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Visual Tracking Robot Using Computational Sensors in VLSI

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Abstract: Self target aiming and pre-processing of visual data is one of the biggest challenges in solving red-world problem using autonomous robots. Conventional methods generally depend on CCD cameras and computers associated with base station which doesn't implies real world interaction. Our approach attempts to solve this problem by using computational sensors and small/inexpensive embedded processors. The computational sensors are custom designed to reduce the amount of data collected, to extract only relevant information and to present this information to the microcontroller , in a format which minimizes post-processing latency. Consequently, the post-processors are required to perform only high level computation and decision making on given data. The computational sensors, however, have wide applications in many problems that require image pre-processing such as edge detection, motion detection, centroid localization and other spatiotemporal processing.

Keywords: Computational sensor, Pre-processing, Motion centroid computation, Weapon identification.

I. INTRODUCTION

Consider a hostage situation in an urban environment. When the law enforcement individuals arrive on the scene, it would not be prudent to enter the building containing armed terrorists. Instead a group of semi-autonomous robots are placed at the doorway and they search the building to find the captives. Portable workstations or personal digital assistance allows the officers to inspect the situation without any harm. On the other hand, computational sensor can be used to pre-process visual data and to extract the relevant information from it. The extracted visual information can be used to guide the robots. The robots autonomously execute the officers' command using the information provided by the computational sensors and decisions made by local/remote processing hardware. To ensure their survival, the robots must have a variety of specialty skills, such as stealth (quiet, low EM signature), hazard detection (obstacle avoidance and evasion), speech recognition and homing, and cooperative map building (landmark recognition and location), as shown in figure 1.

Over the past few years, a few information extracting computational sensors have been developed [Koch, 1995]. The application of these sensors to real problems requiring visually guided interaction with the environment is still in its infancy [Kramer, 1998]. Consequently, the problems that have been attempted are small and relatively easy for the robotics community. They are, however, the sentry problems that evaluate the potential of using computational sensors in difficult and complex robotics systems and tasks [Etienne, 1998].

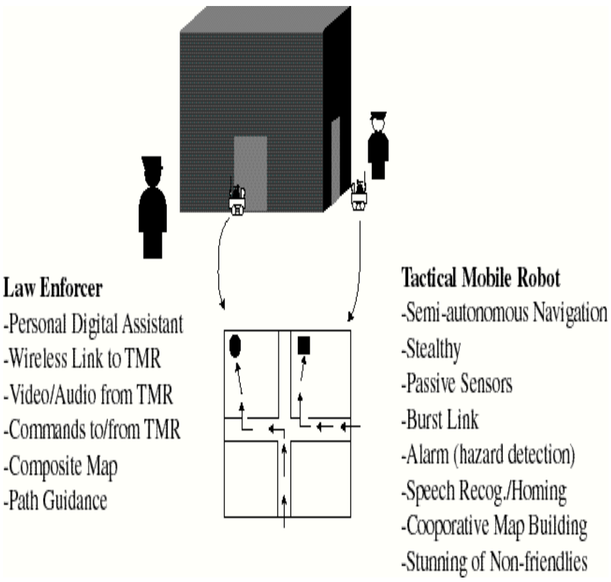

Fig.1 Semi-Autonomous Urban Search/Locate Robot

II. MOTION DETECTION USING COMPUTATIONALSENSORS

Motion centroid computation is used to isolate the location of moving targets on a 2D focal plane array. Using the centroid computation, a chip which realizes a neuromorphic visual target acquisition system based on the saccadic generation mechanism of primates can be implemented. Our approach focuses on realizing a compact single chip solution by only mimicking the behaviour of

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the saccadic system, but not its structure. The benefit of our approach is its compactness, low-power consumption and large response dynamic range.

A. Hardware implementation

Our approach uses a combination of analog and digital circuits to implement the functions of the retina and superior colliculus at the focal plane. The retina portion of this chip uses photodiodes, logarithmic compression, edge detection and zero crossing circuits. These circuits mimic the first three layers of cells in the retina with mixed sub-threshold and strong inversion circuits. The edge detection circuit is realized with an approximation of the Laplacian operator implemented using the difference between a smooth (with a resistive grid) and original versions of the image [Mead, 1989]. The high gain of the difference circuit creates a binary image of approximate zero-crossings. After this point, the computation is performed using mixed analog/digital circuits. The zero-crossings are fed to ON-set detectors (positive temporal derivatives) which signal the location of moving or flashing targets. These circuits model the behaviour of some of the amacrine and ganglion cells of the primate retina [Barlow, 1982]. These first layers of processing constitute all the "direct" mimicry of the biological models. Figure 2 shows the schematic of these early processing layers.

