Introduction to Scientific Computing

Physics 129AL

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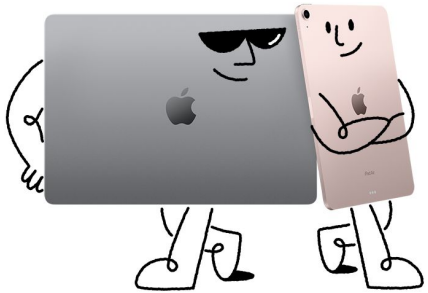
What is happening in a modern computer?

Modern computers have various forms, but they all have similar architectures.

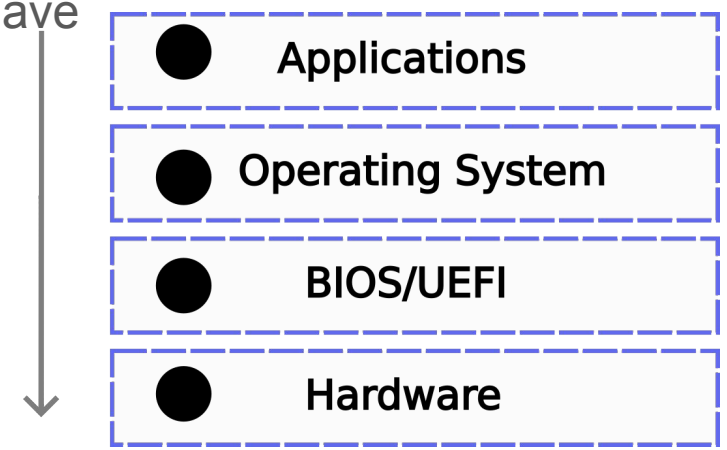
A Supercomputer (HEP)

https://cs.lbl.gov/news-media/news/2021/berkeley-lab-deploys-next-generation-supercomputer-perlmutter-bolstering-u-s-scientific-research/



A Laptop

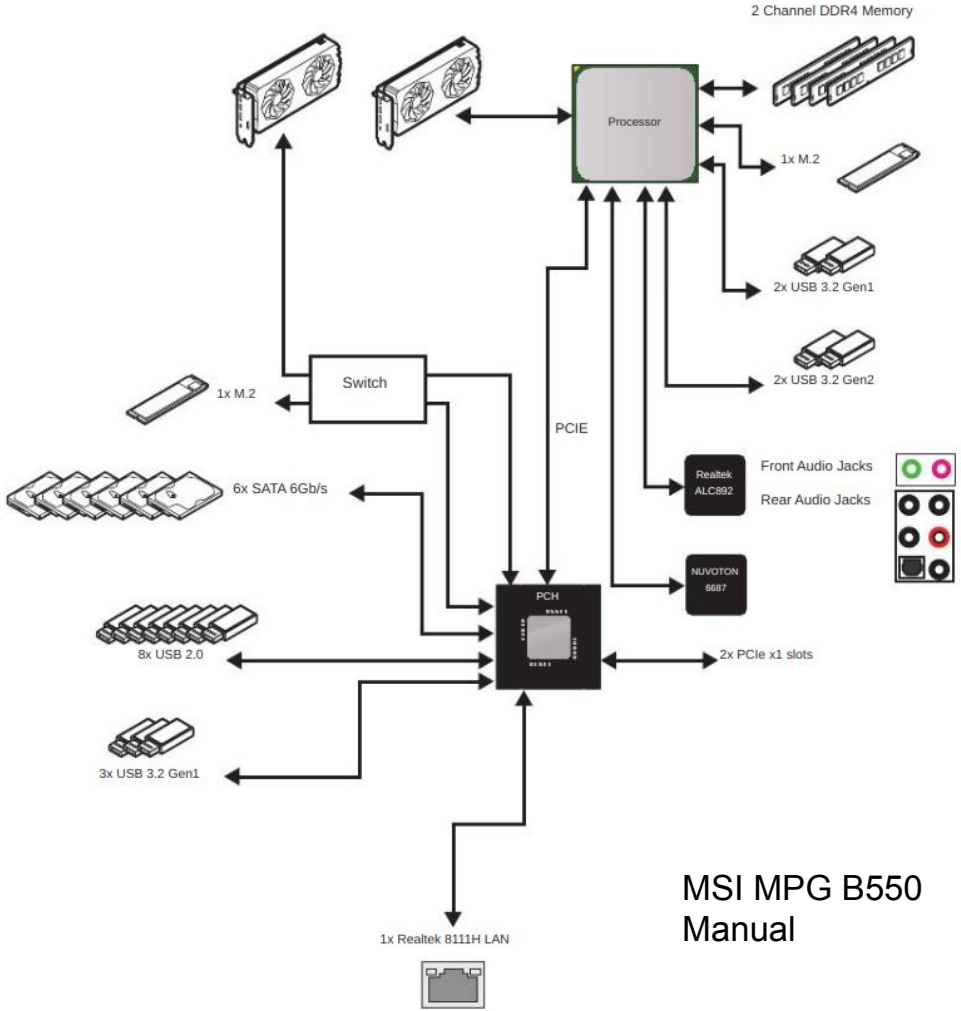
https://www.apple.com/us-edu/shop/back-to-school



