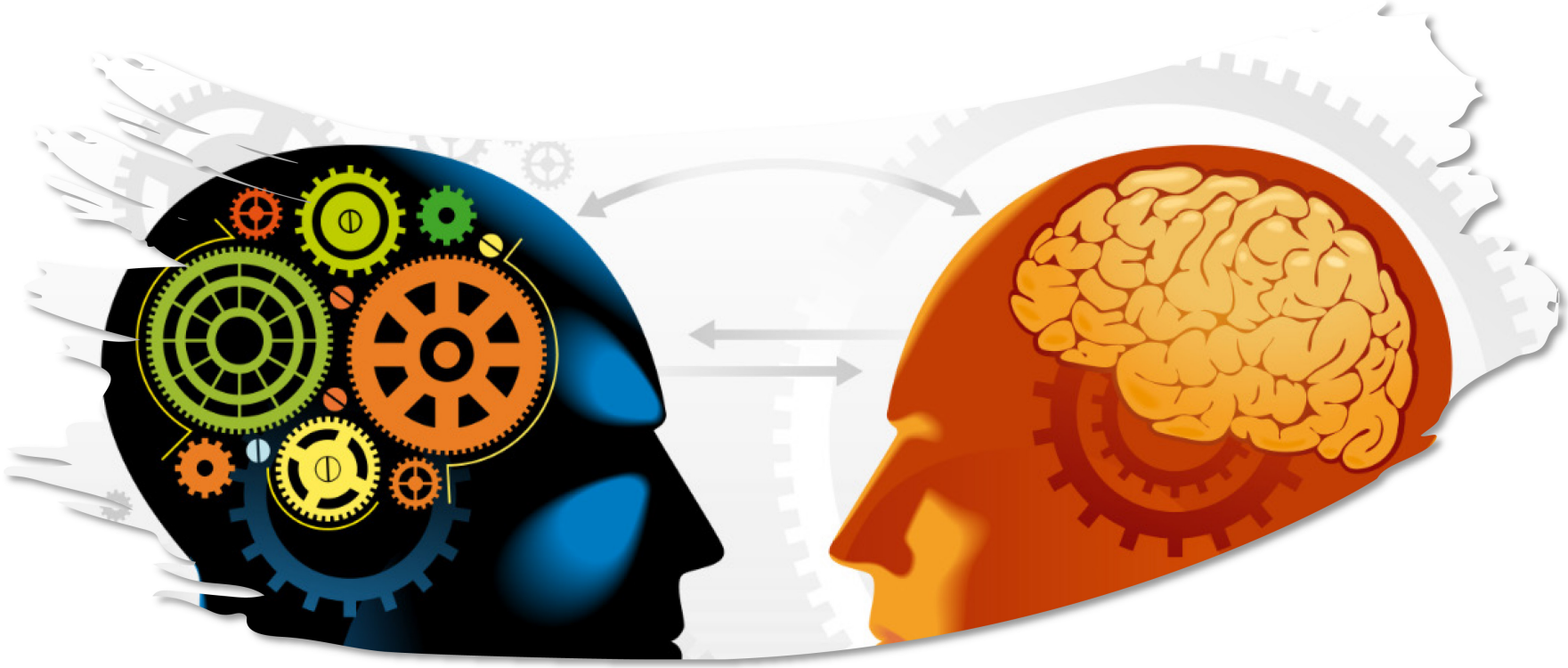

Building the Infinite Brain

COMP 590/790

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of NORTH CAROLINA
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Quick Review

Signup on Piazza

What are BCIs?

Broadly, systems that read, process, and modulate neural activity in the brain

Types of BCIs

Many, both invasive/implanted and wearable

What are BCIs used for?

Understanding brain function, treat dysfunction, restore lost function, and augment cognition

Intimately tied to an individual's identity

What are the computational challenges in designing BCIs?

Growing sensor data needs to be processed on the device

Computers today are limited in achieving both efficiency and flexibility, under safety constraints

1-page write-up due in class on 8/27

More on The Project

Working project

Examples

- An FPGA/microcontroller implementation of FFT and analysis of power and performance
- Software to improve/maintain a BCI tool or other software
  - BRAND: https://github.com/brandbci/brand
  - Foresee: https://github.com/bci-foresee/foresee
- Verification (or Correctness) specification and analysis of a BCI hardware or software kernel
- An EEG BCI game of Pong
- An analysis of algorithms used for seizure detection and their suitability for on-device execution
- A compiler to translate a BCI application to fit microcontrollers
- Python to Verilog translation for DWT in BCI processor design
- Extension of a BCI processing architecture
- Evaluation of a machine learning algorithm for speech decoding and suggested re-design for on-device execution
- Leveraging neuroscientific markers for efficient movement intent decoding on device
- An analysis of cursor movement methods identifying key computational techniques and bottlenecks

…

You should argue for why your design (hardware, software) is good

You can search online for inspiration, but do not use someone else's code or work—recall the honor code

Suggestions

Take notes

No need to repeat what's in the slides, but note connections, insights

Write down ideas and follow-ups

Even if you don't plan to revisit them (for now)

When reading, go down (good) rabbit holes

Trails of papers—builds background knowledge, but don't lose sight of the overall goal: Tree traversal!

