Topic 1: Overview of Computer Organization and Systems Programming

CSE 30: Computer Organization and Systems Programming
Summer Session II 2011

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Information about the Instructor

• Dr. Ali Irturk
• Education:
  B.S., Diploma: Turkish Naval Academy
  M.S, M.A: UCSB
  Ph.D. : UCSD
• Currently a Research Scientist at CSE

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• Email is the best: airturk@cs.ucsd.edu
• Office: 2114 at CSE
• Office Hours:
  Or by appointment

Any Questions?
Information about the Class

• Goal of this class?

• Beware! This class is only 5 weeks, but we have a lot to learn. We have a total of 20 classes + 1 final.

The best way to learn is to practice,
WE WILL PRACTICE A LOT!

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<th>Monday</th>
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<th>Wednesday</th>
<th>Thursday</th>
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<td>Quiz (30 min)</td>
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<td>Quiz (30 min)</td>
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<td>No Quiz – Why?</td>
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Information about the Class

- How about the homeworks and labs?

- We will also solve sample quiz questions in the class.. (on Wednesdays last 30 min)

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<tr>
<td>1st</td>
<td>HW 0</td>
<td>Sample Questions</td>
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<td>HW 1</td>
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<td>Sample Questions</td>
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<td>HW 2 + LAB 1</td>
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<td>Sample Questions</td>
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<td>Sample Questions</td>
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<td>HW 4 + LAB 3</td>
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<td>Sample Questions</td>
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<td>No HW – Why?</td>
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Information about the Class

• GRADES:

  Class Participation: %5 (will take roll)
  CSE 30 Folder: %5 (will check)
  Problem Sets: %15
  Programming Assignments: %10
  3 Quizzes: %10
  Midterm Exam: %20
  Final Exam: %35
Course Logistics: On the Web

- Course web site URL
  http://www.cse.ucsd.edu/~airturk/cse30
- On-line material
  - lecture viewgraphs in PDF
  - copies of handouts, homeworks, project description, etc.
  - important announcements
- Online bulletin board
  - https://csemoodle.ucsd.edu/

I assume that you check these daily
Course Logistics: Textbooks

- ARM Assembly Language: Fundamentals and Techniques, William Hohl
- The C Programming Language, Kernighan and Ritchie, 2nd edition
- Essential C - Stanford CS Education Library (online)
Development Kit
Course Problems...Cheating

What is cheating?

- Studying together in groups is encouraged
- Turned-in work must be completely your own.
- Common examples of cheating: running out of time on an assignment and then pick up output, take homework from box and copy, person asks to borrow solution “just to take a look”, copying an exam question, …
- Both “giver” and “receiver” are equally culpable
- Cheating on PA and PS: negative points for that assignment (e.g., if it’s worth 10 pts, you get -10)
- Cheating on projects / exams; At least, negative points for that project / exam. In most cases, F in the course.
- Any instance of cheating will be referred to Academic Integrity Office
The Evolution of Computing

Revolution: Mechanical Calculation

2400 BC

Stepped Reckoner

17th Century

Pascaline

Schickard’s Machine

1804

Jacquard’s Loom

1822

Analytical Engine
The Evolution of Computing

Revolution: Ability to Scalar Many Digital Operations on the Same Material

ENIAC

WWII

1949

Integrated Circuit

1965

Moore’s Law

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REvolution: Computers/Person

Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2054. However, the needed technology will not be economically feasible for the average home. Also, the scientists readily admit that the computer will require new and invented technology to actually work. But in 50 years from now, scientific progress is expected to solve these problems. With a desktop interface and the European language, the computer will be easy to use.
Current State of Computing

- Computers are cheap, embedded everywhere
- Transition from how to we build computers to how to we use computers
Current State of Computing

- Computers are cheap, embedded everywhere.
- Transition from how we build computers to how we use computers.

eMerging Societal-Scale Systems

New System Architectures
New Enabled Applications
Diverse, Connected, Physical, Virtual, Fluid

Source: Alberto Sangiovanni-Vincentelli®

Source: UCSD
The Next REvolution

Biotechnology

Ecological Monitoring

Robotics

Financial Computation

“The use of [these embedded computers] throughout society could well dwarf previous milestones in the information revolution.”
Optical Mapping

Two Camera (Dual Wavelength) Setup

- Optical Bath Chamber
- 37°C
- 70 mmHg
- Objective Lens
- Condensing Lens
- Dichroic Mirror
- CMOS Camera
- Emission Filter 540 nm
- Condensing Lens
- Emission Filter 615 nm
- Excitation Light
- Dichroic Mirror

Flowchart:

