ECEN 5803

Mastering Embedded Systems Architecture

University of Colorado **Boulder**

Architectural Trade-Offs in Selected Embedded Systems

Sensor Array Monitoring

How would you approach the design of the architecture?

What’s the first step to take?

Kim Fowler, “Some Observations on Architectural Trade-Offs in Selected Real-Time Systems“, in *What Every Engineer Should Know About Developing Real-Time Embedded Products*, Boca Raton, FL. CRC Press, 2012, pp. 393-412.

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Define Requirements

What are the expected outputs?

What are the expected inputs?

What are the use cases? Who are the customers?

What are applicable standards?

What is the budget?

When does this need to be available for the market?

How do we calculate system trade-offs?

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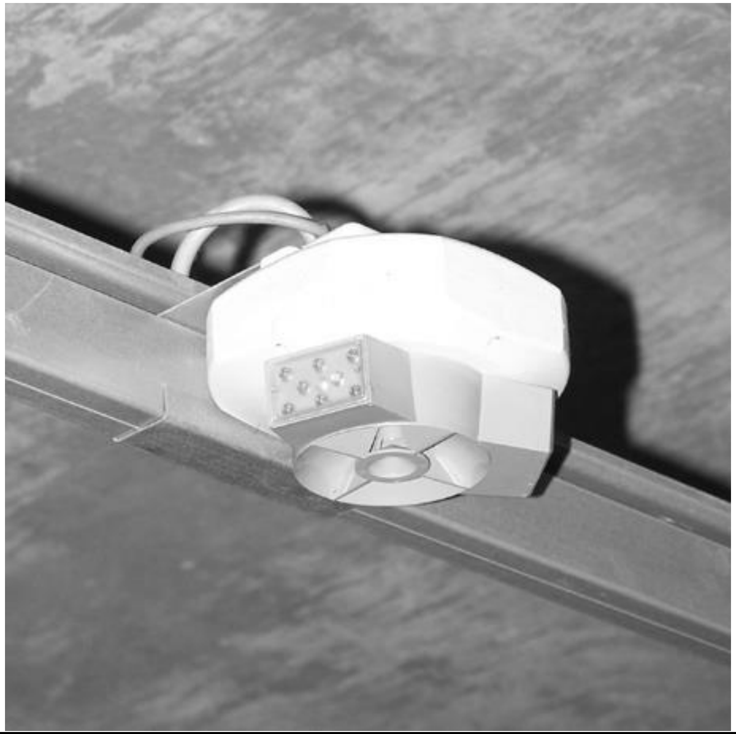