Learn to refine your thoughts into formal and precise summaries, ideas

Even if you don't plan to revisit them (for now)

"Writing is nature's way of letting you know how sloppy your thinking is. Math is nature's way of letting you know how sloppy your writing is." Leslie Lamport

For Today

- Quick review
- **Introductions**
- **What is computer architecture?**
- **How are computer architectures analyzed and compared?**

Introductions!

Name

Grad/undergrad

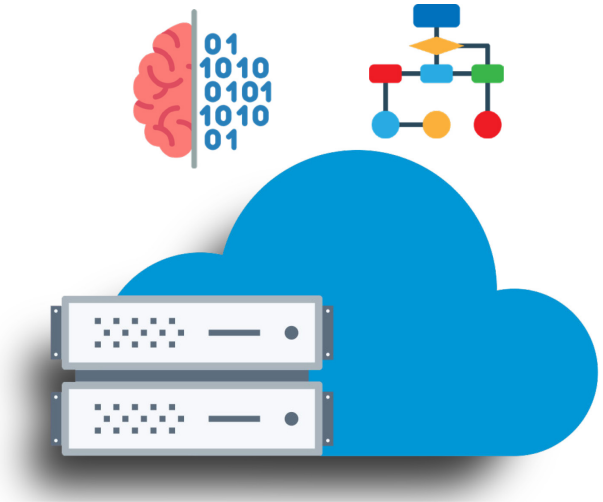
Focus area

Why are you taking the course?

Example Application

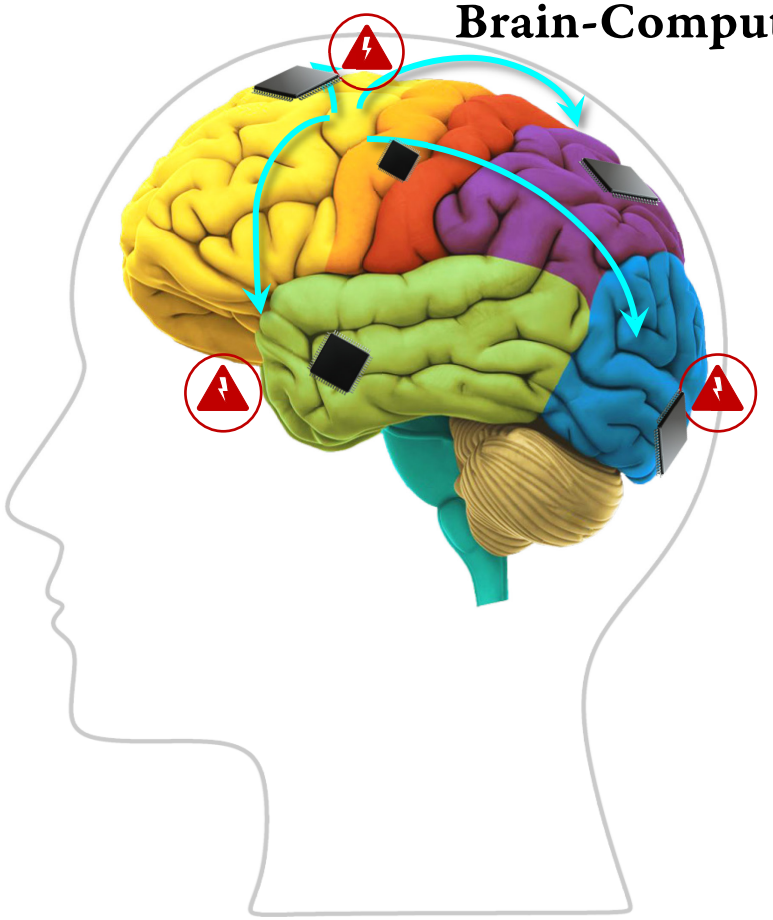
Restoring function

Computational cognitive frameworks



Mitigating seizures

Brain-Computer Interfaces (BCIs)



BCI Computing is a Full Stack Problem

Algorithm

Program description

Binary instructions

Program output

Programmer

Compiler

OS/Runtime

Processor

Programming languages and frameworks

+Linker

Assembly language

Intermediate representation

+Loader

OS/Runtime interface

Devices

Circuits

Gates

Register transfer level blocks

Microarchitectural components

Instruction set architecture

Processor | **Memory**

Focus of this course—in the context of BCIs

Don't be misled—most crucial determiner of overall efficiency and flexibility

Recall co-design!