Hardware

A modern computer requires few essential components: CPU, Memory, Storage, (GPU), and a Motherboard.

As an example, let's look at a typical gaming computer assembly.

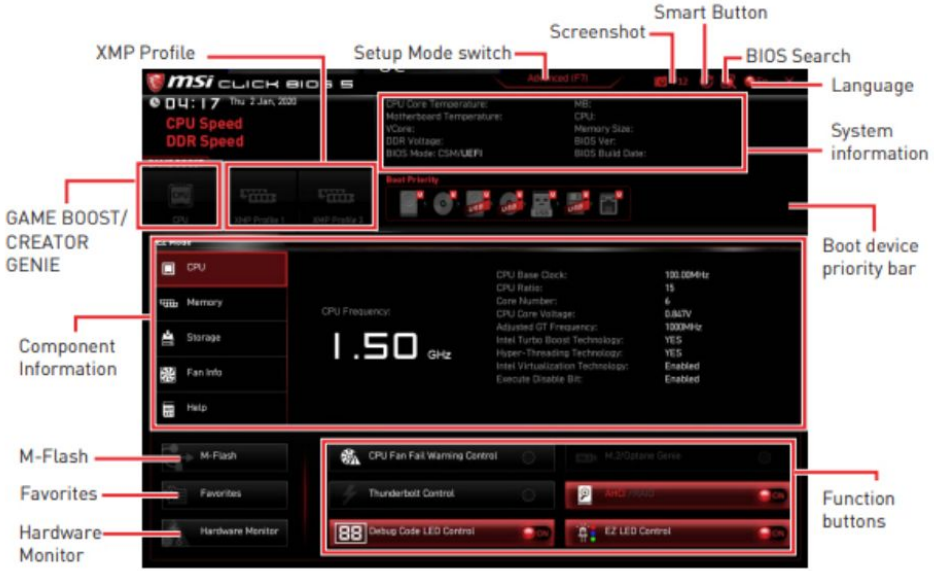


MSI MPG B550 Manual

BIOS/UEFI

Basic Input/Output System (BIOS) or Unified Extensible Firmware Interface (UEFI) is one example of a firmware that perform low-level control of a hardware, such as booting and interacting with operating system.

The firmware is read-only memory (ROM) and usually stored in a motherboard. For example, the MSI BIOS interface.



