selecting one object among several, the subject becomes more complex, especially if the targets are of nearly same color.
In this case, system can track the target more

accurately by limiting the search window while zoomed around the target.
In the following project, our goal is tracking of moving target over a plane and turning it on by laser pointer.
This device can be used as image processing algorithm benchmark in laboratories. Figure 3 shows the image of the device.

Fig3. Image processing based laser tracking system

6.1 Mechanical and electronic sections

For moving the laser point over objects plane, two stepper motors are used. These motors are connected to a gear by a worm gear. The movement of these gears changes the position of laser point. The necessary control command is given by computer through parallel port to the interface circuit. Power transistor is used in the interface circuit. These transistors can turn off/on stepper motor inductors due to command received directly from parallel port. The interface circuit can also turn the laser pointer off or on.
A web camera with 352x288 pixel resolution is mounted on the device as well. It transfers the images through a USB link to the computer.

6.2 Determining the necessary control commands for laser pointer movement

After finding the target coordinates and the light of laser pointer, the correct command must be given to the stepper motors trough the parallel port in order to move laser pointer to correct direction.
In order to find the correct movement, the nearest neighbor method is used. According to this method, since the pointer movement in 2D image plane is limited to the eight boxes around the pointer position. To find the right direction, it is enough to find the distance of each of the eight boxes from the target. Then, the proper direction is toward the box which has the less distance to the target (Figure 4).

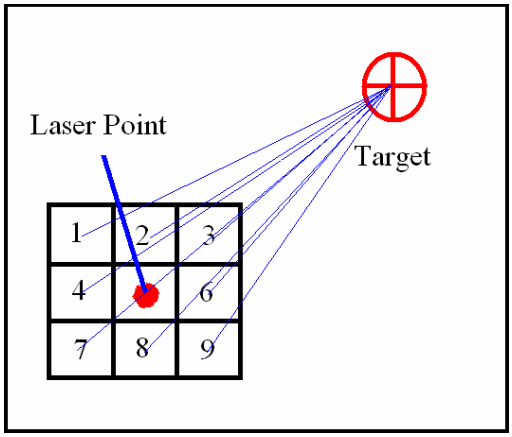

Fig 4. nearest neighbor method

7 Position recognition of free load of a crane

The goal in this project was to find the position of a free load in mid air. 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.

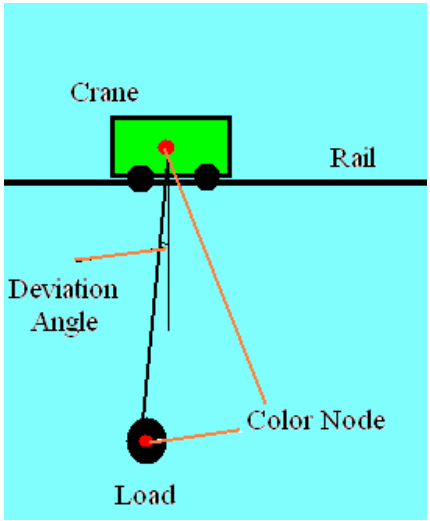

Fig7. Crane and free load Schematic

In figure 5 the schematic of the system is shown. Similar to tracking systems, in this system the windowing technique has been used for reducing the time of image processing.

8 Results and Discussions

In this paper several 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, specially position parameter, image processing can provide one of the best alternative. Improvement methods for noise elimination and pattern recognition 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.

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