Embedded Systems and Ubiquitous Computing

Introduction

CSE 199

Fall 2017

What are Embedded Systems?

An embedded system is a computer system that:

- Performs specific functions related to its role
- Often serves as part of a larger whole
- May have a non-traditional user interface (or no interface at all)
- May interact with physical processes

Example Systems

- Microwave control panel
- Automobile instrument cluster [video ↗]
- Blu-ray player
- Thermostat

Ubiquitous Computing / “Internet of Things”

Many embedded systems can and do communicate.

- Within local systems
  - Automobiles
  - Hot shoe camera flash
- With remote systems
  - GPS units
  - Restaurant notification coasters
- With the global Internet
  - Nest
  - Echo
  - Smart TVs

Embedded Concerns

Embedded systems often have somewhat different concerns from other computing devices.

Software Lifecycle

A software lifecycle is the activities surrounding software from idea, through execution, to support and beyond.

Embedded system lifecycles are sometimes *very* long and may be almost entirely static after deployment.

Designing and supporting such software is entirely different from modern desktop or mobile applications!

Extreme Example: Voyager 2

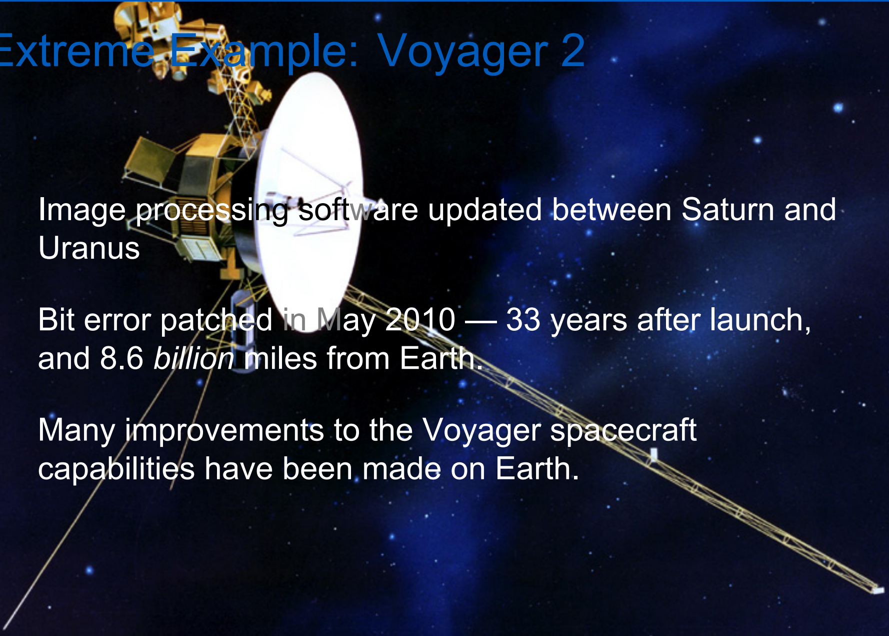


Image processing software updated between Saturn and Uranus

Bit error patched in May 2010 — 33 years after launch, and 8.6 *billion* miles from Earth.

Many improvements to the Voyager spacecraft capabilities have been made on Earth.

Example: Commercial Lifecycle

The LinkSys WRT54GL wireless access point / router

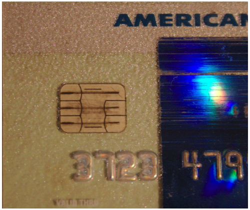
- Released in 2005
- Still sold today!
- Contains a sophisticated, Internet-connected software package

Power

Many embedded systems labor under severe power constraints.

- Available power may be limited
- Power may be lost frequently or without warning
- Some tasks may use vastly more power than others

Example: Power Management



Smart cards (like the "chip" in your credit card) have *no power source*.

They get their power through the contact connector.

The maximum power available to them is between 6 and 50 mA, and disappears when the card is pulled.

Computation

Computation resources on embedded systems may be minuscule.

- Hardened processors
- Power savings
- Legacy concerns

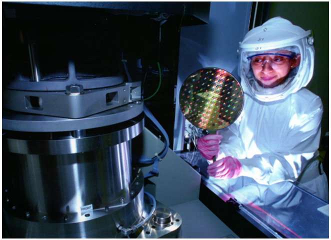


Photo by Randy Montoya

Sandia National Laboratories

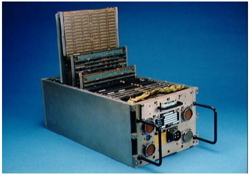
Example: Computation Power

The space shuttle computers were upgraded in 1990.

