Smart Health – CSE 40816

University of Notre Dame
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Smart Systems

- Internet of Things
- Embedded Systems
  - A computing system designed for a specific function and embedded as a part of a complete device
- Real-Time Systems
  - Functional and temporal correctness are equally important
- Cyber-Physical Systems
  - Focus on integration of physical and virtual world
- Ubiquitous/Pervasive Computing
  - Computer always present, but invisible
- (Wireless) Sensor Networks
  - Large collection of connected sensors
- RFID (Radio Frequency Identification)
- Virtual/Augmented Reality
- Smart Things/Objects, Web of Things
Embedded System/Computer

- “Any sort of device which includes a programmable computer but itself is not intended to be a general-purpose computer”
  — Wayne Wolf
- General purpose
- Dedicated

Automotive Embedded Systems

Adaptive cruise control systems detect if cars in front of you are too close and, if necessary, adjust the vehicle’s throttle, may apply brakes, and/or sound an alarm.

Advanced airbag systems have crash-severity sensors that determine the appropriate level to inflate the airbag, reducing the chance of injury in low-speed accidents.

Tire pressure monitoring systems send warning signals if tire pressure is insufficient.

Drive-by-wire systems sense pressure on the gas pedal and communicate electronically to the engine how much and how fast to accelerate.

Cars equipped with wireless communications capabilities, called telematics, include such features as navigation systems, remote diagnosis and alerts, and Internet access.
Automotive Embedded Systems

- Today’s high-end automobile may have 100+ microprocessors:
  - Seat belt; dashboard devices; engine control; ABS; automatic stability control; navigation system; infotainment system; collision avoidance system; tire pressure monitoring; lane warning; adaptive cruise control; climate control; airbag control unit; electric window and central locking; parking aid; automatic wiper control; alarm and immobilizer; power seat; electric power steering; electronic transmission; active suspension

Embedded Processor Market

- 80 million PCs every year
- 3 billion embedded CPUs every year
- Embedded systems market growing, while PC market mostly saturated
Ubiquitous Computing Concepts

• “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”, Mark Weiser 1991

Evolution of Pervasive Computing
Pervasive Computing

• During one of his talks, Weiser outlined a set of principles describing pervasive computing (also called ubiquitous computing):
  – The purpose of a computer is to help you do something else.
  – The best computer is a quiet, invisible servant.
  – The more you can do by intuition the smarter you are; the computer should extend your unconscious.
  – Technology should create calm.

• Calm technology
  – “A technology that informs but doesn’t demand our focus or attention”.
    (Designing Calm Technology, Weiser and John Seeley Brown)

Pervasive Computing

• One does not need to continually rationalize one's use of a pervasive computing system.

• Having learnt about its use sufficiently well, one ceases to be aware of it.

• It is "literally visible, effectively invisible" in the same way that a skilled carpenter engaged in his work might use a hammer without consciously planning each swing.

• Similarly, when you look at a street sign, you absorb its information without consciously performing the act of reading.
Internet-of-Things

How Does My Fridge Do That?

- You are leaving the home (sense user)
- There's no milk in fridge (sense object)
- Use this information to make a decision (process)
- Inform user of decision (communicate)
How Does My Fridge Do That?

• You are leaving the home (sense user)
  – What type of sensor?
  – Distinguish between parent and child
  – Identify reason for leaving home
  – Identify other contexts (e.g., store hours)
• There’s no milk in fridge (sense object)
• Use this information to make a decision (process)
• Inform user of decision (notify)

How Does My Fridge Do That?

• You are leaving the home (sense user)
• There’s no milk in fridge (sense object)
  – What type of sensor?
  – Is milk needed?
  – No milk or “little” milk? (prediction)
• Use this information to make a decision (process)
• Inform user of decision (notify)
How Does My Fridge Do That?

- You are leaving the home (sense user)
- There’s no milk in fridge (sense object)
- **Use this information to make a decision (process)**
  - Where is processor?
  - What are the rules?
  - Fixed rules versus dynamic rules (learning)
- Inform user of decision (notify)

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How Does My Fridge Do That?

- You are leaving the home (sense user)
- There’s no milk in fridge (sense object)
- Use this information to make a decision (process)
- **Inform user of decision (notify)**
  - How?
  - When?
  - Privacy?
  - Subtleness?
  - Information overflow?
Internet-of-Things (IoT)

Physical object (“thing”)
  + Controller (“brain”)
    + Sensors
    + Actuators
  + Networks (Internet)
Related Areas

- Machine-to-machine (M2M) communications
- Internet of Everything (Cisco Systems)
- “Skynet” (Terminator movie)

“Internet-of-Things”

- Term coined by British entrepreneur Kevin Ashton, while working at MIT Auto-ID Labs
- Referred to (and envisioning) a future global network of objects connected specifically by RFID (radio-frequency identification)
- Complete automation of data collection
- Article about IoT in 2004 from MIT; called “Internet 0”
Internet-of-Things Vision & Growth

THE INTERNET OF THINGS

Connected devices (billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cellular IoT</th>
<th>Non-cellular IoT</th>
<th>PC/laptop/tablet</th>
<th>Mobile phones</th>
<th>Fixed phones</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>0.4</td>
<td>4.2</td>
<td>1.7</td>
<td>7.1</td>
<td>1.3</td>
</tr>
<tr>
<td>2015</td>
<td>1.5</td>
<td>14.2</td>
<td>1.8</td>
<td>8.6</td>
<td>1.4</td>
</tr>
<tr>
<td>2020</td>
<td>20 billion</td>
<td>28 billion</td>
<td>16 billion</td>
<td>30 billion</td>
<td>5 billion</td>
</tr>
</tbody>
</table>

CAGR 2015-2021: Cellular IoT 27%, Non-cellular IoT 22%, PC/laptop/tablet 1%, Mobile phones 3%, Fixed phones 6%

Figure 1. The Internet of Things was "Born" between 2008 and 2009.

World Population

Connected Devices

- 2003: 0.08
- 2010: 1.84
- 2015: 3.47
- 2020: 6.58

Connected Devices Per Person

Source: Cisco VSO, April 2011
Internet-of-Things Vision & Growth

Snapshot: the rapid growth of the Internet of Things

- There are forecast to be 28 billion connected devices worldwide by 2021.
- Almost 16 billion of them will be IoT devices.
- IoT devices will overtake mobile phones as the largest category of connected devices in 2018.
- The number of IoT devices in Western Europe is projected to quadruple between 2015 and 2021.
- This will be driven by the spread of smart meters and connected cars, as well as by consumer devices.