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REVIEW ARTICLE

A Simplified Review on Video Analysis to Detect and Track the Road Ahead for Safety

Laxmi[1], Dr. Neelam Shrivastva[2]

Ganga Institute of Technology and Management, Kablana, Jhajjar, Haryana, India

ABSTRACT

This is a review paper on real-time in-car video analysis to detect and track road ahead for safety, auto driving, and target tracing. This paper describes a comprehensive approach to localizing target vehicles in video under various environmental conditions. The extracted geometry features from the video are continuously projected onto a 1-D profile and are constantly tracked. We rely on temporal information of features and their motion behaviors for vehicle identification, which compensates for the complexity in recognizing vehicle shapes, colors, and types. We probabilistically model the motion in the field of view according to the scene characteristic and the vehicle motion model. The hidden Markov model (HMM) is used to separate target vehicles from the background and track them probabilistically. We have investigated videos of day and night on different types of roads, showing that our approach is robust and effective in dealing with changes in environment and illumination and that real-time processing becomes possible for vehicle-borne camera.

INTRODUCTION

VIDEO IN AUTOMOTIVE SAFETY SYSTEMS

In many ways, car safety can be greatly enhanced by video-based systems that use high-performance media processors. Because short response times are critical to saving lives, however, image processing and video filtering must be done deterministically in real time. There is a natural tendency to use the highest video frame rates and resolution that a processor can handle for a given application, since this provides the best data for decision making. In addition, the processor needs to compare vehicle speeds and relative vehicle-object distances against desired conditions—again in real time. Furthermore, the processor must interact with many vehicle subsystems (such as the engine, braking, steering, and airbag controllers), process sensor information from all these systems, and provide appropriate audiovisual output to the driver. Finally, the processor should be able to interface to navigation and telecommunication systems to react to and log malfunctions, accidents, and other problems.

Figure 1 shows the basic video operational elements of an automotive safety system, indicating where image sensors might be placed throughout a vehicle, and how a lane departure system might be integrated into the chassis. There are a few things worth noting. First, multiple sensors can be shared by different automotive safety functions. For example, the rear-facing sensors can be used when the vehicle is backing up, as well as to track lanes as the vehicle moves forward.

In addition, the lane-departure system might accept feeds from any of a number of camera sources, choosing the appropriate inputs for a given situation. In a basic system, a video stream feeds its data to the embedded processor. In more advanced systems, the processor receives other sensor information, such as position data from GPS receivers.

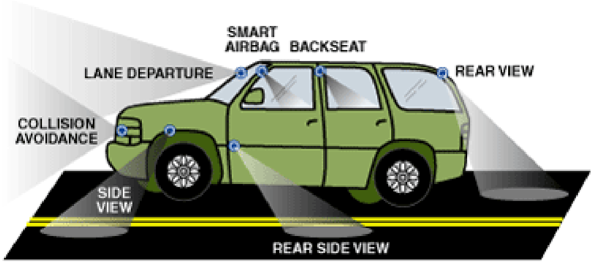

Figure 1. Basic camera-placement regions for automotive safety applications

Smart Airbags

An emerging use of media processors in automotive safety is for “intelligent airbag systems,” which base deployment decisions on who is sitting in the seat affected by the airbag. At present, weight-based systems are in widest use, but video sensing will become popular within five years. Either thermal or regular cameras may be used, at rates up to 200 frames per second, and more than one might be employed—to provide a stereo image of each occupant. The goal is to characterize the position and posture of the occupants—not just their size. In the event of a collision, the system must choose whether to restrict deployment entirely, deploy with a lower force, or deploy fully. In helping to determine body position, image-processing algorithms must be able to differentiate between a person’s head and other body parts.

In this system, the media processor must acquire multiple image streams at high frame rates, process the images to profile the size and position of each occupant under all types of lighting conditions, and constantly monitor all the crash sensors, located throughout the car, in order to make the best deployment decision possible in a matter of milliseconds.