The upgraded computers had one MB of storage and ran at 1.2 MIPS.

(This is comparable to an early 1980s desktop computer.)

These computers served until discontinuance in 2011.



Connectivity

For many of the same reasons that power and computation may be constrained, connectivity may be limited for embedded systems.

- “Wi-Fi”
- Bluetooth / BLE
- Sensor networks
- ZigBee
- Z-Wave

Embedded Systems vs. General Computing

Embedded Systems are both like and unlike general computing platforms.

We've seen some differences, what about similarities?

Big Embedded Systems or Little Computers?

Where do smart phones, tablets, wearables, *etc.* fit?

- User interfaces are limited, but still expressive
- Software is easily changed and very modular
- Computation power nears that of personal computers
- Connectivity can be very good

Shared Concerns

Some concerns are often shared between embedded and general computing.

- HCI issues
- Communication protocols
- Security

Ubiquitous Computing

Ubiquitous computing is the realization of an environment where connected computing devices are *everywhere*.

It's been predicted for years, but it's finally (mostly) here.

Some say it will improve productivity and quality of life.

Some say it's an Orwellian nightmare of lost humanity.

The Time Is Now

Why now?

- Improvements in power storage density
- Reduction in joules per instruction
- Miniaturization of components
- Advances in radio technologies

Power Density Improvements

$\mathrm{LiFePO_4}$ Lithium-Iron-Phosphate chemistry was *first proposed* in 1996.

It has a power density (MJ/L) about *twice* NiMH.

Additional significant improvements have come in the past 10 years.

Computing Energy Improvements

Smaller transistors require less power for computation.

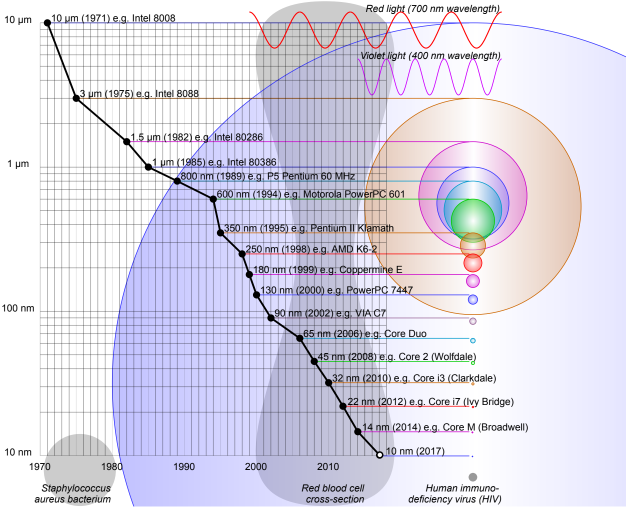
Faster transistors require less power for computation.

Some modern processors require *very* little power:

- Texas Instruments MSP430: $100\mu\mathrm{A}/\mathrm{MHz}$
- STMicroelectronics STM32L0: $0.49\mu\mathrm{A}/\mathrm{MHz}$

A CPU comparable to a mid-90s desktop computer *now requires less power than its power LED*.

Miniaturization



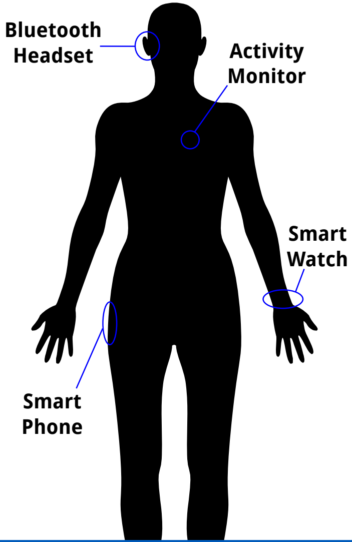
RF Advances

Advances in RF ICs and circuitry have paralleled computation.

Modern communication ICs are

- Lower power
- Higher bandwidth
- Smaller
- *Smarter*

How Connected Are *You*?



How many connected devices do you have right now?

How many are in your home / dorm / car?