EECS 488: PROJECT **31 January 2018**

A Low Cost System for Video Surveillance:
Specification, Design, Implementation and Tradeoffs

Introduction

Recently several vendors have released electronic surveillance devices suitable for home and small business use. A typical home surveillance system includes an embedded processing device (could be a PC) as well as video/infrared sensors which observe on a regular basis close-by home areas for moving targets and then transfer their images to the system's embedded device. There are options for image storage and retrieval and possibly a web interface access to the owner. The purpose of this project is to work through the specification, design and implementation process of a surveillance system appropriate for a warehouse which may be similar to a typical one available today, with some notable differences.

Basic System

The warehouse considered has polygonic shape with a sketch of its surveillance system illustrated in Figure 1. You may want to consider an octagonally shaped area of medium overall size. There are eight sensory devices X_1 , ..., X_8 located on the eight side walls of the warehouse. The sensories can cover about 180 degrees angular area. In addition to optical video, the sensors also perform motion detection, infrared, and possibly acoustic sensing. We have assumed a simple polygonic geometry in Figure 1, however, a more complex wall geometry can easily be employed as long as corresponding sensories are attached on each wall side of the warehouse perimeter. Although sensors seem to be mounted in the "middle" of each wall, other configurations are quite possible.

The core component of the surveillance is the embedded processing device (inside the warehouse) which processes sensory data and, moreover, is connected through a Host computer and a Network Switch to the Internet. It is assumed that the owner is remote (could be inside) and not on the system console, however, he/she could be notified by a warning message. The device monitors the sensors X_1 , ..., X_8 periodically and processes their responses to identify external events. Depending on the severity of the event the device may dispatch a warning to the owner's attention.

The main parts of the device are shown in Figure 2. They consists of the Microcontroller Unit, the Sensory Interface, the DSP/Video processor, the Memory Unit, the Network Interface and the Storage Unit. The Microcontroller communicates with all the units of the system coordinating the sensory event activities. The DSP/Video process sensory signals and video images compressing them in storage. The Network interface provides Internet connectivity. The Microcontroller can be implemented in hardware (communicating state machines), in software (embedded code), or in combination of both. More likely, however, the DSP/Video processor possibly together with the

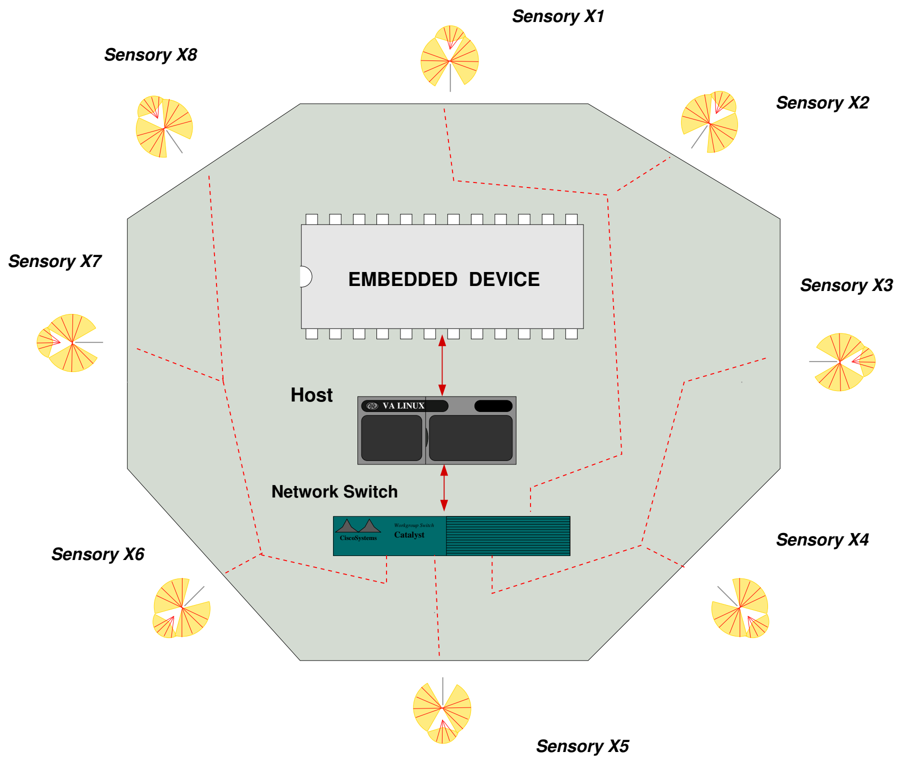

Figure 1: Surveillance System Overview

microcontroller would be implemented by one multicore processor.