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Operating system, UNIX

UNIX was developed in Bell labs (AT&T) in 1969, it is the first attempt for creating a platform for researchers to develop then use on other systems, referring as the Unix philosophy, e.g. make it easy to read and write, make programs work together, choose portability over efficiency. Various OS systems are developed based on the UNIX,

GNU

1983, Richard Stallman

Linux

1991, Linus Torvalds

OS X

MacOS

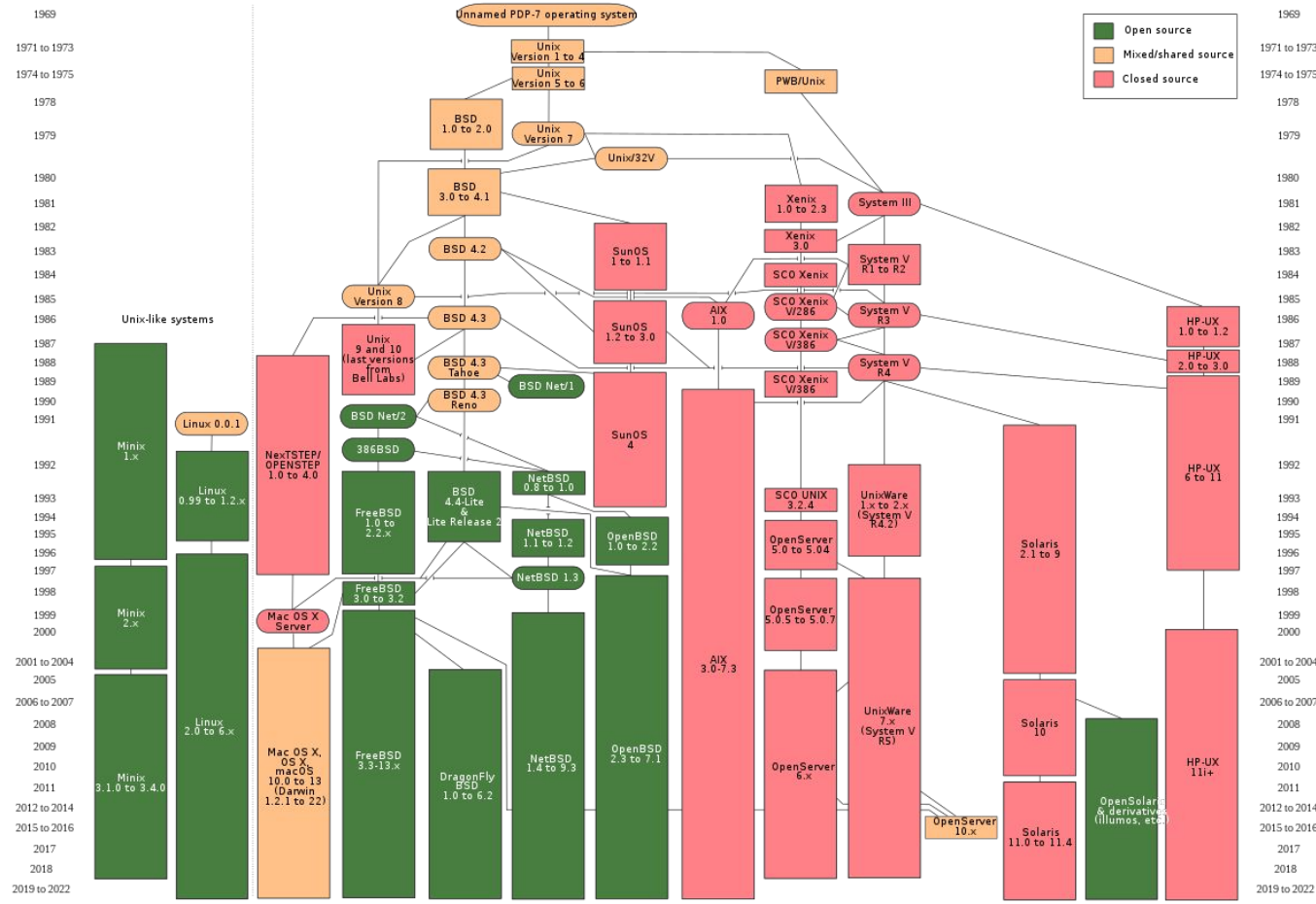
2001

Not this one. At least not directly.