What is Computer Architecture?

Previously, it meant the ISA

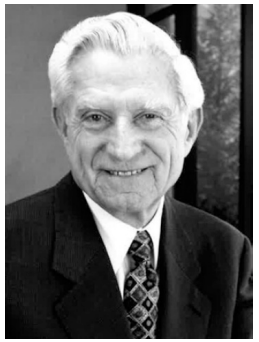
Most are register based (operands and results in registers), other variants include stack, accumulator

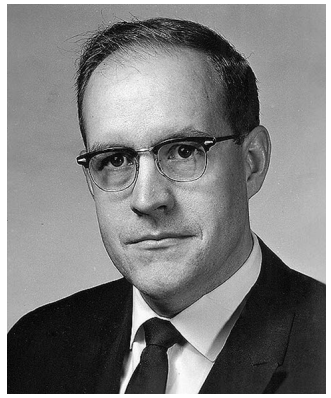
Now, it could mean everything between the OS and circuit design!

Distinctions are made based on the context

What we discuss is also called computer organization


Gerrit A. Blauuw


Gene Amdahl


Fred Brooks Jr

> "The term architecture is used here to describe the attributes of a system as seen by the programmer, i.e., the conceptual structure and functional behavior, as distinct from the organization of the data flow and controls, the logical design, and the physical implementation."

Architecture of the IBM System/360, Apr 1964

Goals of A Computer Architect

Reading task: "Hints and Principles for Computer System Design (2021)"
https://arxiv.org/abs/2011.02455

STEADY by AID with ART

Butler Lampson, *Pioneer in computer system design*

Applicable for BCI computers too!

Simple	**Timely**	**Efficient**	**Adaptable**	**Dependable**	**Yummy**	Goals
Is it clean?	Is it ready?	Is it fast?	Can it evolve?	Does it work?	Will it sell?	

Approximate	**Incremental**	**Divide and conquer**	Techniques
Speculate, compress…	Independent, iterate…	Abstractions, concurrent…	

Architecture	**Automate**	**Review**	**Techniques**	**Test**	Process

What? **Goals** STEADY —Simple, Timely, Efficient, Adaptable, Dependable, Yummy

How? **Techniques** by AID —Approximate, Incremental, Divide & Conquer

When, who? **Process** with ART —Architecture, Automate, Review, Techniques, Test

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- Thought clouds: F. Willett et al./*Nature* 2021/Erika Woodrum, https://med.stanford.edu/neurosurgery/news/2022/bci-award. https://www.the-scientist.com/news-opinion/brain-computer-interface-user-types-90-characters-per-minute-with-mind-68762
- Picture of scientists: https://www.cs.auckland.ac.nz/~brian/rutherford8.html (original: Pierre de Latil), Bush (Carnegie Science), Others (Wikipedia)
- Flowchart: Pause08 – flaticon.com
- Digital brain: Smashicons – flaticon.com
- Server rack: upklyak – freepik.com
- Quantum processor icons created by Paul J. - Flaticon
- Arm, Lotus: Adobe stock
- Quantum processor: Rigetti computing
- Images of implanted users: Top: Case Western Reserve University (https://thedaily.case.edu/man-quadriplegia-employs-injury-bridging-technologies-move-just-thinking/), Bottom: Jan Scheuermann (University of Pittsburgh/UPMC; https://www.upmc.com/media/news/bci-press-release-chocolate)
- Images of wearable BCIs: Cognixion, NextMind
- Types of BCIs: "Brain–computer interfaces for communication and rehabilitation,
- Illustrative BCI: Neuralink
- Electrodes: "Electrochemical and electrophysiological considerations for clinical high channel count neural interfaces", Vatsyayan et al.
- Form factors: Neuropace, Medtronic, Bloomberg, "Fully Implanted Brain–Computer Interface in a Locked-In Patient with ALS" by Vansteensel et al., Blackrock Neurotech
- Jose Delgado's video: Online, various sources (CNN, Youtube)
- Video of Kennedy and Ramsey: Online, various sources (Youtube, Neural signals)