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Low Cost Image Transmission System*

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Image Transmission System (ITS)

- Low cost
- 40 seconds for first image
- 10 seconds for second image
- Power management permits battery operation

ABSTRACT

Throughout the Department of Energy (DOE) complex, sites protect themselves with intrusion detection systems. Some of these systems have sensors in remote areas. These sensors frequently alarm -- not because they have detected a terrorist skulking around the area, but because they have detected a horse, or a dog, or a bush moving in the breeze. Even though the local security force is 99% sure there is no real threat, they must assess each of these nuisance or false alarms. Generally, the procedure consists of dispatching an inspector to drive to the area and make an assessment. This is expensive in terms of manpower and the assessment

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is not timely. Often, by the time the inspector arrives, the cause of the alarm has vanished. A television camera placed to view the area protected by the sensor could be used to help in this assessment, but this requires the installation of high-quality cable, optical fiber, or a microwave link. Further, to be of use at the present time, the site must have had the foresight to have installed these facilities in the past and have them ready for use now. What is needed is a device to place between the television camera and a modem connecting to a low-bandwidth channel such as radio or a telephone line. This paper discusses the development of such a device: an Image Transmission System, or ITS.

THE CONCEPT

To sharpen the focus of this investigation, we sought a

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specific application. It was felt that this would help ensure that the design was grounded in reality and met at least one specific need. It was decided to design the device to meet the needs of the DOE's Nevada Test Site. Preliminary discussions with the site's personnel revealed two paramount requirements:

- 1) Low cost.
- 2) Solar charged battery operation.

The preceding drawing illustrates the concept. The box labeled ITS is our device. Connected to it is an intrusion sensor, (here, an automobile detector across the road), a television camera, a radio modem, and a solar-charged battery. The ITS by itself draws very little current (30 mA) from the battery. Further, the ITS controls the power to all the devices connected to it. When these devices are idle, power to them is turned off and is only turned on as the device is needed. Even the high-power elements within the ITS are so controlled. When standing by, the ITS does nothing but examine the state of the intrusion sensor. When the sensor alarms (closes its switch), the ITS turns on power to all its devices. It takes and digitizes two video snapshots of the scene. The snapshots are separated in time by one second. Then, using its modem, it reports that this station is in alarm and begins sending in the data for the first snapshot. This black and white image is at a resolution of 240 x 240 pixels at 5 bits per pixel. Presuming a modem capable of transmitting at 9.6 Kbits/second, the time required to send the first image is 40 seconds.

There certainly exists higher-cost (both in dollars and power) equipment capable of reducing this time, but we deliberately traded off this transmission time to save that higher cost. Certainly, when compared with the 30 minutes typically needed to dispatch an inspector, 40 seconds is a very short time.

While the first image is being transmitted, the ITS is comparing the two images and isolating those data needed to describe their difference. When transmission of the first snapshot is complete, the ITS decides which of two strategies for sending the second snapshot will take the least time:

- a) send the data describing the difference, or
- b) send the entire second snapshot in the same manner it sent the first.

At the review station, as the data for the first image are received, the scene is displayed using progressive resolution. As the observer watches the television monitor, the first scene evolves seemingly out of smoke. The perception is much like viewing a photographic positive print as it appears in developing solution. As more and more of the data are received, they are processed into the display to improve the

image's resolution. We found that the processing power of an 80386 PC operating at 16 MHz (slow by modern standards) was ample for this processing.

The display computer holds the first scene on the display until the second scene's data are all in place. It then switches between two snapshots at the same one-second interval that separated their capture. This makes it easy for the observer to quickly focus on the moving objects and greatly facilitates the assessment task.

The ITS was designed primarily as an image acquisition system, i.e., it takes in a video signal from the television camera and outputs data. However, all the hardware needed for it to operate in reverse is in place. With a different program, the ITS can operate as a battery-operated review station. It can accept data into it and output a video signal to a television monitor for viewing. Such a program has been written.

DESIGN LIMITATIONS

The present electronic schematic design has been rendered in a printed circuit version. A mechanical design for placing the device in a semi-rugged package has been completed. The design is only semi-rugged because cost is still considered such an important parameter in the ITS design. It uses commercial-grade components that are only guaranteed to operate in the temperature range of 0°C to 70°C. Also, a mechanical construction that would permit it to be thrown from a truck onto a cement surface would make it more expensive than we wished. We hope to offer to the user who is willing to take a modest amount of care with the device an opportunity to save a substantial amount of cost. It is hoped that this system may be provided for less than \$1200 (camera, modem, and solar charger excluded).

This tradeoff is a good match for the limitations inherent in most TV cameras which must contain internal heaters to operate below freezing temperatures. Providing the power for this heater is inconsistent with battery operation. Although the device still has an excellent chance of succeeding even below 0°C, its failure there must be forgiven.

OTHER APPLICATIONS

Our department at Sandia is presently working on a Laboratory Directed Research and Development (LDRD) project to demonstrate the application of image processing to transportation problems. We recognized that the ITS might be of use to law enforcement organizations for assessing traffic conditions at remote locations. We are engaged in

two projects for this demonstration: one with the New Mexico State Police in Espanola, NM, and the other with the Albuquerque Police Department. Both projects will begin using the ITS described above. They will employ dial-up telephone lines and allow the police to call the remote ITS and get snapshot pairs permitting verification and assessment of accident reports. However, both police branches have said that this capability has less utility to them than being able to have recorded a sequence of images that embrace an accident. Their primary concern is in placing blame for the accident. Who gets the ticket?