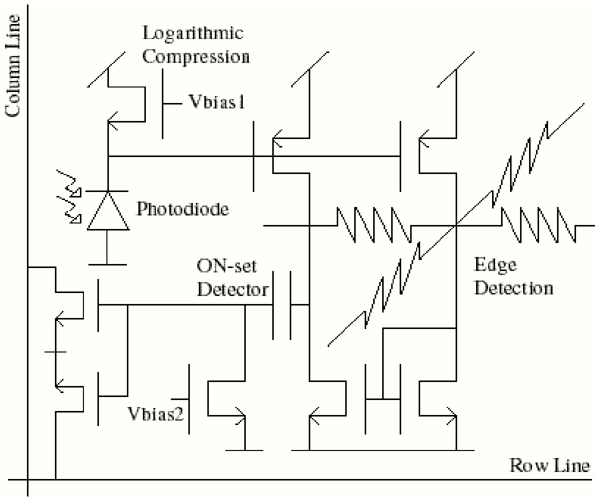

Fig.2 Schematic of the model of the retina

The ON-set detectors provide inputs to the model of the superior colliculus circuits [Sparks,1990]. The ON-set detectors allow us to segment moving targets against textured backgrounds. This is an improvement on earlier centroid and saccade chips which used pixel intensity [DeWeerth, 1992]. The essence of the superior colliculus map is to locate the target to be foveated. In our case, the target chosen to be foveated will be moving. Here motion is define simply as the change in contrast over time. Motion, in this sense, is the earliest measurable attribute of the target that can trigger a saccade without requiring any high-level decision making. Subsequently, the coordinates of the location of motion must be extracted and provided to the motor drivers. The circuits for locating the target are implemented entirely with mixed signal circuits. The ON-set detector is triggered when an edge of the target appears at a pixel. At this time, the pixel broadcasts its location to the edge of the array by activating a row and column line. This row (column) signal sets a latch at the right (top) of the array. The latches asynchronously activate switches and the centroid of the activated positions is provided. The latches remain set until they are cleared by an external control signal. This control signal provides a time-window over which the centroid output is integrated. This has the effect of reducing noise by combining the outputs of pixels which are activated at different instances even if they are triggered by the same motion (an artifact of small fill factor focal plane image processing). Furthermore, the latches can be masked from the pixels' output with a second control signal. This signal is used to de-activate the centroid circuit during a saccade.

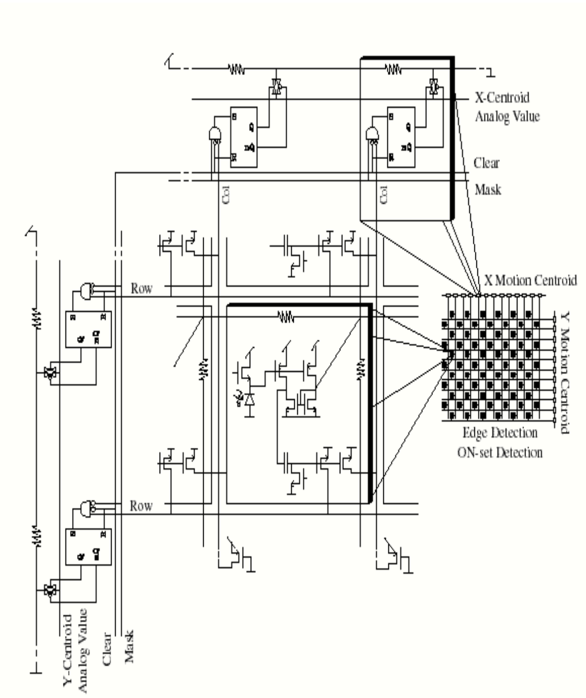

Fig.3 Schematic of the model of the superior colliculus

B. Result

In contrast to previous work, this chip provides the 2D coordinates of the centroid of a moving target. Figure 4 shows the oscilloscope trace of the coordinates as a target moves back and forth (at a fixed y- displacement), in and out of the chip's field of view. The y-coordinate does not changes while the x-coordinate increases and decreases as the target moves to the left and right, respectively. The chip

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has been used to track targets in 2D by making micro saccades. In this case, the chip chases the target as it attempts to escape from the center. The eye movement is performed by converting the analog coordinates into PWM signals that are used to drive stepper motors. The system performance is limited by the contrast sensitivity of the edge detection circuit, and the frequency response of the edge (high frequency cut-off) and ON- set (low frequency cut-off) detectors. With the appropriate optics, it can track walking or running persons under indoor or outdoor lighting conditions at close or far distances.