In this project you will focus on the specification and design of the the three main units of the embedded device i.e. the DSP/Video unit, the Microcontroller and the Memory Unit. Note that the units in Fig. 2 do not imply an actual hardware/software partitioning, it is just a convenient functional block diagram.

Basic Operation

The main operation scenario of the surveillance system is to provide timely warehouse protection from a possible intruder target. Note there could be other possible protection scenarios. There are several types of events that need identification.
- Event 1 occurs when there is no motion sensed, no moving target outside.
- Event 2 corresponds to a ”passing by” target.
- Event 3 occurs when the target is approaching the warehouse.
- Event 4 corresponds to a ”suspicious” target that keeps on moving closer.

Infrared sensing may be used to distinguish between animal and human targets. More events may be used to further refine the monitoring process, for example, a target first moving close but then staying still, then leaving, and so on. The device decides on an event ID (1,2,3,4) based on sensory signals, that is, signals from the motion sensing, infrared and possibly acoustic. Depending on cost considerations, image analysis, although desirable, may or may not be feasible. Given an event ID, the device gets into a corresponding operation mode, i.e. modes 1,2,3,4. These modes are actually

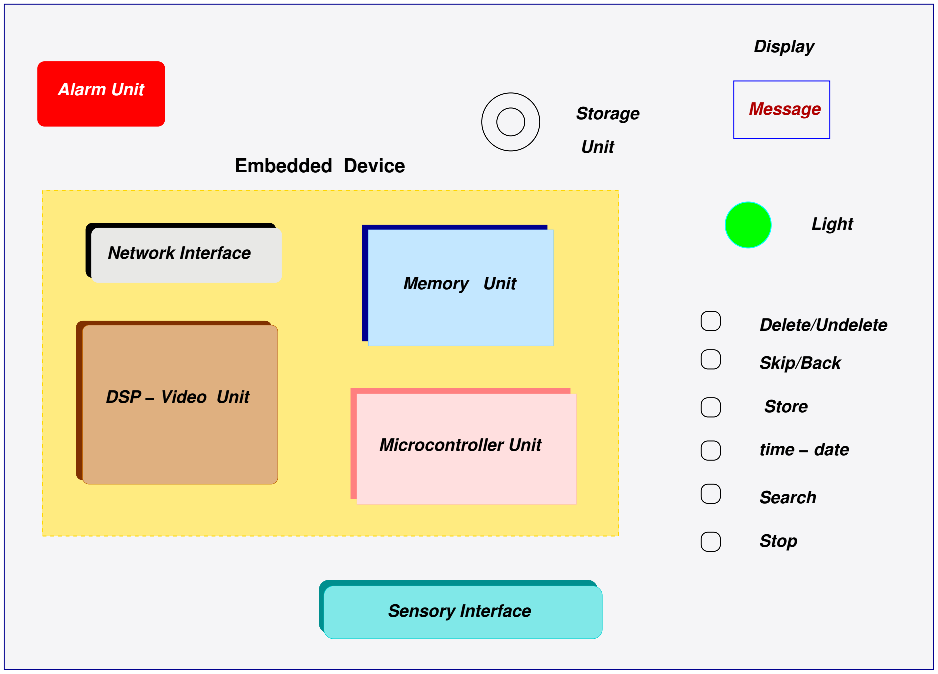

Figure 2: Device Functional Components

implemented by the Microcontroller unit of the device, Fig. 2.

- Mode 1. This is the normal device mode which is maintained as long as the device identifies event 1 while polling the sensories. The device waits few seconds observing a sensory event 1, and then moves to the next sensory.

