CMP 101
Introduction to Computer Science Module 1A

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Course Outline

- CMP 101 – INTRODUCTION TO COMPUTER SCIENCE (3 UNITS)
- The computer, historical development and generations of computers, classification of computers: analogue, digital, hybrid, supercomputers, mainframes, minicomputers, personal computers, component parts, inputs/output, Peripheral devices: printers, CRTs, Keyboards, Optical Character Recognition, Operational Amplifiers; Analogue-to-Digital and Digital –to-Analogue Converters. Analogue computers and their major features, Systems software and application software, computer networks and the Internet, Types of computer users, Application of computers .Number System: Study of various number systems including binary, octal, hexadecimal, 1's and 2's complements, 9's and 10's complement, BCD etc. Conversion of one number system to the other and their programming implementation. Laboratory Practicals on Application packages such as MS Word, MS Excel and others as time permits.

What is Computer Science?

What is Computer Science

- Computer Science is defined in different ways by different authors.
- Wikipedia defines:
- Computer science as the collection of a variety of disciplines related to computing, both theoretical and practical: theoretical foundations of information and computation, language theory, algorithm analysis and development, implementation of computing systems, computer graphics, databases, data communications, etc.

  (http://en.wikipedia.org/wiki/Computer_science)

What is Computer Science..

- The US National Coordination Office for *Networking and Information Technology Research and Development* (NITRD) defines computer science in a similarly broad way:
- The systematic study of computing systems and computation. The body of knowledge resulting from this discipline contains theories for understanding computing systems and methods; design methodology, algorithms, and tools; methods for the testing of concepts; methods of analysis and verification; and knowledge representation and implementation. (http://www.nitrd.gov/pubs/bluebooks/1995/section.5.html)

What is Computer Science..

- Another broad definition comes from the *Association for Computing Machinery* (ACM) Model Curriculum.
- It says that computer science is the "study of computers and algorithmic processes, including their principles, their hardware and software design, their applications, and their impact on society."
- A famous definition of computer science by Gibbs and Tucker (Gibbs and Tucker, "A Model Curriculum for a Liberal Arts Degree in Computer Science," *Comm. of the ACM*, vol. 29, no. 3, March 1986) emphasizes algorithm development and analysis as the central focus of computer science.

What is Computer Science..

- Despite many variations, essentially all definitions of computer science emphasize the study of algorithms.
- Algorithms, in one form or another, are central to computer science.
- Computer science combines the theoretical concepts of algorithm design and analysis with the practical considerations of how to implement algorithms on a computer and solve practical problems.

Sample Questions

1. Give a comprehensive definition of Computer Science and state your authority.
2. How does ACM define Computer Science?
3. How does Computer Science relate to algorithm?

How is Computer Science a Science?

- It is a fair question to ask, “How is computer science a science?”
- In contrast to physics, biology, and chemistry, computer science is not based on the study of the natural world.
  - In that sense, computer science is more like mathematics than science.
- Some argue that computer science is really computer art (where “art” means practice).

How is Computer Science a Science?

- On the other hand, computer scientists do use the scientific method to propose and test hypotheses, and some very non-obvious discoveries in computer science have important real-world implications.
  - An example is the discovery that some important problems simply cannot be solved by computation.

What is a computer?

- The term computer is derived from the Latin term '*computare*', this means compute or calculate.
- A *computer* is an electronic machine that accepts data from the user, processes the data by performing calculations and operations on it, and generates the desired output results.
    - Computer performs both simple and complex operations, with speed and accuracy.

Classification of Computers

- Computers differ based on their data processing abilities.
- They are classified according one of three parameters: purpose, data handling and functionality (power and size).

Nature of Data

- Efficient processing of data is key to the operations of businesses and organisations.
- National population census, monitoring of cargo ship in and out of harbour and business management decisions by chief executives all need data and their processing can be facilitated by computer applications.
- Data processed by computer are of two types:
  - Discrete data, or
  - Continuous data.

Nature of Data..

- Discrete data is countable data.
  - This type of data has a specific value.
  - For example, the number of people in a family, the age of a person or the number of people playing a particular game are usually counted in whole values such as 1, 2, 3, 0, etc.
- Continuous data, on the other hand, is measurable data.
  - It can take any value within a range.
  - For instance, the height of students in this class can take such values such as 1.2m, 1.46m or 5.7ft.

Nature of Data..

- Discrete and continuous data can coexist in various life situations.
  - For instance the age of a person can be 21 while his height can be 1.57m and his temperature can be 36.5°C.
  - In a game between Arsenal and Manchester United, attempts could be made by each team to score and the shots could be taken at different ranges.
    - The number of goals scored in the match are discrete data while the different ranges from which shorts are taken would be continuous data.
  - Variables which handle discrete data are known as **discrete variables** while those handling continuous data are called **continuous variables**.

Sample Questions

1. Explain the terms discrete and continuous data
2. What is a discrete variable?
3. How can discrete data and continuous data co-exist? Give examples?

