



UC Berkeley
Teaching Professor
Dan Garcia

CS61C

Great Ideas
in
Computer Architecture
(a.k.a. Machine Structures)



UC Berkeley
Teaching Professor
Lisa Yan

Summary & Farewell

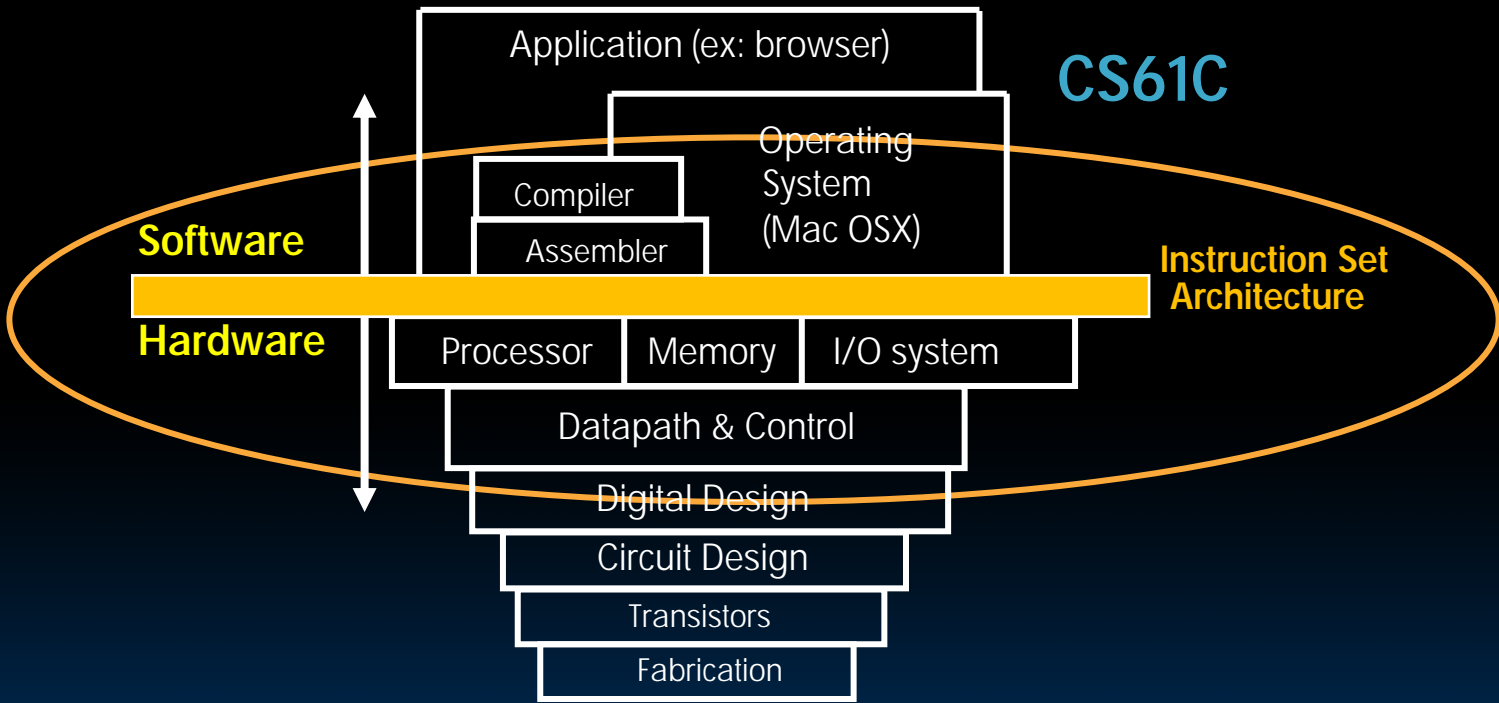


6 Great Ideas in Computer Architecture

1. **Abstraction (Layers of Representation/Interpretation)**
2. **Moore's Law**
3. **Principle of Locality/Memory Hierarchy**
4. **Parallelism**
5. **Performance Measurement & Improvement**
6. **Dependability via Redundancy**



We learned Old School “Machine Structures”



New-School Machine Structures (It's a bit more complicated!)