Collision Avoidance and Adaptive Cruise Control

Another high-profile safety application is *adaptive cruise control* (ACC), a subset of *collision avoidance systems*. ACC is a convenience feature that controls engine and braking systems to regulate the speed of the car and its distance from the vehicle ahead. The sensors employed involve a combination of microwave, radar, infrared, and video technology. A media processor might process between 17 and 30 frames per second in real time from a camera—focused on the roadway—mounted near the car’s rear-view mirror. The image-processing algorithms may include frame-to-frame image comparisons, object recognition, and contrast equalization for varying lighting scenarios. Goals of the video sensor input are to provide information about lane boundaries and road curvature, and to categorize obstacles, including vehicles ahead of the car.

ACC systems are promoted as a convenience feature, while true collision avoidance systems actively aim to avoid accidents by coordinating the braking, steering, and engine controllers of the car. As such, they have been slower to evolve because of the complexity of the task, the critical reliability considerations, and legal and social consequences. It is estimated that deployment of these systems may be well on its way by 2010. In view of the typical 5-year automotive design cycle, such system designs are already underway.

Collision *warning* systems, like ACC, are a subset of the collision-avoidance category. These provide a warning of a possibly impending accident, but they don’t actively avoid it. There are two main subcategories within this niche:

Blind spot monitors—Cameras are mounted strategically around the periphery of the vehicle to provide a visual display of the driver’s blind spots—and to sound a warning if the processor senses the presence of another vehicle in a blind-spot zone. In reverse gear, these systems also serve as back-up warnings, cautioning the driver about obstructions in the rear of the car. A display could be integrated with the rear-view mirror, providing a full, unobstructed view of the car’s surroundings. Moreover, the system might include a video of “blind spots” *within* the car cabin, allowing the driver to monitor a rear-facing infant, for example.

Lane-departure monitors—These systems can notify drivers if it is unsafe to change lanes or if they are straying out of a lane or off the road—thus aiding in detecting driver fatigue. Forward-facing cameras monitor the car’s position relative to the roadway’s centerline and side markers, up to 50 to 75 feet in front of the car. The system sounds an alarm if the car starts to leave the lane unintentionally.

LANE DEPARTURE—A SYSTEM EXAMPLE

In addition to the role that a media processor can play in video-based automotive safety applications, it is instructive to analyze typical components of just such an application. To that end, let’s probe further into a lane-departure monitoring system that could employ the Blackfin media processor.

The overall system diagram of Figure 2 is fairly straightforward, considering the complexity of the signal processing functions being performed. Interestingly, in a video-based lane departure system, the bulk of the processing is image-based, and is carried out within a signal processor rather than by an analog signal chain. This represents a big savings on the system bill-of-materials. The output to the driver consists of a warning to correct the car’s projected path before the vehicle leaves the lane unintentionally. It may be an audible “rumble-strip” sound, a programmed chime, or a voice message.

The video input system to the embedded processor must perform reliably in a harsh environment, including wide and drastic temperature shifts and changing road conditions. As the data stream enters the processor, it is transformed—in real time—into a form that can be processed to output a decision. At the simplest level, the lane departure system looks for the vehicle’s position with respect to the lane markings in the road. To the processor, this means the incoming stream of road imagery must be transformed into a series of lines that delineate the road surface.

The processor can find lines within a field of data by looking for edges. These edges form the boundaries within which the driver should keep the vehicle while it is moving forward. The processor must track these line markers and determine whether to notify the driver of irregularities.

Keep in mind that several other automobile systems also influence the lane-departure system. For example, use of the braking system and the turn signals typically will block lane departure warnings during intentional lane changes and slow turns.

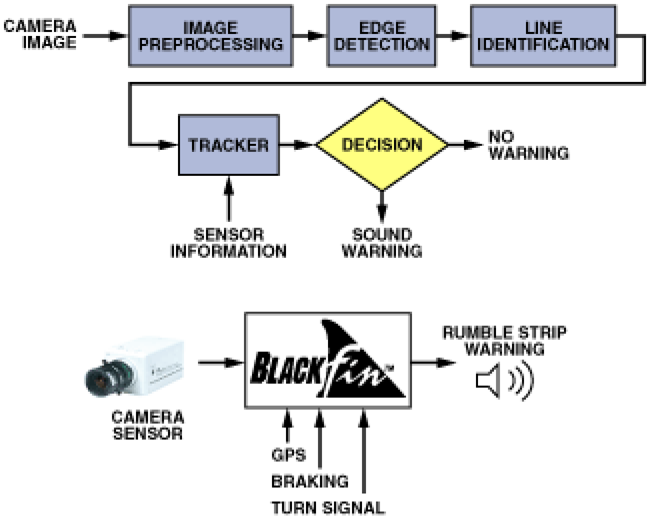

Figure 2. Basic steps in a lane-departure algorithm and how the processor might connect to the outside world