1. Raw Camera Data
2. Temporal Fluorescence Normalization
3. Inversion
4. Spatial Phase Shift Filter
5. Temporal Median Filter
6. Filtered and Normalized Data
Optical Mapping

Raw Camera Data

Processed Camera Data
Cell Analysis

Problem: Fast, accurate method to analyze cell populations

Step 1: Determine location of cell nuclei
Cell Analysis

Problem: Fast, accurate method to analyze cell populations

Step 2: Determine amount of striation
The Next REvolution

Biotechnology

Financial Computation
Financial Computation

- Value at Risk

- Asset Allocation

- Option Pricing
The Next REvolution

Biotechnology

Ecological Monitoring

Financial Computation
Ecological Monitoring

- Quantify long-term trends in ecosystem attributes & drivers
- Understand processes that:
  - Modulate ecosystem function
  - Shape community structure & diversity
  - Determine population abundance & dynamics
- Forecast responses to climate forcing & acute disturbances
Existing Sensors

“Flipper Net”
Vision for Underwater Networking in Moorea
AquaNode

- Deploy ad hoc wireless underwater networks around island
- Transmit data to/from underwater sensors
- AquaNode requirements:
  - Low cost, low power wireless modems
  - Associated networking functionality
  - Plug and play interface with variety of sensors
  - Near real-time data and adaptive sampling
The Next REvolution

Biotechnology

Ecological Monitoring

Robotics

Financial Computation
Drifters

- Autonomous Underwater Explorers: Self organizing drifters
- Dynamic, spatiotemporal 3D sampling
- Track water motions or mimic migration behavior of organisms

- Buoyancy control can follow ocean surface
- Acoustic modem for 3D localization amongst drifters
- 25 cm diameter
- Under development by Curt Schurgers (ECE), Jules Jaffe, Peter Franks (SIO), Raymond de Callafon (MAE)
Stingray AUV
Underwater Object Detection

- Buoy erosion, dilation and centroid calculation

- Fish
  - Feature based detection possible but
  - Constantly in motion,
  - At different angles,
  - With many species.
  - Detection must be fast!

- Sonar+optics?
AUVSI UAS

- Mission: Use autonomous aircraft to survey a given section of land, and autonomously find and identify targets.
Hardware

- Electric Plane with 10ft wingspan.
  - Competition Weight ~ 40lb, 1 hour endurance
  - Gimbal, HD Video Camera, onboard Microprocessor

- Ground Station Computer
  - Quad Core AMD, Nvidia GTX 280 GPU, 8GB RAM
Image Processing Pipeline

HD Video Camera -> SD Transmitter -> Ground station -> Saliency (GPU) -> OCR (CPU) -> User Validation

Saliency (GPU):

OCR (CPU):

(b) A yellow G on a blue square
The Next REvolution

Biotechnology

Ecological Monitoring

Financial Computation

Robotics

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National Geographic Engineers for Exploration

Happening at UCSD now:

http://ngs.ucsd.edu/
Oktokopter
Aerial Image Stabilization
Sample
By: Michael Luong

Face Detection Activated:
- Searching Target Database...
  Target: Bear
- Searching Species Database...
  Species: Black Bear
- Search Successful

1
2
3
Safari Park: Future Deployment

Targets:
Critter Cams
The Next REvolution?

- Biotechnology
- Ecological Monitoring
- Financial Computation
- Robotics

？”

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Computing Systems

- Increasingly smaller
- Higher performance
- More memory
- Lower power
- Embedded
- Everywhere
- ...but extremely complex
How do we handle complexity?

- Coordination of many levels of abstraction

Diagram:

- Hardware:
  - Transistors
  - Circuit Design
  - Digital Design
  - Datapath & Control
  - Processor
  - Memory
  - I/O system
  - Operating System (Mac OSX)
  - Compiler
  - Assembler
  - Application (ex: browser)

Software:

- Instruction Set Architecture

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Levels of Representation

High Level Language Program (e.g., C)

Assembly Language Program (e.g., ARM)

Machine Language Program (ARM)

Compiler

Assembler

Machine Interpretation

Hardware Architecture Description (e.g., block diagrams)

Architecture Implementation

Logic Circuit Description (Circuit Schematic Diagrams)

temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;

ldr r0, [r2]
ldr r1, [r2, #4]
str r1, [r2]
str r0, [r2, #4]

0000 1001 1100 0110 1010 1111 0101 1000
1010 1111 0101 1000 0000 1001 1100 0110
1100 0110 1010 1111 0101 1000 0000 1001
0101 1000 0000 1001 1100 0110 1010 1111
Components of Computer

**Processor**
- Control ("brain")
- Datapath ("brawn")

**Memory**
(where programs, data live when running)

**Devices**
- Input
- Output

**Computer**

**Keyboard, Mouse**

**Disk**
(where programs, data live when not running)

**Display, Printer**
Overview of Physical Implementations

The hardware out of which we make systems.