Microsoft Windows

History of UNIX

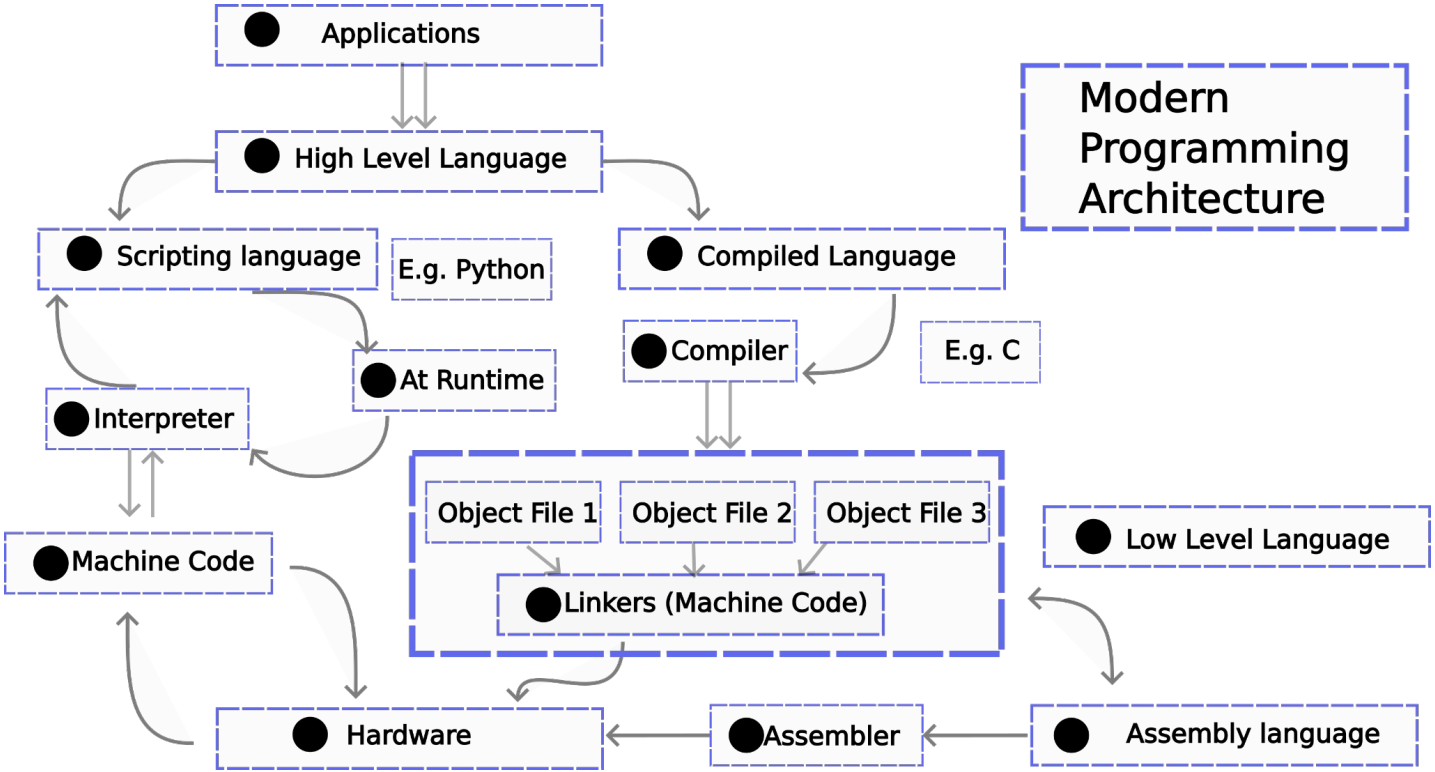
Over the time, people realize the power of open-source systems…