Software

Parallel Requests

Assigned to computer
e.g., Search "Cats"

Parallel Threads

Assigned to core e.g., Lookup, Ads

Parallel Instructions

>1 instruction @ one time
e.g., 5 pipelined instructions

Parallel Data

>1 data item @ one time
e.g., Add of 4 pairs of words

Hardware descriptions

All gates work in parallel at same time

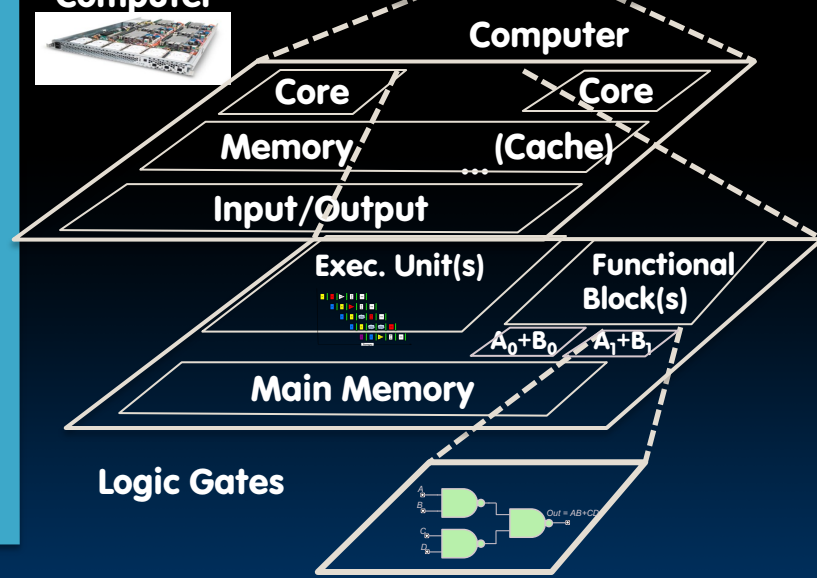
**Harness
Parallelism &
Achieve High
Performance**

Hardware

Warehouse
Scale
Computer



Smart
Phone



We made HW/SW Contact!

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

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

Compiler
Assembly Language
Program (e.g., RISC-V)

```
lw    x3, 0(x10)
lw    x4, 4(x10)
sw    x4, 0(x10)
sw    x3, 4(x10)
```

Anything can be represented
as a number,
i.e., data or instructions

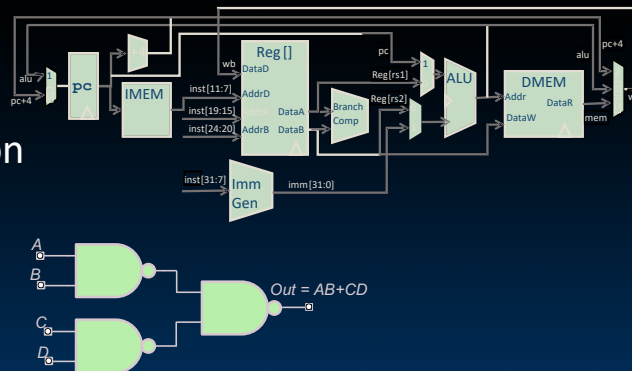
Assembler
Machine Language
Program (RISC-V)

```
1000 1101 1110 0010 0000 0000 0000 0000
1000 1110 0001 0000 0000 0000 0000 0100
1010 1110 0001 0010 0000 0000 0000 0000
1010 1101 1110 0010 0000 0000 0000 0100
```

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

Architecture Implementation

Logic Circuit Description
(Circuit Schematic Diagrams)





Upcoming Calendar

Week #	Mon	Tue	Wed	Thu	Fri
#15 Last week o' classes					Today Summary
#16 RRR Week					
#17 Finals Week	Final Exam 8-11am				

Administrivia: Become active!

- Final Exam details
 - ALL Material since Midterm, anything since strike “lighter touch”
 - 3 Hours (but we’re aiming it to take << 3 hours)
 - 2 handwritten double-sided sheets of paper allowed, we give “ref sheet”

- If you did well in CS10 or 61[ABC] (B or above) and want to be on staff?
 - Usual path: AI (Academic Intern) → Tutor/Reader → TA
 - Reader/TA/AI forms: <https://eecs.berkeley.edu/resources/gsis/prospective>
 - I strongly encourage anyone who gets an B or above in the class to follow this path...