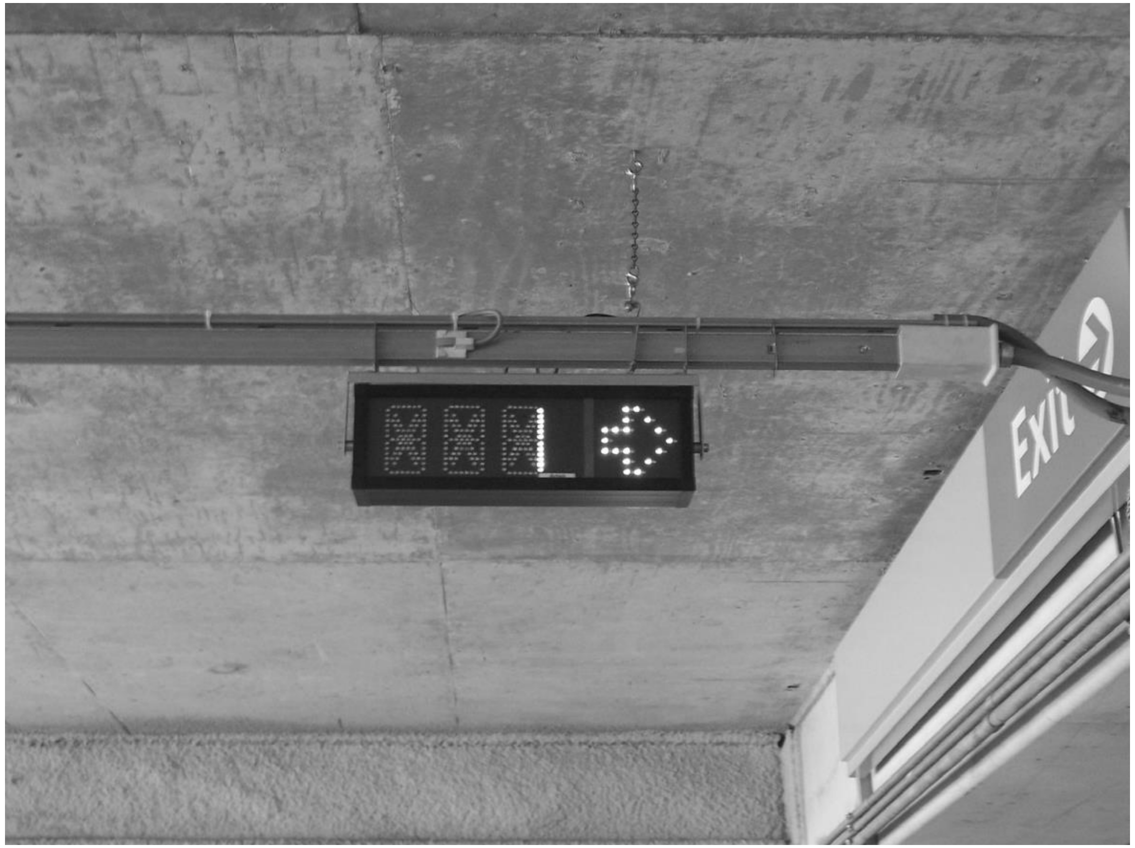

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How would you approach the design of the architecture?

What's the first step to take?

Define Requirements

What are the expected outputs? LED at each spot, display on each row

What are the expected inputs? 5000 ultrasonic sensors/garage

What are the use cases? Who are the customers? See next slide

What are applicable standards? UL for base station, FCC for all

What is the budget? Probably need to raise $2-3M

When does this need to be available for the market? Yesterday

How do we calculate system trade-offs? See next slide

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What are the use cases? Who are the customers?

Customers are parking garage operator/owners and secondarily car owners.

Worst case traffic: maximum potential holiday traffic volume of 2000 cars entering and leaving the parking garage every hour, then the average time between cars is (3600 sec/h)/(2000 cars/h) = 1.8 sec. This is considered soft real-time.

Car every 4 m, so cable length of 200m in a row of 50 cars.

How do we calculate system trade-offs? See next slide

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Sensor Array Monitoring

How do we calculate system trade-offs?

Installation cost may be more than component cost – minimize it.

Cable cost may be more than circuit board cost – use cheaper cable and more expensive electronics.

Cable cost is dependent on communication network chosen. Options:

1. 2 wire DC power + proprietary signaling. What common system do you know of that does this?
2. PoE, 4 or 6 wires – why is this not a good idea?
3. RS485 2 wire + 2 wire power – versus (1)
4. 1553 2 wire + 2 wire power – versus (1)
5. CAN or DeviceNet – 2 + 2 wires.
6. 4 wire signaling + 2 wire cable (Fowler)

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Partner Problems

PS = X, AL = Y.

Determine trade-offs for the parking lot sensor array. Assume there are 50 rows of 50 parking spaces each. How many sensors are there? How many base stations? How many row displays?

PS = Y, AL = X.

Where should the most design effort be placed to achieve lowest system cost?

Sensors or Displays or Base Stations? How should the sensors be connected together to minimize system cost? What networking standard should be employed and why?

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How do we calculate system trade-offs?

Network – why not wireless? Eliminate cost of cable! Zigbee or Bluetooth Mesh network without communication cable may be cheaper. Still need power cable though, so solution #1 may prevail. Is a Zigbee radio cheaper than a modem?

Power distribution – using DC @ 12 volts, calculated voltage drop across cable is 1.37 volts, so this should work. However, assumed 80m, if 200m then this will be more, but still enough to get 3.3v to electronics.

Hardware – MCU versus ASIC for 1 million a year sensor boards. MCU is \$0.50 and ASIC is \$3 at these volumes. MCU the choice here.

Software – Fowler thinks it is simple, but what about the networking protocol? Modbus may work.

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How do we calculate system trade-offs?

Packaging – should sensor units be replaceable or repairable? Replaceable makes more cost sense, so conformal coating is indicated.

Buy vs Build

1. Sensor boards

Table of costs indicates sensor board should be built at a CM, likely with ICT testing, but a custom design at these volumes.

2. Display – suggest build as well, but Daktronics makes these kind of displays in volume and it is unlikely the NRE would be made up. Buy.

3. Central control processor – a COTS SBC, Buy.

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Portable Data Acquisition System

For biological uses – we would now call this a wearable!

Sensor inputs, data stored output, perhaps USB or RF to transfer data.

Requirements include low power to extend battery time, mass data storage, ruggedness, GPS, moderate precision ADC and DACs.

Packaging – look ma, no wires!

Software probably requires an RTOS.

Build vs. Buy – tends to be very specific, so Build. No COTS solution available.

Manufacturing – Fowler suggests student labor – how do you feel about that? CM also possible, but best choice might be industrial design firm with offshore connections.

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Short-time Actuator System

Proximity fuse control –

Inputs: shell velocity, distance to target, azimuth, wind velocity, temperature (some via network)

Outputs: fuze timing adjustment transmitted over RF using NFC

Requirements: timing accuracy to 1 microsecond, 97 microseconds to acquire data and send commands. RTOS is required. Minimum 100 MHz processor, probably more like 400 MHz or more. Networking connection, probably Ethernet is required. Power is 24v battery or 120VAC.

Buy or Build

Shell processor and sensors – Build

Control processor - Buy

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