- Mode 2. The device moves into this mode if event 2 occurs during a sensory observation. The device will wait in place, i.e. will not go to poll another sensor area, until it identifies an event change (e.g. to ensure whether event 2 transitions to event 1, and not to event 3).

- Mode 3. The device gets in this mode on identification of, or transition to, event 3.

- Mode 4. The device gets in this mode on identification of, or transition to, event 4.

The embedded device is adaptable taking variable quality pictures of the target area depending on the events. Thus to save storage, no pictures may be taken on event 1 (mode 1). Low resolution still pictures are taken on event 2 (mode 2). Higher resolution at faster data (frame) rate may be required on event 3 (mode 3). For example, the data rate in mode 2 may be 2 or 3 frames/second, whereas in mode 3 may be 6 or 7 frames/sec. Furthermore, event 4 (mode 4) may require taking movie clips of the target. All pictures and movie clips are compressed, by JPEG or MPEG, time-indexed, and stored in the device's storage.

Concurrently with the above modes, the embedded device performs other functions. It coordinates the sensory signal processing by the DSP unit, it organizes and indexes compressed images for storage, produces periodic report logs, and keeps track of the hardware units in Fig. 2. If after certain warning time there is no response from the owner, the device may trigger an alarm.

At any time, the device may be interrupted and get into a manual mode by the remote owner. This could be done using a web interface or another network protocol. This project will not consider authentication or security issues. However, the design of the device should accommodate manual intervention having at least the following capabilities.
- turning off the device or degrading some of its functions,
- retrieving and observing selected images,
- reading report logs,
- restarting the system.

Some of the above functions may be done while the device is in operation. It should be noted that retrieving images requires a decompressing (decoding) operation on each image using the same DSP/Video unit. There should be also certain manual buttons on the device including a console display, as shown in Fig. 2, that the business owner may want to use locally at the warehouse.

Basic Device Units

Shown in Fig. 2 are the basic units of the embedded device.

- Alarm Unit. It may sound an alarm under certain conditions.
- Network interface. A simple Ethernet device to connect to a local network. May be set by the host PC.
- Microcontroller. Could be a separate device built in hardware or in software using a typical embedded controller.
- DSP/Video unit. Should be capable of performing standard signal sensory processing algorithms within the timing constraints of the surveillance system. Moreover, it should be capable of fast compression and decompression of images at the required data rate.
- Memory Unit. It records incoming images. The memory is organized in memory blocks or "pages" for efficient storage utilization.
- Display. This flat LCD unit can display still or moving images coming through the Video Processing Unit. The display is needed for local operation.
- Sensory interface. This is a peripheral device with the capability of accommodating multiple I/O communications with the sensors. We assume fast serial data transfer over DMA channels.
- Storage. This could be a flash memory device or a low end disk.

There are also groups of sensors at the warehouse sides or corners performing video, motion and infrared sensing.

Requirements

It is suggested that this project be done in groups of 2 people. Each group will be responsible for the following minimal requirements. Requirements (a), (b), (c) and (d) will be done by all groups. The other requirements have implementation options which depend on your design choices. For example, as an option, the embedded device could be implemented using our the Raspberry Pi platform shown in Fig. 3. More details will become available from the Instructor and his Assistant later.

(a) Specification of your surveillance system functions, block diagrams and flowcharts. User defined constraints should be specified. Specification of the basic embedded device units and their signal communications. Incompleteness in given specs should be corrected.

(b) Marketing feasibility study regarding the whole system. The overall cost should be in the range \$1,000 to \$1,500 per system. However, you may come up with more realistic cost estimates, hopefully lower.

(c) Technical feasibility study regarding some key control device units especially the Memory unit. How big memory would you need to perform video compression in this system? What are the key timing requirements or constraints for some basic functions such as video compression/decompression? you only need rough estimates here to ensure feasibility within the expected cost.

(d) Modeling of the device units, functions and subfunctions. Use a C-modeling technique including basic simulations to validate the functionality.