Taking advantage of Cal Opportunities

"The Godfather answers all of life's questions"

– Heard in "You've got Mail"

- Why are we one of the top Univ in the WORLD?
 - Research, research, research!
 - Whether you want to go to grad school or industry, you need someone to vouch for you!
 - ...as is the case with the Mob
- Techniques
 - Find out what you like, do lots of web research (read published papers), hit OH of Prof, be a go-getter!
- <http://research.berkeley.edu/>
- <http://researchmatch.heroku.com/>



Research Opportunities in Systems

(From Dave Patterson)

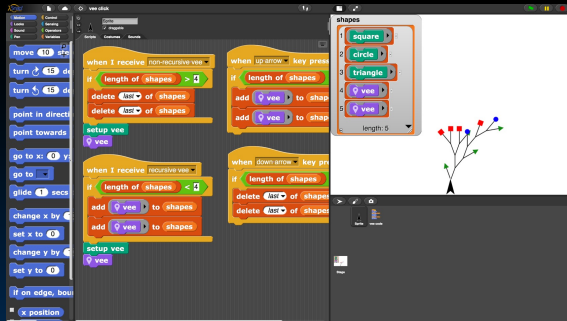
- **General-purpose applications:**
 - Make Python run like C with compiler + HW
 - Deja vu: make HLLs fast on RISC
- **Domain-specific applications (bigger opportunity?)**
 - What are the right DSLs for important applications?
 - Co-design of new DSLs and DSAs
 - Advanced compilation techniques for optimizing the matching:
 - New territory: not extraction of high level structure from C/Fortran but matching/optimization ●



Dan's Research and Development Projects

■ CS Education

- Improve CS10/Snap!
- "A's for All" software
- If interested, send email
`<ddgarcia@berkeley.edu>`



■ Computational Game Theory

- If interested, take my CS199 class
- LOTS of opportunities for CS61C material (parallel solvers, etc.)!
- If interested, just show up
11-noon 606 Soda MWF!





Lisa's Research and Development

- Her current research interests are
 - applications of machine learning and data analysis techniques to student programming assignments in large computer science courses



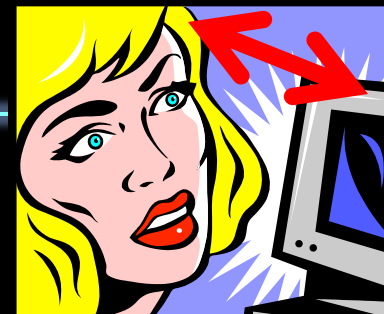
Opportunities Next Semester

- **CS152** (Computer Architecture and Engineering)
 - If you liked CPU design, this is a great follow-on course!
- **CS162** (OS and System Programming)
 - If you liked the rest, this is a great follow-on course!
- **GamesCrafters CS198 DeCal** (Game Theory R & D)
 - Develop SW, analysis on 2-person games of no chance. (e.g., go, chess, connect-4, nim, etc.) **Taught by Dan!!**
 - Req: Game Theory / SW Interest / MWF 11-noon free
- **iOS Dev CS198 DeCal** (Mac Student Developers)
 - Learn to program Macintoshes.
 - Req: Interest. Owning a mac helps, not required.
- **UCBUGG CS198 DeCal** (Recreational Graphics)
 - Develop computer-generated images, animations.
 - Req: 3D interest

Opportunities Next Semester

- **EE16A, EE16B** (lower-div EE courses)
 - Fundamentals of signal processing, learning, control, and circuit design while introducing key linear-algebraic concepts motivated by application contexts.
- **EE12X** (signals, systems, comm, networks and optimization)
 - If you like making the computer solve interesting problems and make things work!
- **EE105, 14X series** (Circuits)
 - If you like to know what's below the gates
- **EE13X** (Devices)
 - ...To know how to make IC and devices for computing
- **EECS151** – Intro to Digital Systems and Circuits
 - EECS151LA – ASIC lab, EECS151LB – FPGA lab
 - Build RISC-V processors, peripherals, run on an FPGA or create chip layout

Peer Instruction Opinion



- “Forget cloning. Forget TVs on your wrist watch. The biggest invention of the next 100 years will be the ability to directly connect your brain to a machine, aka wet computing.” – Dan Garcia
 - A macaque monkey at Duke University can already control a robotic arm with thought.
 - DARPA interested for mind-control robots & flying
 - Virtual Reality achieved with proper I/O interfacing...



Jose Carmena, UCB EECS Prof
 Research: Brain-Machine Interface
www.eecs.berkeley.edu/~carmena/



Penultimate slides: Thanks to the Staff!



Penultimate slides: Standing on the shoulder of giants

Also, thanks to all the former CS61C instructors who have added to these lectures & resources...



The Future for Future Cal Alumni

- **What's The Future?**
- **New Millennium**
 - Ubiquitous & Quantum Computing, Nanotechnology, The Internet of Things, AI, the Parallel revolution...
 - Rapid Changes in Technology, Post-PC Era!
 - World's Best Education
 - Never Give Up!

**"The best way to predict the future...
is to invent it" – Alan Kay**

The Future is up to you!