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Abstract

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An Inexpensive, All Solid-state Video and Data Recorder for Accident Reconstruction

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ABSTRACT

An accurate record of the events preceding a traffic accident is useful to trucking companies, car rental agencies, commercial carriers, and insurance providers, as well as to passenger car drivers. A video and data recording is very helpful for accurate accident reconstruction. We have made a prototype of a “personal eye witness”: a small video camera with solid state memory and a short recording time. The camera records continuously until it senses an accident, then it saves a video record of the events surrounding the accident in time. Since video is available from both before and after the collision, accident reconstruction becomes easier. The camera uses only solid state memory with no moving parts, can be manufactured inexpensively, and can be packaged in a crash-resistant and tamper-resistant module. Automobile data can be added as sideband data or overlaid text to the video data storage path.

INTRODUCTION

A video and data record of the events just preceding or following a traffic accident would be very useful for accident reconstruction or during litigation or arbitration. One possible approach would be to mount a consumer video camera inside the passenger compartment of the vehicle. It could be facing forward, and always recording, to provide the desired video record. However, such a camera would be relative large and obtrusive, it would cost several hundred dollars, and has many moving and vibration-sensitive parts which can fail, in addition to videotape that must be periodically rewound.

Our approach is to use a small, inexpensive all-solid-state recorder with no moving parts. The video signal is digitized, compressed, and stored in the camera’s solid state memory. To meet size, power, and cost constraints, we use only a small amount of video memory, which is constantly over-written with fresh video data. An accelerometer detects when an accident has occurred, which causes the overwriting to stop, yielding a video record of just the events surround the traffic accident in time.

The Personal Eyewitness module is designed to be mounted securely onto a vehicle in a tamper-resistant fashion, and operates for the lifetime of the vehicle. It requires no service or maintenance for the lifetime of the vehicle, and is self-contained except for vehicle power and status connections.

We have constructed two successive prototypes of the Personal Eyewitness Video Accident Data Recorder device and are currently engaged in testing and refinement of the concept. The second prototype uses Mitsubishi Electric's Artificial Retina chip (M64282FP) as the detector [Johannes, 1998], the M32R single-chip integrated microprocessor/DRAM with 2MB of on-chip memory (M32000D4AFP), and an integrated circuit accelerometer (Analog Devices ADXL202). Video signal digitization is done with an 8-bit flash A/D converter (Maxim MAX153). At present prices, a production version recording 30 seconds of video at 5 frames per second with 128 x 128 image resolution would cost less than $100 retail. Figure 1 shows a block diagram of the unit.

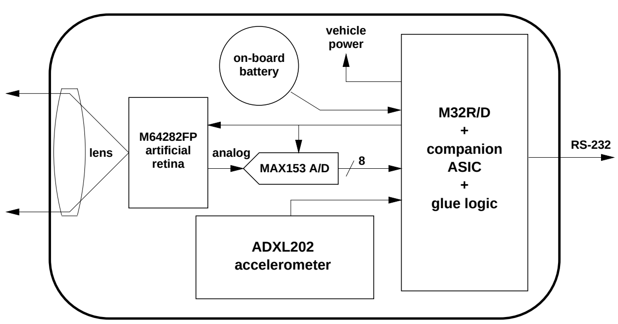

Figure 1: *System block diagram*

The current Personal Eyewitness device prototype is built using breadboard technology rather than the flexible printed circuit system that would be used in a production unit; the prototype is not potted or armored to permit access for debugging. The test version of the device is built using M32R evaluation kits and additional hand-made expansion cards.

The design parameters such as recording time, frame rate, and camera resolution were established by the limits of current technology at the under $100 retail price point. Given the marketing price point, our question was "would it be possible to design and construct a useful solid-state video accident recorder".