- Integrated Circuits (ICs)
  - Combinational logic circuits, memory elements, analog interfaces.
- Printed Circuits (PC) boards
  - Substrate for ICs and interconnection, distribution of CLK, Vdd, and GND signals, heat dissipation.
- Power Supplies
  - Converts line AC voltage to regulated DC low voltage levels.
- Chassis (rack, card case, ...)
  - Holds boards, power supply, provides physical interface to user or other systems.
- Connectors and Cables.
Integrated Circuits (2009 State of the Art)

- Primarily Crystalline Silicon
- 1mm - 25mm on a side
- 2009 feature size ~ 45 nm = 45 x 10^{-9} m (red light has a wavelength of ~700nm)
- 500 - 2000M transistors
- 2 - 864 cores
- 3 - 10 conductive layers
- “CMOS” (complementary metal oxide semiconductor) - most common.

Package provides:
- spreading of chip-level signal paths to board-level
- heat dissipation.
- Ceramic or plastic with gold wires.

Bare Die

Chip in Package

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Dan Garcia®
Printed Circuit Boards

- Fiberglass or ceramic
- 1-20 conductive layers
- 1-20 in on a side
- IC packages are soldered down

Provides:
- Mechanical support
- Distribution of power and heat
In 1965, Gordon Moore predicted that the number of transistors per chip would double every 18 months (1.5 years).
Did Moore’s prediction hold?
Side effects of Moore’s Law

World-wide semiconductor revenues

Source: Intel/WSTS, 12/02
Side effects of Moore’s Law

Number of transistors shipped per year

Source: Dataquest/Intel, 12/02
Side effects of Moore’s Law

Average transistor price per year

Source: Dataquest/Intel12/02
Side effects of Moore’s Law
Side effects of Moore’s Law
Side effects of Moore’s Law

Moore didn’t get everything right

Actual size of wafer today - 300 mm diameter, approx. 12’

Moore’s prediction
Computer Technology – Dramatic Change!

- **Memory**
  - DRAM capacity: 2x / 2 years (since ‘96);
    64x size improvement in last decade.

- **Processor**
  - Speed 2x / 1.5 years (since ‘85);
    100X performance in last decade.

- **Disk**
  - Capacity: 2x / 1 year (since ‘97);
    250X size in last decade.
Computer Technology – Dramatic Change!

- State-of-the-art PC when you graduate: (at least…)
  - Processor clock speed: 16.0 GigaHertz
  - Memory capacity: 64.0 GigaBytes
  - Disk capacity: 8000 GigaBytes
  (8.0 TeraBytes)

- New units! Mega => Giga, Giga => Tera
  (Tera => Peta, Peta => Exa, Exa => Zetta
  Zetta => Yotta = 10^{24})


5 exabytes information of print generated in 2002!
CSE 30: So what's in it for me?

- Learning computing systems from a programmer's view
  - What the programmer writes
  - How it is converted to something the computer understands
  - How the computer interprets the program
  - What makes programs go slow
Learn big ideas in computer engineering
  - Principle of abstraction, used to build systems as layers
  - 5 Classic components of a Computer
  - Data can be anything (integers, floating point, characters): a program determines what it is
  - Stored program concept: instructions just data
  - Principle of Locality, exploited via a memory hierarchy (cache)
  - Greater performance by exploiting parallelism
  - Compilation v. interpretation thru system layers
CSE 30 can also help you

- Assembly Language Programming
  - This is a skill you will pick up as a side effect of understanding the Big Ideas

- Hardware design
  - Hardware at abstract level, with only a little bit of physical logic to give things perspective
  - 140 teaches this

- Understanding fundamentals of C
  - If you know one, you should be able to learn another “low” level programming language on your own
  - C constructs used in many other “higher” level programming languages
CSE 30 Does Not Teach

- A specific assembler language in detail
  - x486 Instruction set
  - ARM instruction set
  - MIPS instruction set

- Because technologies change so dramatically
  - Learning the concepts is more important than learning the language
  - Learning abstract ideas is more important than learning the specific features
Summary

- Continued rapid improvement in computing
  - 2X every 2.0 years in memory size;
  - every 1.5 years in processor speed;
  - every 1.0 year in disk capacity;
- Moore’s Law enables processor
  (2X transistors/chip ~1.5 yrs)
- 5 classic components of all computers
  Control  Datapath  Memory  Input  Output