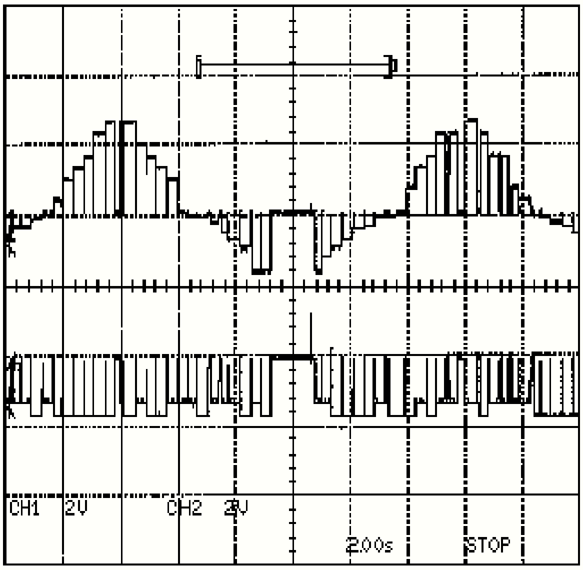

Fig.4 Oscilloscope trace of 2D centroid for a moving target

III. AUTONOMOUS NAVIGATION

The simplest form of data driven auto-navigation is the line-following task. In this task, the robot must maintain a certain relationship with some visual cues that guide its motion. In the case of the line-follower, the visual system provides data regarding the state of the line relative to the vehicle, which results in controlling steering and/or speed. If obstacle avoidance is also required, auto-navigation is considerably more difficult. Our system handles line following obstacle avoidance by using two sensors which provide information to a microcontroller (µC). The µC steers, accelerates or decelerates the vehicle. The sensors, which use the centroid location system outlined above, provide information on the position of the line and obstacles to the µC. The µC provides PWM signals to the servos for controlling the vehicle. The algorithm implemented in the µC places the two sensors in competition with each other to force the line into a blind zone between the sensors. Simultaneously, if an object enters the visual field from outside, it is treated as an obstacle and the µC turns the car away from the object. Obstacle avoidance is given higher priority than line-following to avoid collisions. The µC also keeps track of the direction of avoidance such that the vehicle can be re-oriented towards the line after the obstacle is pushed out of the field of view. Lastly, for line following, the position, attitude and velocity of drift, determined from the temporal derivative of the centroid, are also used. The speed control strategy is to keep the line in the blind zone, while slowing down at corners, speeding up on straight always and avoiding obstacles. The angle which the line or obstacle form with the x-axis also affects the speed. The value of the x-centroid relative to the y-centroid provides rudimentary estimate of the attitude of the line or obstacle to the vehicle. For example, angles less (greater) than +/- 45 degrees tend to have small (large) x-coordinates and large (small) y-coordinates and require deceleration (acceleration). Figure 5 shows the organization of the sensors on the vehicle and control spatial zones. Figure 6 shows the vehicle and samples of the line and obstacles.