METHODS

Software simulation provided our initial concept test and first prototype. We simulated the desired final configuration; a consumer-grade camcorder and a car driving around town was used to capture a video stream. The recorded NTSC color video stream was then digitized and processed to yield the price-point limited recording duration, frame rate, gray scale, and screen resolution. From the resulting video sequences we concluded that a gray-scale video recording of thirty seconds duration, 5 frames per second, and 256 x 128 format[1] was adequate to indicate the actions and visibility of a vehicle on the road negotiating traffic.

Additionally, we tested an asymmetrical compression method [Adelson and Simoncelli, 1990] to allow a longer duration of recording. With 4:1 compression, we found the recordings to be of equivalent quality to the uncompressed 30-second, 5 frame/second, 256 x 128 grayscale video stream.

Our initial results and analysis justified the second prototype. The second prototype uses the commercially available image-sensing Artificial Retina chip, the M32R integrated DRAM/microprocessor, and Analog Devices accelerometer chips. Although the silicon is production quantity, the circuit cards are M32R evaluation modules and handmade interface cards to the Artificial Retina imaging sensor. [2]

[1] Initial manufacturing plans for the Artificial Retina image sensor would be available in this 256x128 form factor initially. This was later revised by manufacturing to 128x128, but with on-chip image sharpening capability. Thus, the initial experiments were done at 256x128, while later experiments at 128x128 resolution.

[2] The M64282FP Artificial Retina imaging sensor is the same imaging sensor used in the popular Nintendo "game boy"

The second prototype is mounted in a consumer-grade 1/12 scale radio-controlled toy vehicle. The vehicle is capable of a real top speed of approximately 4 meter/sec (13 ft/sec), which corresponds to a scale speed of roughly 170 kph (105 MPH). Acceleration is roughly 2 m/secˆ2 (0.2 G).[3] The M32R evaluation kit card and the Artificial Retina interface card, plus a battery, fit into the rear “cargo area”. Figure 2 shows the second prototype installed in the toy vehicle.

Figure 2: *The prototype device mounted on a model car.*

Note that the cards are mostly empty space; a production version of this prototype using the same chipset and including an on-board battery would occupy approximately 64 cubic centimeters (˜ 4 cubic inches). Figure 3 shows a closeup of the boards of prototype 2.

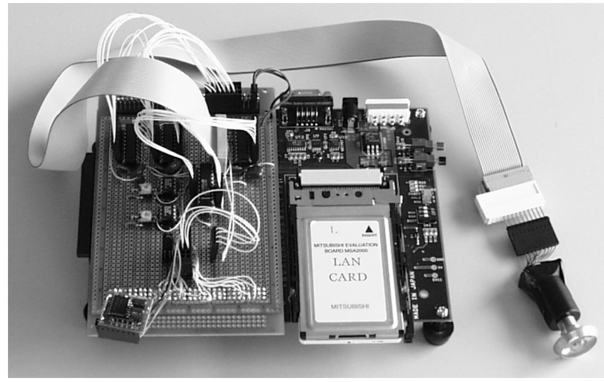

Figure 3: *The prototype built on an evaluation board. The parts that do the actual work are two tiny surface mount integrated circuits.*

The optical system of the second prototype is a full-hemispherical fisheye lens, with a field of view of very nearly 180 degrees. This lens is a commercially available security door-viewing device, modified by the addition of a relay lens in the barrel to focus the viewable virtual image as a real image onto the Artificial Retina (AR) chip. The image-sensing area of the Artificial Retina chip is only 3 mm on a side, which is about 1/3 the linear dimension of industry-standard CCD image sensors. The relay lens is a commercially available Hastings achromat, 8mm diameter by 12.5mm focal length, and the lens barrel is bored to accommodate the achromat as a friction fit. The resulting minimum spot size is approximately 0.05 mm which is slightly larger than the pixels on the AR chip.

The AR chip is clocked directly by the M32R, and the analog video output is digitized by a Maxim MAX153 8-bit A/D converter. The M32R controls the electronic shutter speed of the AR chip, to maintain proper image exposure levels. There is no other exposure control or iris diaphragm in the system; under microprocessor control the AR chip can maintain useful image quality at scene lighting intensities from 1 lux to 10,000 lux.

