



MOVEMENT DETECTION SYSTEM USING CRIO AND LABVIEW

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KEYWORDS: LabVIEW, Absolute difference, Object movement detect, cRIO.

ABSTRACT

Motion detection is the principal entity from scientific to house-hold applications such as burglar detection system, automatic lights ON / OFF based on person's presence, parking ticket systems, closing or opening of a door by determining the proximity or distance of objects and the door, emergency air bag systems in vehicles etc. Motion detection involves identifying the object of interest and determines if the target objects have been displaced from its previous position or not. The current paper touches upon image noise filtering techniques of mean, median and Gaussian filter. Object movement detection mechanism of back-ground subtraction and absolute difference method is explored. The paper describes how real-time video in Lab VIEW is pro-cessed and interfaced with cRIO chassis and digital output mod-ule NI 9472 to indicate end user whenever object movement is detected. The embedded processor at the core of cRIO allows communication with external devices. cRIO is a programmable device that can be interfaced with Analog and Digital I/O devices. Ethernet cable is used to exchange data between cRIO chassis and host computer. NI 9472 is a digital output module specifically designed for cRIO or compact DAQ chassis which has up to 8 channels.

INTRODUCTION

Motion sensors

A sensor is a device which is interested in capturing the changes in the environment of its working area. The captured changes serve as input to the devices while the output is transmitted out either in the form of signals or digital data. The way end user interprets the output forms the foundation of the motion detection application he/she intends to develop. Typical qualities of sensors are A) the measurements should be precise and accurate with very less tolerance to error B) It should be sensitive enough to capture even the minutest of changes C) The number of measurements the sensor can rec-ord between given points of time D) The operating environ-ment of the sensor. Sensors that detect motion are referred to as motion sensors. Motion sensors can be classified as active and passive. Active motion sensors emits energy in some form such as sound, light (ordinary, infrared), magnetic etc and measure the changes in energy that it received compared to previous data recordings. Microwave sensor is an example of active sensor which emits microwave pulses periodically. Whenever an obstruction is encountered on its path, it chang-es the direction of pulse. The sensor upon receiving the reflect-ed pulses calculates the motion the objects by continuous comparison with its previous readings. Passive sensors on the other hand do not emit energy by itself but waits to the energy to change within its surroundings. Passive Infrared is an ex-ample of passive sensor. In this technology the sensor waits for a



changes in heat signature of human / animals which they emit constantly. This heat can be viewed as light by the sensor.

LabVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a visual programming language for system-design and platform development offered by National Instruments Corporation. LabVIEW programming language known as “G” is a dataflow programming language. In LabVIEW, graphical block diagram are referred as source code, user interfaces are called as front panels while subroutines/programs are called as Virtual Instruments (VI's). Block diagram, front panel and connector pane are the three important components of VI. User interfaces or front panels are developed from Controls and Indicators. Any information that user passes as input are developed using Controls. Indicators act as output which shows the result depending on the evaluation of input passed to the VI through Controls. The graphical source code is contained in back panel or block diagram. Terminals appearing on back panels represent all the objects that are placed on the front panel. The graphical block diagram determines the execution flow of the program. The programmer connects different function nodes by drawing what is known as wires i.e. output of one node is connected as input of other node or vice versa. Variables in a LabVIEW program are propagated using wires. Any node is ready for execution once all input data becomes available.