THEORY OF OPERATION

HARDWARE

The design of the ITS is based on a commercially available frame grabber. It is the CORTEX-PC manufactured by:

Imagination Corporation
P. O. Box 276
Beaverton, Or. 97075-0276
Phone: (503) 641-7408 or (800) 366-9131

This low-cost frame grabber was designed to operate in an IBM PC. It accepts RS170 television video signals from a camera. It can digitize this video into a single high-resolution image of 512 by 480 8-bit pixels or into four individual medium-resolution images of 256 by 243 8-bit pixels. It allows the computer to access this data through the bus connections at the base of the card. Any of these images may be viewed using the card's output RS170 television signal.

Our design is based on the 87C51 microprocessor. With this \$30 device, we emulate all the back-plane signals of the PC. The microprocessor back plane contains two 62-pin connectors. One is intended to accept the frame grabber card and the other may be used for another adapter. Perhaps an interior telephone modem such as the VIVA 14.4 could be placed here. Alternatively, an encryption card might be placed here for situations where digital line supervision is required.

The ITS can operate under two power supply situations and accommodates these situations with the change of jumpers on the back plane. If an AC power supply is available, it may be connected to a terminal block provided for this purpose. The ITS and any cards plugged into it can then draw power from the back plane. If this power supply does not have -5V available, the ITS can derive this at low-current demand (~20 mA) from the +5V supply and provide it to the bus. If only a 12V battery is available, it is connected to another terminal block. The ITS will produce +12V, +5V, and -5V for the back plane power from the

battery. It is capable of turning these voltages off and on as needed.

The ITS can control power to two external devices as well. The devices we have in mind are the modem and the television camera. We include MOS power transistors to provide high-side switching for these 12 volt / 2 Amp devices. Extra circuitry has been included to cover the case where battery voltage becomes too low. The microprocessor is then held in its RESET state. In this state, the power to all peripheral devices is turned off. This prevents the "deadly embrace" situation that can occur if any of these devices is left on. If left on, the device might divert all available power from the charger that should go to recharging the battery. The system would never recover.

Each ITS may be given an identification number from 1 through 15. This may be accomplished on the back plane using jumpers.

Communication to and from the ITS card may be accomplished by using the back plane signals to an internal modem. Alternatively, an external RS-232 device may communicate via a DB-25 connector.

Although not strictly required for routine operation, a RAM chip set may be inserted. This permits one to upload different programs from the review station without having to actually travel to the remote site and physically insert new program chips. These devices may be omitted for routine applications.

FIRMWARE

Three different programs have been written for the ITS. These programs reside in the microprocessor's on-board EPROM. The three programs provide for operation with three different modems:

- 1) External telephone model - Telebit T1000.
- 2) Internal telephone modem - VIVA 14.4.
- 3) Spread Spectrum Radio modem - Cylink Airlink64.

In the first two programs, the ITS waits for the review station to call. It then takes and transmits a pair of snapshots. In the third program, the ITS watches for an intrusion sensor's switch closure and then transmits an image pair via radio.

In all cases, the first of the two images is sent in a progressive resolution mode. In the first pass through the image, the data are sampled at every eighth position in every eighth row. The transmission of the first pass data takes about 0.6 seconds to complete and provides a blurry but recognizable image at the review station. One way to

present this low resolution image is shown in Figure 1.

Figure 1. Low resolution blocks

We were unhappy with this presentation of the low resolution data. We had hoped to provide what appeared to be a blurry image and exploit the wonderful image processing capability of the observer's brain. While the observer's *mind* might wish to accept the above presentation as blurry, his *brain* sees the sharp edges and has trouble reconciling this as a blurry image. Making use of the mostly idle computing capacity of the review station computer, we interpolate between the received data points to fill in the missing pixels. This interpolation is performed using previously computed look-up tables. This is done first vertically and then horizontally. The result for the first pass data is shown in Figure 2.

Figure 2. Image after .6 seconds.

The second pass samples between each of the columns of the first pass and doubles the image's resolution so that after 1.3 seconds, the image in Figure 3 is viewed.

Figure 3. Image after 1.3 seconds.

Each succeeding pass through the image extracts twice as much data as the preceding pass and permits doubling of the resolution as is shown in Figures 4 through 7. All these images are better viewed at arm's length.

Figure 4. Image after 2.5 seconds.

Figure 5. Image after 5.0 seconds.

If the assessment hinged upon deciding if there is a car in the intersection, the operator could at this point make a quite good guess.

Figure 6. Image after 10.0 seconds.

Figure 7. Image after 20 seconds.

Figure 8. Image after 40 seconds.

The now complete first image shown in Figure 8, is held on the monitor while the data describing the differences between the first and second snapshots are transmitted.

Figure 9. Second snapshot complete at 45 seconds.

For this image pair, the transmission of the second image shown in Figure 9., took only 5 seconds. While the pixels of the first image contain only 5 bits, the pixels that are different in the second image are rendered with 7 bits. The image in Figure 10. shows those pixels that were different in the two images.

Figure 10. The difference image.

Notice that objects in the difference image take roughly twice the pixels that the objects subtend. We also need to describe the background occluded by the moving objects in the first image.

CONCLUSION

We have presented the design of an image transmission system that trades off transmission speed for cost. Our design can certainly be out-performed by commercially available "Ferrari" systems. We hoped to provide our community with an option to buy a "Chevrolet" where that is appropriate.

DISCLAIMER

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