The M32R retains the digitized output of the A/D converter in the on-chip DRAM. The 2 megabytes of on-chip DRAM provide storage for just over 20 seconds of 128x128 images at 5 frames per second. The current prototype is not using any image compression; we intend to pursue that in later research.

The image buffer onboard the M32R is organized as

camera. Other researchers duplicating or extending our work should be advised that the Nintendo product is quite easy to cannibalize for use in prototype machine vision devices.

[3]The scale acceleration is an astounding 2.4 G’s.

a ring of images with a total duration of 20 seconds at 5 frames per second. Every 1/5 of a second, the oldest image is overwritten. This overwriting process runs continuously until the accelerometer detects a velocity change of a magnitude that indicates a collision has occurred. At this point, the M32 continues to record for ten seconds and then goes into a low-power mode, refreshing memory in the DRAM and maintaining a minimum current draw. The low-current mode is appropriate because during or after a collision event, vehicle power may be disrupted. The on-board battery is adequate to power the M32R in image-acquisition mode for the duration of the accident recording, and maintain the memory for approximately one week even if vehicle power fails at the moment of impact.

The low-power mode continues until the device is retrieved, supplied with external power, and commanded via the serial port to output the saved image data. The image data is retrieved over the serial link onto a Linux-based[4] workstation. Using the GNU Image Processing Software package (the "GIMP" package)[5] on the workstation, the individual frames of the collision are assembled into an animated GIF motion picture, and displayed. The assembled animated GIF is also displayed via web browsers.

Additional information, such as the engine RPM, the accelerometer data stream, turn signal/brake light status, or other vehicle information can be included as auxiliary data in the image ring buffer, and can be embedded in the animated GIF.

RESULTS

Scenario one

We tested the Personal Eyewitness prototype using several scenarios in which the pre-accident video data could prove useful. In the first scenario, the camera equipped car (vehicle A) collides with a second car (vehicle B) which has run a stop sign. Several frames from the video footage are shown in Figure 4. In frame (a), vehicle A clearly has an unobstructed path. Frames (b) and (c) show vehicle B entering the intersection without stopping, depriving vehicle A of sufficient time to avoid a collision. Frame (d) was taken as vehicle A maneuvered desperately (but unsuccessfully) to miss the other car. The collision was detected by the on-board accelerometer and, after several more seconds of data were captured, all of the video was stored to be downloaded later. The video record clearly shows that vehicle B caused the accident.

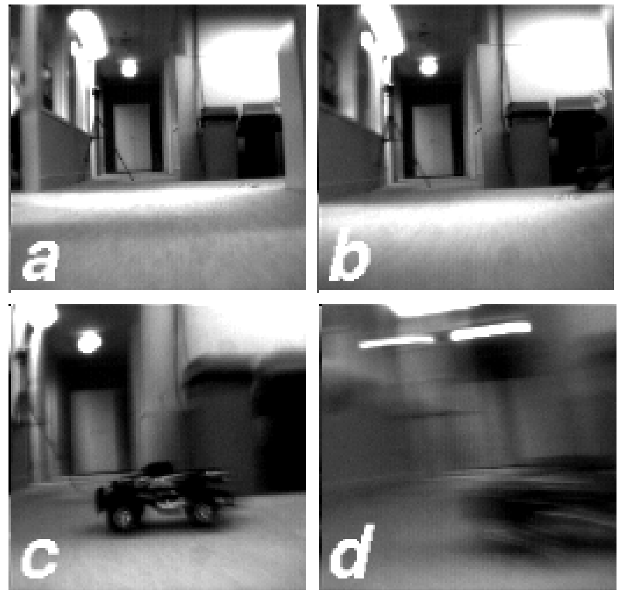

Figure 4: *A car runs a stop sign.*

The motion blur in Frame (d) is caused by several factors. These small, but powerful model cars are capable of large accelerations and scale velocities, and they exhibit significant amounts of vibration while doing so. The relatively low lighting conditions of our indoor "test track" required the camera to use longer than usual exposure times, compounding this problem. However, the blur can actually provide useful

[4]The Linux operating system is available for download at no cost at http://www.redhat.com or http://www.linux.org

[5]The GIMP image-processing package is available for download at no cost at http://www.gimp.org

information about relative vehicle motions for accident reconstruction purposes. If desired, the image can even be de-blurred somewhat using standard image processing techniques.