cRIO and NI 9472

CompactRIO (cRIO) stands for Compact Reconfigurable I/O which is currently made by National Instruments. Its major components are real time controller, Reconfigurable I/O system, Ethernet and FPGA (Field-programmable gate array) Modules. The compact RIO controllers are mainly used as control logic for the system. The controller is embedded within the systems. The RIO is used to either receive input or sent output. The I/O modules can be hot inserted and removed anytime. The FPGA module does data processing on the fabric where data is obtained or sent from the I/O modules. LabVIEW can be used to program the cRIO and FPGA modules. FPGA allows building control for embedded system or data acquisition programs since they offer greater configuration options, performance while at the same time are small in size and relatively costs less. Since FPGA allows user programmable and reconfiguration options, requirement of VHDL a hardware design language is not required. The core of the RIO has embedded processor which can be used to transfer data, perform real-time data analysis, log data or networked with external computer. The FPGA I/O module allows cRIO to communicate to each individual hardware I/O devices since it has built-in functions for AC to DC and DC to AC conversion, device connectivity, signal processing. The cRIO 9074 chassis can be mounted on a 35mm DIN rail or on a panel based on user preference or availability of DIN rail mount kit. Panel based mounts are preferred in rugged environments. Ensure the C-series I/O modules are connected to the chassis. Up to 8 I/O modules can be attached to cRIO 9074. The Ethernet cable can be connected between the controller and external system such as a computer. When the cRIO is powered on, if the part number begins with 192172, the IP address is set to 0.0.0.0. If the part number starts with 198944, the BIOS modules tries to obtain DHCP IP. If the host or cRIO is not on a network, they can be interconnected via a cross cable. The Ethernet connection is used as communication channel between host and cRIO system. cRIO 9074 chassis can be seen in Figure 1.



Fig.1 Movement detection work flow

NI 9472 is a digital output module specifically designed for cRIO or compact DAQ chassis by National Instruments as seen in Figure 2. It has 8 channels with output delay of 100 μ s digital output capacity operating at 750 mA/ch. Every channel can withstand voltages in the range of 6-30V and an individual LED indicator. NI C series modules can be used in variety of applications and can be connected to devices such as motors, signals, temperature recorders, etc. The Figure 2 represents NI 9472 with industry standard DSUB. It has 8 channels for Digital Output (DO) 0 to 7, Vsup for external voltage where the positive end of power supply is connected along with a COM channel where negative end of power supply is pinned. The software required to communicate LabVIEW programs with cRIO 9074 and NI 9472 are DAQ and I/O assistant, real-time module, LabVIEW FPGA and embedded control and monitoring module. To ensure that the device is not damaged, ensure there is no overcurrent passed by measure voltage between DO and Vsup. Whenever an overcurrent condition is detected, it is suggested to reset the channel after fixing the erring source.

Noise filtering

Since images are most of the time associated with accompanying external noise at the time of capturing, it is essential to weed out this noise. Some of the existing methods are explored below.



Fig.2 NI 9472

Averaging / Mean filter. The process of decreasing the strength of adjacent pixels is known as Averaging or mean filter. In this procedure, target pixel is replaced with calculated mean value of the pixels adjoining the target. This will remove pixels that have no similarity between its neighbors. For example consider below 3X3 matrix of pixels.

[[2 4 5], {8 7 1}, {3 6 9}]

Mean value = $1/9 * (2 + 4 + 5 + 8 + 7 + 1 + 3 + 6 + 9) = 5$



In the above example matrix, 7 is the target pixel while the rest of them are adjoining to the target pixel. The target pixel 7 is now replaced with calculated mean value of 5.

Median filter. This filter differs from mean filter in the sense that instead of mean, target pixel is replaced with calculated median value of the pixels adjoining the target. First the cho-sen pixel and its neighbors are sorted in ascending order. The value of middle pixel in sorted list is chosen and target pixel is reinstated with this value. For example consider below 3X3 matrix of pixels.

[[{12 24 35}, {28 17 31}, {33 26 19}]]

Median value = Mid = (12,17,19,24,26,28,31,33,35) = 26 .

In the above matrix, 17 is the target pixel while rests of them are adjacent or neighboring pixels. The target pixel 17 is now replaced with calculated median value of 26.