Let’s now drill deeper into the basic components of the lane-departure system example. Figure 3 follows the same basic operational flow as Figure 2 but with more insight into the algorithms being performed. The video stream coming into the system needs to be filtered and smoothed to reduce noise caused by temperature, motion, and electromagnetic interference. Without this step, it would be difficult to find clean lane markings.

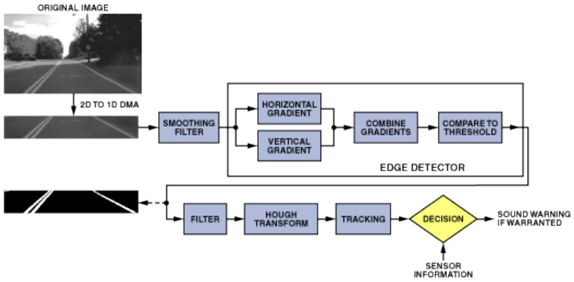

Figure 3. Algorithm flow, showing results of intermediate image-processing steps

The next processing step involves edge detection; if the system is set up properly, the edges found will represent the lane markings. These lines must then be matched to the direction and position of the vehicle. The *Hough transform* will be used for this step. Its output will be tracked across frames of images, and a decision will be made based on all the compiled information. The final challenge is to send a warning in a timely manner without sounding false alarms.

Image Acquisition

An important feature of the Blackfin Processor is its *parallel peripheral interface* (PPI), which is designed to handle incoming and outgoing video streams. The PPI connects without external logic to a wide variety of video converters. In addition to ITU-R 656-compliant video encoders and decoders, the PPI can connect to CMOS camera chips and LCD displays, which find common use in the automotive industry. Because it can capture video in real time, the PPI is instrumental for the kinds of auto safety applications discussed in this article.

In devices supporting ITU-R 656, each boundary between blanking data and active video data is set using a 4-byte data sequence that is embedded within the data stream. The PPI automatically decodes this sequence, without processor intervention, to collect the incoming active video frames. With this embedded control scheme, the physical connection is simply eight data lines and a clock.

The PPI also connects to a wide range of image sensors and data converters that do not have an embedded control scheme. In these cases, the PPI provides up to three frame syncs to manage incoming or outgoing data. For a video stream, these frame syncs function as physical horizontal sync, vertical sync and field lines (HSYNC, VSYNC, and FIELD).

For automotive safety applications, image resolutions typically range from VGA (640 × 480 pixels/image) down to QVGA (320 × 240 pixels/image). Regardless of the actual image size, the format of the data transferred remains the same—but lower clock speeds can be used when less data is transferred. Moreover, in the most basic *lane-departure warning systems*, only gray-scale images are required. The data bandwidth is therefore halved (from 16 bits/pixel to 8 bits/pixel) because chroma information can be ignored.

Memory and Data Movement

Efficient memory usage is an important consideration for system designers because external memories are expensive, and their access times can have high latencies. While Blackfin processors have an on-chip SDRAM controller to support the cost-effective addition of larger, off-chip memories, it is still important to be judicious in transferring *only the video data needed* for the application. By intelligently decoding ITU-R 656 preamble codes, the PPI can aid this "data-filtering" operation. For example, in some applications, only the active video fields are required. In other words, horizontal and vertical blanking data can be ignored and not transferred into memory, resulting in up to a 25% reduction in the amount of data brought into the system. What's more, this lower data rate helps conserve bandwidth on the internal and external data buses.

Because video data rates are very demanding, frame buffers must be set up in external memory, as shown in Figure 4. In this scenario, while the processor operates on one buffer, a second buffer is being filled by the PPI via a DMA transfer. A simple semaphore can be set up to maintain synchronization between the frames. With Blackfin's flexible DMA controller, an interrupt can be generated at virtually any point in the memory fill process, but it is typically configured to occur at the end of each video line or frame.