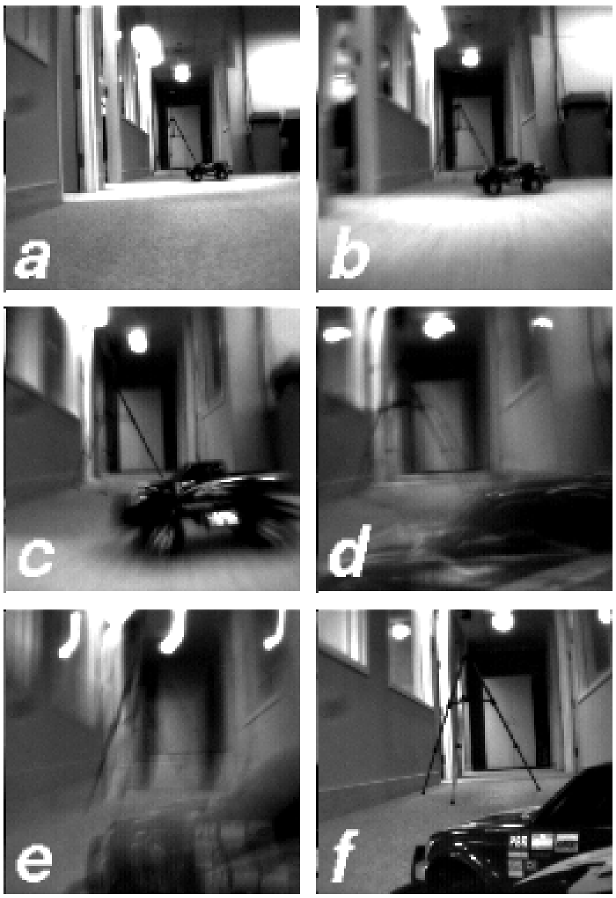

Figure 5: *A deliberate collision.*

Scenario two

The second scenario is the opposite of the first: while vehicle B is stopped in the middle of the intersection, vehicle A deliberately rams it. The video data is shown in Figure 5. Frames (a), (b) and (c) clearly show that vehicle B was not in motion before the collision and that vehicle A had adequate time to see it and stop. Frames (d) and (e) were captured during the collision and thus show substantial amounts of motion blur. Frame (f) was captured after the vehicles had come to rest. The pre-accident video record clearly distinguishes between scenarios one and two, even if the physical outcomes appear similar.