Gaussian smoothing. Gaussian smoothing is a mathemati-cal operation on two dimension input whose output is overlap of inputs. Gaussian smoothing uses a kernel whose graph when plotted resembles a symmetric bell curve and represent-ed as below:

$$h(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma^2}} \quad (1)$$

x and y represent horizontal and vertical axis of graph respectively while σ denotes standard deviation. The distribution when applied results in a convoluted matrix. The convoluted matrix is applied to the image where target pixel is replaced with highest Gaussian value while adjacent pixels are given lower value based on the distance from target pixel. Gaussian distribution in theory will result in non-zero values and would need very large matrix to apply transformations. In practice however, if transformations are applied more than thrice, the resultant value is small enough to be replaced with zero. Gaussian smoothing (or Gaussian blur) has a property known as “Separable” filter. This method can be applied on a 2D image as two independent one dimensional transformations. This is achieved by applying the filter first on Y or horizontal axis in the first pass and then on X or vertical axis in the second pass. This reduces the number of operations required to arrive at same output when compared to applying the filter in a single pass on an entire 2D image.

Object movement detection

Background subtraction. This is one of the well-recognized means of detecting objects that are under movement when the source of image is stationary such as stationary cameras. The idea behind this approach is to estimate an appropriate representation of the background such that object(s) of interest in the current frame can be identified. This is achieved by subtracting the chosen frame with the background image(s) which is known as reference image. In other words, classify those regions of the image that are moving relative to the background. Background subtraction is represented by below formula (2):



$$|P_t - P_r| > T \quad (2)$$

Where, P_t – Image target pixel, P_r – Image reference pixel, T – Threshold value.

If the pixels have not changed much between the images, and the resultant of pixel difference is less than chosen threshold, its value is assumed to be near to zero and is con-sidered as background. On the other hand, if resultant of pixel difference is greater than chosen threshold value, those pixels are treated as foreground.

Sum of Absolute difference (SAD). SAD is the popular method to detect movement changes amid blocks of images. This method calculates absolute difference amongst every pixel in the selected image block and the interrelated pixel in the block similarity. In this technique, first color transfor-mation is applied on the frames of video as part of pre-processing step. This deducts foreground object from background which is followed by background subtraction. The frames where intensity changed suddenly are instantly identified by the actions mentioned above. While the above process is in progress, the boundary of the object where intensity changed is determined by applying edge detection mechanism. SAD is represented by below formula (3):

$$SAD = \sum_i \sum_j |I_k(i, j) - I_{k-1}(i, j)| \quad (3)$$

Where: $I_k(i, j)$ = Current Kth Frame & $I_{k-1}(i, j)$ = Previous (K-1) th Frame For example consider below 3X3 matrix of pixels of K-1 and Kth frame.

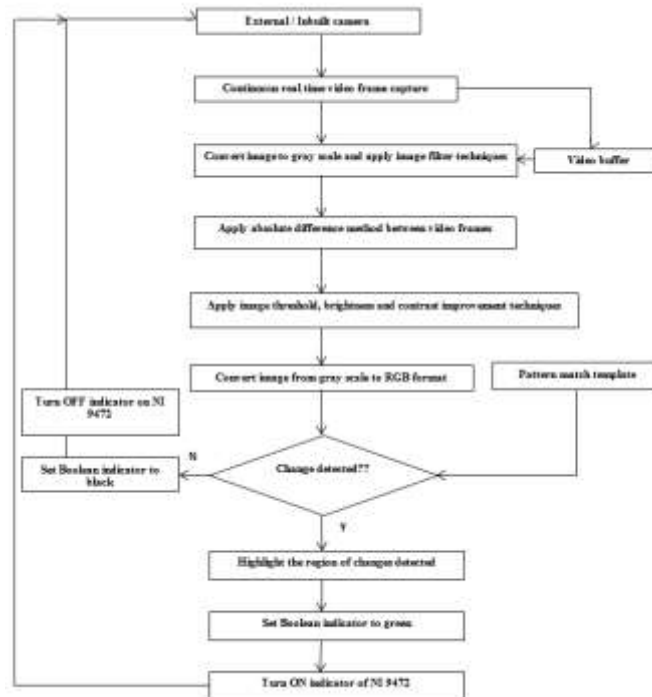
$$\{12 \ 24 \ 35\} \ , \ {28 \ 17 \ 31}, \ {33 \ 26 \ 19}$$

$$\left[\begin{array}{l} \{16 \ 32 \ 08\} \quad \{18 \ 09 \ 22\}, \ {26 \ 07 \ 15} \end{array} \right]$$