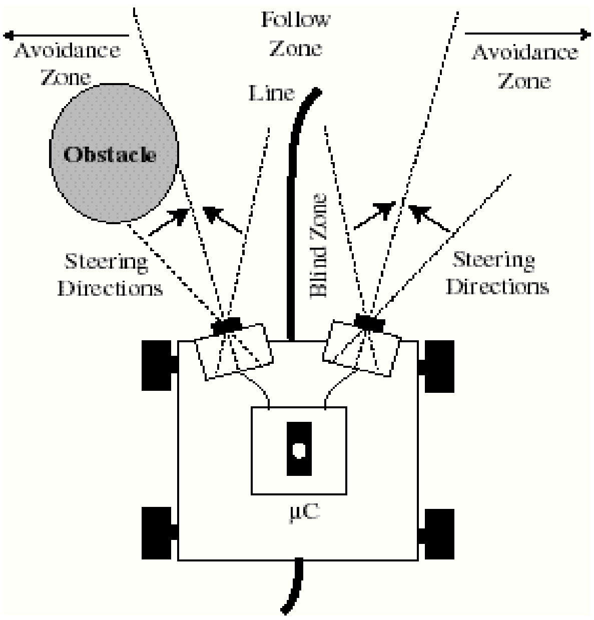

Fig.5 Block diagram of the autonomous line-follower system

A. Hardware Implementation

The coordinates from the centroid localization circuits are presented to the µC for analysis. The µC used is the Atmel ATmega8L. This chip is chosen because 8 ADC channels and 3 PWM channels. An analog coordinates are presented directly to the A/D inputs. PWM outputs are connected to the steering and speed control servos. The ATmega8L runs at 16 MHz and has 8KB of programmable flash memory. The AVR program determines the control action based on the signal provided by the sensors. The vehicle used is a four-wheel drive radio controlled model car (the radio receiver is disconnected) with Digital Proportional Steering (DPS).

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IV. IDENTIFICATION OF CONCEALED WEAPON

Imaging techniques based on a combination of sensor technologies and processing will potentially play a key role in detecting weapon. In our proposed plan, basically two images RGB and IR are taken as input which is processed as per mentioned algorithm.

A. Algorithm

Step1: Take visual image (basically RGB) and IR image as input.
Step2: Resize the two images so that they have same size.
Step3: Resize visual and IR image.
Step4: Complement the IR image.
Step5: Combine visual image and complemented IR image.
Step6: Convert visual RGB image to HSV format.
Step7: Perform DWT fusion on step 5's combined image and step 6's converted HSV image.
Step8: Convert fused image to gray scale format.
Step9: Binarize the fused image.
Step10: Detect the weapon from that image.
Step11: Combine the detected weapon with visual image.
Step12: For detecting the weapon clearly we find out the contour of the Weapon.
Step13: Combine the contour of the weapon with visual image.
Step14: End

B. Result

It takes several steps to identify the weapon. Firstly two images (RGB and IR) of same posture are taken simultaneously as shown in fig.6 and 7.



Fig.6 RGB image Fig.7 IR image Fig.8 Gray image

The visual and IR images are then combined to detect any foreign object. Since fig. 9 is hazy, so we do not get enough information from fig. 9 .To get the useful information, the IR version of image is complemented. This image is then combined with visual image to get correct allocation of object as shown in fig. 11.



Fig.9 Combined image Fig.10 Comp image Fig.11 Combined1 image

IR images are generally correlated with the amount of light hitting the object, and therefore image description in terms of those components makes object discrimination difficult. To overcome this problem, the IR image is converted into HSV colour model. Then we use DWT fusion technique between HSV colour image and combined images shown in fig. 13. The discrete wavelet transform DWT is a spatial frequency decomposition that provides a flexible multi resolution analysis of an image. Applying fusion techniques, contrast and image sharpness get enhanced. Then this fused image converted into gray scale image as shown in fig. 14.



Fig.12 HSV image Fig.13 Fused image Fig.14 Fused gray

The next step we require is binarization technique. Here we use Ostu method which is a global thresholding method i.e. threshold value are calculated locally and get the result, no extra threshold value is added here. Extract this weapon portion by calculating all connected area component then remove too small component according to the area values. Only weapon portion binary image is shown in fig. 15.Furthur fig. 16 and 17 depicts weapon allocation in visual image as well as the contour of the weapon image.



Fig.15 Weapon binary Fig.16 Weapon in visual Fig.17 Weapon contour Image image

V. CONCLUSION

The need for and the benefit of having computational sensors in the processing pathway of robot vision systems have been argued. The question on the type of computational sensors to use, i.e. application specific or general-purpose, is somewhat more difficult to answer. To address this issue, an application specific computational sensor for motion centroid localization, modelled after the biological retina and superior colliculus, is presented. Furthermore, two of these sensors, together with a simple µC, are used to realize the solution to a toy line-following with obstacle avoidance auto navigation problem. Despite the simplicity of this problem, this experiment shows that we are currently able to create

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application specific sensors which can be used to solve real problems in real-time. Generally, application specific sensors are efficient in function, but not in design and re-use.

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