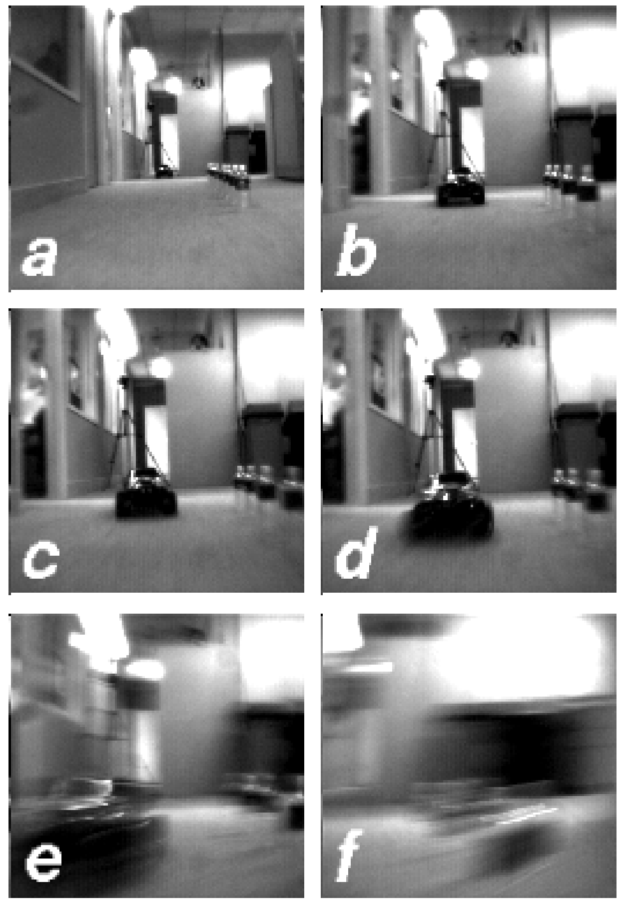

Figure 6: *Avoiding a drunk driver.*

Scenario three

Scenario three involves a single vehicle accident and is shown in Figure 6. Vehicle B, operated by a drunk driver, veers into the oncoming lane, forcing vehicle

A to swerve into the guard rail to avoid a head-on collision. There is no contact between the vehicles, so without the pre-accident video footage there might be no way for the driver of vehicle *A* to prove that that he or she was not at fault.

While most of our testing was performed indoors, Figure 7 shows some Personal Eyewitness video footage taken from the eighth floor window of our laboratory in Cambridge. The sky was overcast, but the images are quit clear. Cars and trucks are readily visible, as are pedestrians on the sidewalk at the bottom of the image. The full-motion video shows things even more clearly. These printed stills do not do it justice.

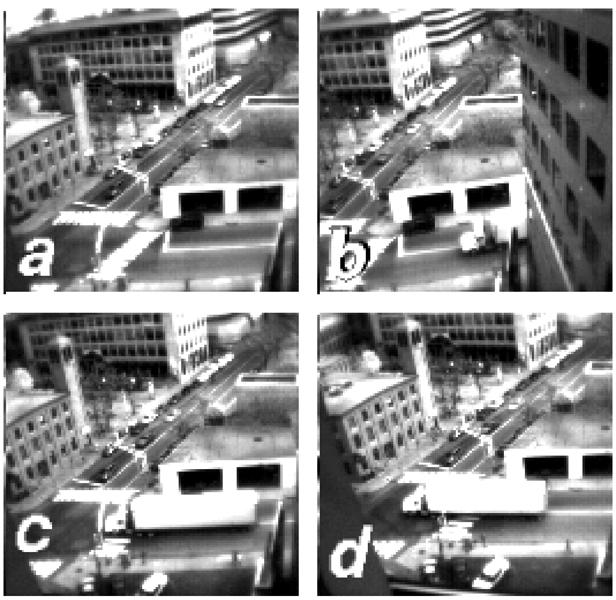

Figure 7: *A view of the real world.*

Our results with the vehicle-mounted prototype have been encouraging. As we showed above, the paths of all participants in the accident are easy to visualize. This provides strong evidence for determining fault in a vehicle accident, as well as a powerful tool in insurance fraud prevention. Near term technological advances will allow improved image quality (color, higher resolution and frame rate, less motion blur) which could provide even more useful information after an accident, such as license plate numbers, better identification of vehicles and their occupants, etc.

DISCUSSION

The use of a short-duration digital video camera and recorder to provide accident involvement data is a powerful tool. It is, unfortunately, only a technical solution to a problem which also has social implications. For example, can the contents of such a video recorder be considered subpoenable? What are the legal ramifications of equipping vehicles with video accident data recorders? Further research and social engineering is required to determine if the short-duration digital video accident recorder is a useful tool in reducing overall end-user costs.

CONCLUSIONS

This experiment demonstrates that solid-state video recording for accident reconstruction is feasible both technically and economically. Current sensor and processor technology provide the ability to record the accident in detail, while the use of limited recording duration and immediate reuse of any image not deemed “accident-worthy” preserves user privacy in non-accident situations.

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