$$\left(\begin{array}{l} |12-16| \ |24-32| \ |35-08| \\ |28-18| \ |17-09| \ |31-22| \\ |33-26| \ |26-07| \ |19-15| \end{array} \right) = \left(\begin{array}{l} |04| \ |08| \ |27| \\ |10| \ |08| \ |09| \\ |07| \ |19| \ |04| \end{array} \right)$$

$$SAD \text{ value} = 04+08+27+10+08+09+07+19+04 = 96$$

Lower values of SAD indicate lesser changes amid block of images while higher value denotes significant changes amid block images.

**MOVEMENT DETECTION WORK FLOW***Fig.3 Movement detection work flow*

The first step is the selection of video source as seen in Figure 3. Video source can be in-built or an external Camera mounted to the computer system. The second step is to continuously capture real time video from camera chosen in step 1. A buffer is set aside to select multiple frames for later use. The next step converts frames to gray scale since it is easier to process single color dimension than Red Blue Green Alpha (RGBA). RGBA requires processing in four color dimensions and then combining them for further processing. Unwanted noises from resultant frames are eliminated using filtering techniques. The frames K and $K-1$ are then subjected to absolute difference method (2) to eliminate background and focus on objects that have moved. The resultant frame quality which is made visible to end user is further improved using image improvement methods. Global thresholding technique is used in the current project whose value is a user configurable parameter. The frames are then converted back to RGB format to compare with pattern. The pattern is either white or grey color. White indicates significant change between the compared images



while grey represents marginal changes in the intensity of pixels. The LED is set to Green and indicator on NI 9472 is set ON if there is a pattern match i.e. movement detection else LED is reset to black and indicator on NI 9472 is set OFF. The region of movement detection is also highlight-ed to indicate end user the areas where changes were detected. The whole process runs in continuous loop until end user terminates the program.

CRITICAL IMPLEMENTATION METHODS

Vision Acquisition Express



Fig.4 Image acquisition Express LabVIEW module

The module seen in Figure 4 is the source from which image/video frames are captured. This module is added by right clicking and navigating to “Vision and Motion->Vision Express->Vision Acquisition”. Double clicking the Vision Acquisition icon takes user to configuration menu. One can select the acquisition source to grab video from either real time input system such as web camera or offline system such as AVI file or folder of images. In the current paper continuous image grab without delay method is chosen.

Absolute difference

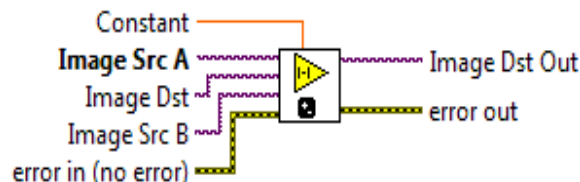


Fig.5 Absolute difference LabVIEW module

Figure 5 shows the important method in the program design where the VI subtracts one image from another or a constant from an image and returns the absolute value of the difference. Successive buffered images were classified as even and odd numbered images. Even numbered images were used as Image Src A and odd numbered images were used as Image Src B. If the images are similar i.e. if there is no difference between Image Src A and Image Src B, the error out terminal will be set to zero.



B, the resultant computed image Image Dst out is empty or blank. If Image Src A and Image Src B are not same, the difference is seen in output i.e. Image Dst Out. This difference in video frames indicates object move-ment changes.