https://en.wikipedia.org/wiki/Unix-like

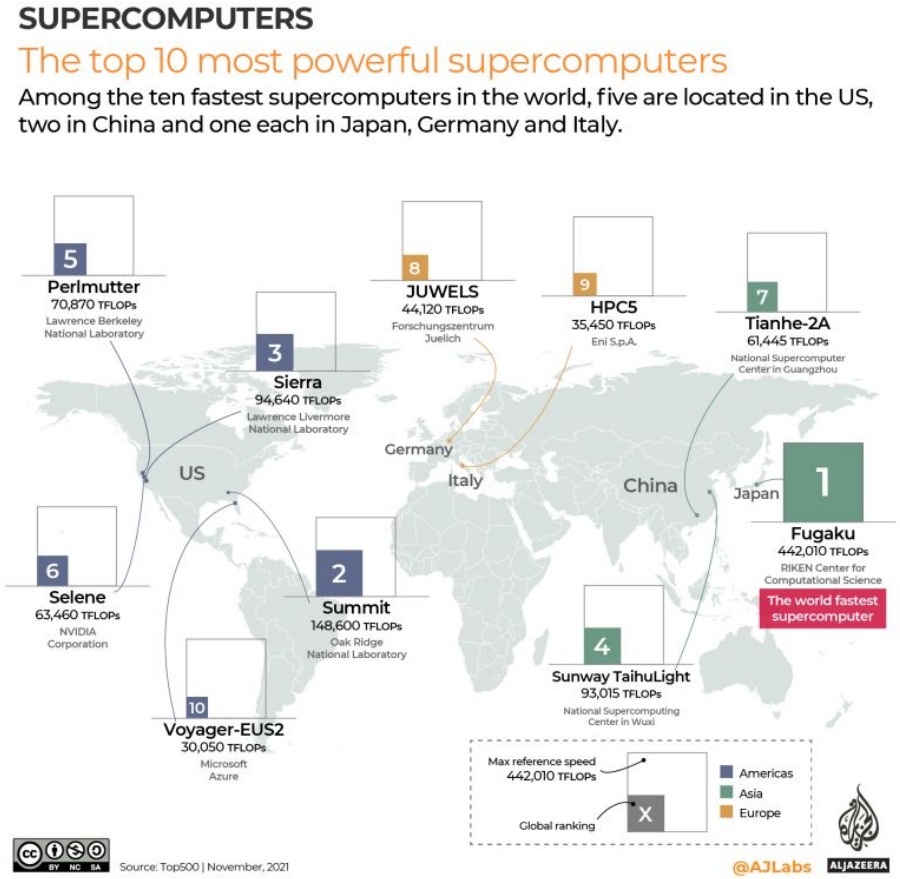
Programming

A program translates the objective of an application to machine-readable language.



Applications in Science

Computation is an extremely powerful tool in processing practical models where the solution cannot be accessed with any analytical tools. In particular, computation is used to discover new physics phenomena and make predictions, e.g. exotic phase transitions, non-equilibrium models, material properties, biophysical processes, nuclear reactions, particle collision, galactic dynamics, etc…



https://www.aljazeera.com/news/2022/1/14/infographic-visualising-race-build-world-fastest-supercomputers-interactive

Concepts in Statistics and Computational Techniques

In this course, you will be exposed to several most popular statistical methods and computational techniques.

Concepts in Statistics

- random process,
- probability density function (PDF),
- central limit theorem,
- Bernoulli process, binomial process,
- Poisson process,
- Lorentz (Cauchy) distribution.

Computational Techniques

- discrete Fourier transform,
- numerical integration and differentiation,
- implicit and explicit iterative methods for differential equations,
- gradient descent, stochastic sampling,
- Monte Carlo, Markov chain, PID control,
- machine learning, and deep learning.

Projects

In this course, you also will be exposed to several research directions in physics,

- Electrostatics,
- Diffusion, Brownian motion,
- Driven system,
- Hydrodynamics, Phase transitions,
- Molecular dynamics, ab initio approaches to electronic structure, Quantum state (Qubit) evolution, numerical renormalization group.

By the conclusion of this course, you will undertake a final project that leverages the techniques acquired in this class to simulate real-world physical systems.