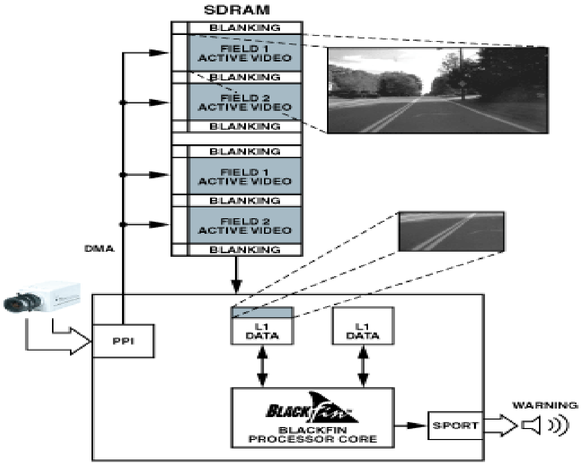

Figure 4. Use of external memory for a frame buffer

Once a complete frame is in SDRAM, the data is normally transferred into internal L1 data memory so that the core can access it with single-cycle latency. To do this, the DMA controller can use two-dimensional transfers to bring in pixel blocks. Figure 5 shows an example of how a 16 × 16 “macroblock,” a construct used in many compression algorithms, can be stored linearly in L1 memory via a 2D DMA engine.

Vision method of detecting lane boundaries and obstacles

US 4970653 A
Abstract
An image processing method operates on an image from a ccd camera viewing a roadway scene in front of a vehicle to detect lane markers and determine the relationship of the vehicle to the lane. Obstacles in the lane near the vehicle are detected and a warning is given to the driver. The method uses template matching techniques or a Hough algorithm to detect the lane markers or road edges.

Description
FIELD OF THE INVENTION

This invention relates to a vision method of detecting lane boundaries and obstacles close to a vehicle within the lane boundaries, and particularly to such a method employing image processing techniques and which is operative for moderately marked roads.

BACKGROUND OF THE INVENTION

The use of an on-board video camera and image processing of the roadway scenes allows useful information to be gathered for vehicle control. Detecting lane boundaries is a core capability for advanced automotive functions such as collision warning, collision avoidance and automatic vehicle guidance. If the lane boundaries and thus the road path can be detected several other functions can be implemented. Lane control uses the boundary information and vehicle dynamics knowledge to derive steering and braking commands for keeping the vehicle in the lane. Headway control uses a laser or radar system to track the vehicle ahead and keeps a safe driving distance. The lane boundary information can be used to prevent the detection of a vehicle in an adjacent lane on a curved road. Then the sensor beam can be directed to points within the lane. To monitor driving performance, the behavior of the driver is tracked and evaluated using the estimated position of the vehicle with respect to the lane boundaries.

Lane boundary detection for guiding vehicles along roadways has been reported in the paper by Dickmanns, E. D. and Zapp, A , "A Curvature-based Scheme for Improving Road Vehicle Guidance by Computer Vision," Proc. SPIE on Mobile Robots, Vol. 727, October 1986, which is incorporated herein by reference. Contour correlation and high order world models are the basic elements of that method, realized on a special multi-processor computer system. Perspective projection and dynamical models (Kalman filter) are used in an integrated approach for the design of the visual feedback control system. That system requires good lane markings and thus is limited to only those roads having good lane markings. It is of course desirable to extend the benefits of the computer vision system to roads with less good markings and to incorporate other features such as obstacle detection.

CONCLUSION

The basic aim of publishing this paper to discuss real-time in-car video analysis to detect and track vehicles ahead for safety, auto driving, and target tracing. The extracted geometry features from the video are continuously projected onto a 1-D profile and are constantly tracked. We rely on temporal information of features and their motion behaviors for vehicle identification, which compensates for the complexity in recognizing vehicle shapes, colors, and types. We probabilistically model the motion in the field of view according to the scene characteristic and the vehicle motion model. The hidden Markov model (HMM) is used to separate target vehicles from the background and track them probabilistically.

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