The above requirements concern analysis, specification and design issues of the project. In consultation with the Instructor, each group will be responsible for implementation of their project on one of our Lab embedded device boards and peripheral sensors. We have the following device boards available: 1) Raspberry Pi Model 2 B; 2) Arduino board Mega; 3) TI-Beagle microcontroller board; 4) ARM mbed boards. However, the preferred platform for the project will be the Raspberry Pi which is Linux-based with several software tools installed such as gcc compilers, python libraries, and OpenCV. There are also several sensors, including cameras, available which are compatible with our boards. Other miscellaneous parts are also available in the Lab.

The following items should be also considered in your design:

(e) Tradeoffs of Hardware, Software, Memory components and units. This should be done based on cost estimation, establishing a realistic hardware/software cost basis.

(f) Power consumption tradeoffs. Estimate power in watts.

(g) Implementation of basic system units on one of our embedded device boards, using our Lab tools. Simulation of the implemented units and system validation.

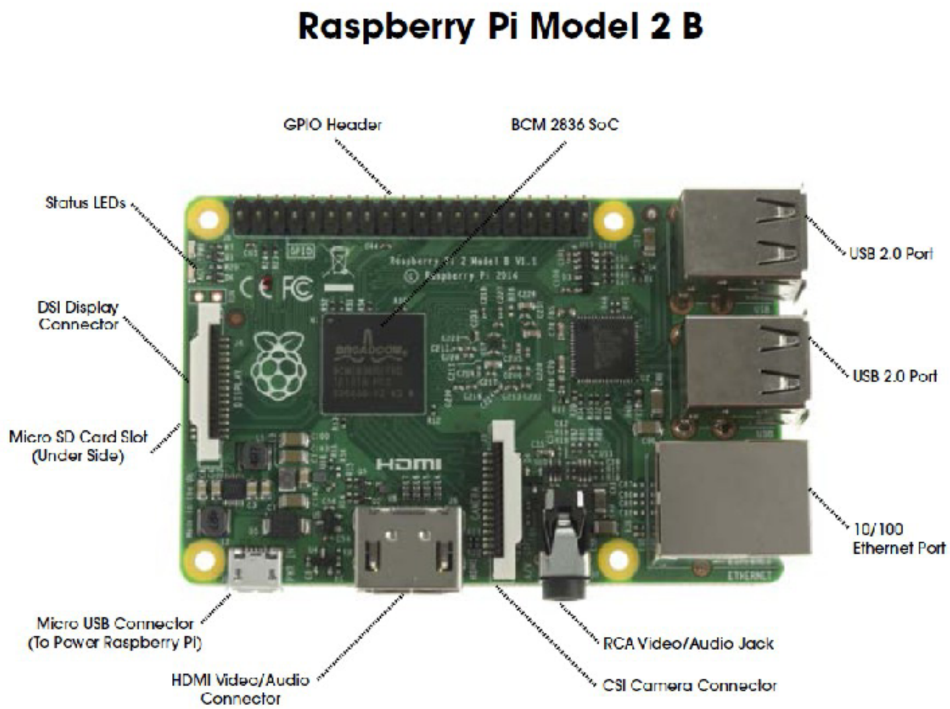

Figure 3: Example Implementation Platform: Raspberry Pi Model 2 B

Time Schedule and Evaluation

A design revision will take place in 2 weeks to make adjustments and choices.

You are required to submit:

1) Proposal by email, February 23, 2018.

2) Mid-term design report, due after the semester break, however, no later than March 22, 2018.

3) Final report of your design at the end of the semester, due by May 4, 2018.

The mid term report should be short 4 to 5 pages. The final report should be professionally written in standard technical format, but should be limited to about 20-25 pages, not including appendices.

Other evaluation elements:

4) A project review and evaluation will be conducted on a group basis after the term break.

5) A project presentation by each group is also required after the review sessions.

6) Project demos are also required on a group-basis in the Lab (Glennan 519E).

Due dates for the project reviews, presentations, and demos are expected to be:

- March 29 and April 5, 2018 – Reviews.
- April 12 and April 19, 2018 – Presentations.
- April 19 till May 4, 2018 – Demos (reviewed by the Instructor/TA).

These dates, group schedules and demos will be confirmed in March after the break.

Please submit PDF files for your project reports. You should also submit your presentation slides together with your final report. Finally, although project reviews and demos are to be conducted on a group basis, presentations should be attended by all.