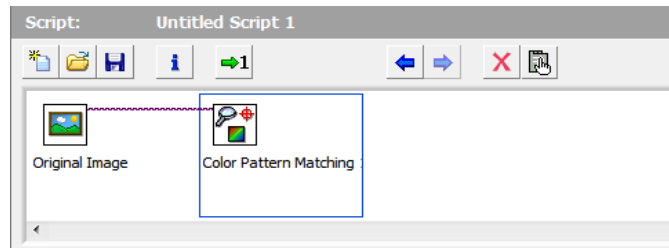


Fig.6 Image pattern match LabVIEW module

Figure 6 shows image being subjected to pattern match on the data received after applying absolute method. LabVIEW provides the end user to create a pattern from available images or load a template that was created pre-viously. Since the absolute difference method was em-ployed on gray scale image, the resultant image would al-so be in grey scale colors (black and white). Pure white color in output indicates significant changes/movement, grey color moderate change/movement while black color indicates no movement of objects at all. Since the experiment requires recognizing the movement of objects, template pattern chosen was mix of grey and white. Pat-tern matching also gives the flexibility to choose the number of matches which is set to 1 in our case. We chose number of matches to 1 due to the requirement of notifying end user of object movement as soon as it is de-tected and set the LED to green immediately.

EXPERIMENTS AND TEST RESULTS

The implemented project output has two screens, the first (Screen 1) showing the real-time video being captured from in-built camera while the second screen (Screen 2) shows object movement detection. There is an LED indi-cator as well to indicate end user whenever an object is in movement or displaces from its current position.

Experiment 1 – Coffee object movement detect.



Fig.7 Coffee mug without movement

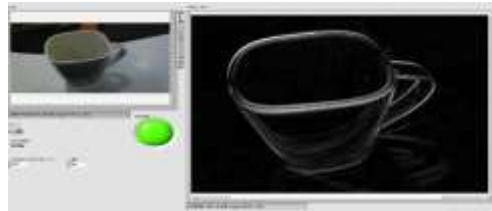


Fig.8 Coffee mug after movement

As can be seen in Fig 7, there is no movement of the object, which is Coffee Mug in current experiment. Hence the LED is Black and correspondingly Screen 2 is also black. Fig 8 snapshots show the Coffee Mug object displaced from its current position. Since movement of the object has been detected, the LED turns green. The grey and white region in Screen 2 indicates the changes in position and the red square on Screen 2 highlights the region where movement has been detected.

Experiment 2 – Human object movement detect.



Fig.9 Human without movement



Fig.10 Human after movement



As can be seen in Fig 9, there is no presence of any ob-jects, in current experiment. Hence the LED is Black and correspondingly Screen 2 is also black. Fig 10 snapshots show a human appearing on screen. As he is walking, the parts of the body are in motion and hence displaced from its previous position. Since movement of the object has been detected, the LED turns green. The grey and white region in Screen 2 indicates the changes in position and the red square on Screen 2 highlights the region where movement has been detected.

Experiment 3 –Interfacing program with cRIO chassis and NI 9472.

Figure 11 shows the LabVIEW program which has been interfaced with cRIO chassis 9074 and digital output NI 9472. It can be seen that the power feed to the cRIO chassis is provided by National Instruments power supply instrument NI PS 15 with yellow colored wire. The net-work between cRIO 9074 and the system is established by a standard RJ 45 LAN. The green LED light on the chassis indicates that power supply is normal.



Fig.11 Interfacing LabVIEW program with cRIO 9074 and NI 9472.



Fig.12 Movement detection and interface with cRIO 9074 and NI 9472.



Figure 12 depicts the output where movement detection program is run in conjunction with interfacing of cRIO chassis 9074 and NI 9472. It can be seen that movement detection of the person taking the snapshot is captured with the LED light turning green on the monitor. The net-work lights on cRIO device shows active communication between the host and the chassis. The green output LED light on 9472 also implies that object movement detection is noted by external system as well.

CONCLUSION

LabVIEW method is low on maintenance since Lab-VIEW program is easy to save and port to different computers/places compared to physical devices. LabVIEW along with its library modules provides simple and easy to use interface for image and video processing. Despite detecting multiple objects movement, the region of change is highlighted one after another and not simultaneously. The end result may vary depending on the light intensity, quality of the camera/video, type of noise in the frames etc. It is hence suggested to try other forms of object detection and noise reduction methods which fit best depending on the application that is being developed. Future enhancement could be adding multiple pattern recognition, counting systems, path tracking, and speed calculation. The cRIO system can be interfaced with other analog and digital input outputs such as alarm trigger system, stepper motor, lighting system etc.

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