Classification of Computers based on data handled

- Based on the type of data a computer handles, it can be classified as analog, digital or hybrid

Analog Computer

- An analog computer (spelt analogue in British English) is a form of computer that uses continuous physical phenomena such as electrical, mechanical, or hydraulic quantities to model the problem being solved.
- Analog computer represents data as variable across a continuous range of values, in other words, analog computers process continuous data.
- The earliest computers were analog computers.
- Analog computers are used for measuring of parameters that vary continuously in real time, such as temperature, pressure and voltage.
- Analog computers may be more flexible but generally less precise than digital computers.
  - Slide rule is an example of an analog computer.

Digital Computer

- Digital computer is a computer that performs calculations and logical operations with quantities represented as digits, usually in the binary number system.
- A digital computer uses distinct values to represent the data internally.
- All information is represented using the digits 0s and 1s.
- The computers that we use at our homes and offices are digital computers.
- Digital computers process data in discrete form.

Hybrid Computer (Analog + Digital)

- Hybrid computers are a combination of computers that are capable of inputting and outputting both digital and analog signals.
- A hybrid computer system setup offers a cost effective method of performing complex simulations.
- A hybrid computer combines the desirable features of analog and digital computers.
- It is mostly used for automatic operations of complicated physical processes and machines.
  - Nowadays analog-to-digital and digital-to-analog converters are used for transforming the data into suitable form for either type of computation.

Hybrid Computer (Analog + Digital)..

- For example, in hospital's Intensive Care Unit (ICU), analog devices might measure the patient's temperature, blood pressure and other vital signs.
- These measurements which are in analog might then be converted into numbers and supplied to digital components in the system.
- These components are used to monitor the patient's vital sign and send as signals if any abnormal readings are detected.
- Hybrid computers are mainly used for specialized tasks.
  - **In this course, we shall limit our study to the digital computers and we would generally use the term "computer" to refer to digital computer.**

Analog, Digital and Hybrid Computers..

Based on the type of data handled, we can classify computers as analog (those processing continuous data), digital (those that process discrete data), and hybrid (those that can handle both discrete and continuous data)

Classification of Computers by Purpose

- There are two types of computers according to their purpose.

General-Purpose Computers

- Most computers in use today are General-Purpose computers — those built for a great variety of processing jobs.
- General purpose computers are designed to perform a wide variety of functions and operations.
- Simply by using a general purpose computer and different software, various tasks can be accomplished, including writing and editing (word processing), manipulating facts in a data base, tracking manufacturing inventory, making scientific calculations, or even controlling organization's security system, electricity consumption, and building temperature.

Special-Purpose Computers

- As the name states, a Special-Purpose Computer is designed to be task-specific and most of the times their job is to solve one particular problem.
- They are also known as dedicated computers, because they are dedicated to perform a single task over and over again.
- Such a computer system would be useful in playing graphic intensive Video Games, traffic lights control system, navigational system in an aircraft, weather forecasting, satellite launch/tracking, oil exploration, and in automotive industries, keeping time in a digital watch, or Robot helicopter.

Special-Purpose Computers..

- While a special purpose computer may have many of the same features found in a general purpose computer, its applicability to a particular problem is a function of its design rather than to a stored program.
- The instructions that control it are built directly into the computer, which makes for a more efficient and effective operation.
- They perform only one function and therefore cut down on the amount of memory needed and also the amount of information which can be input into them.
- As these computers have to perform only one task, therefore, they are fast in processing.
- A drawback of this specialization, however, is the computer’s lack of versatility.
  - It cannot be used to perform other operations.

Classification of by sizes and power

- The digital computers that are available nowadays vary in their sizes and types.
- The computers are broadly classified into four categories (Figure 1.8) based on their size and type—(1) Microcomputers, (2) Minicomputers, (3) Mainframe computers, and (4) Supercomputer.

Classification of by sizes and power..

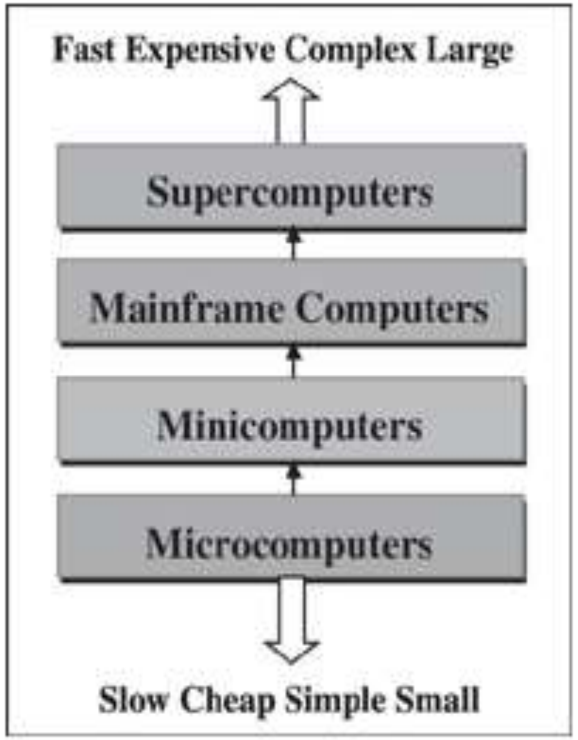


Figure 1.8. Classification of computers based on size and type

Classification of by sizes and power..

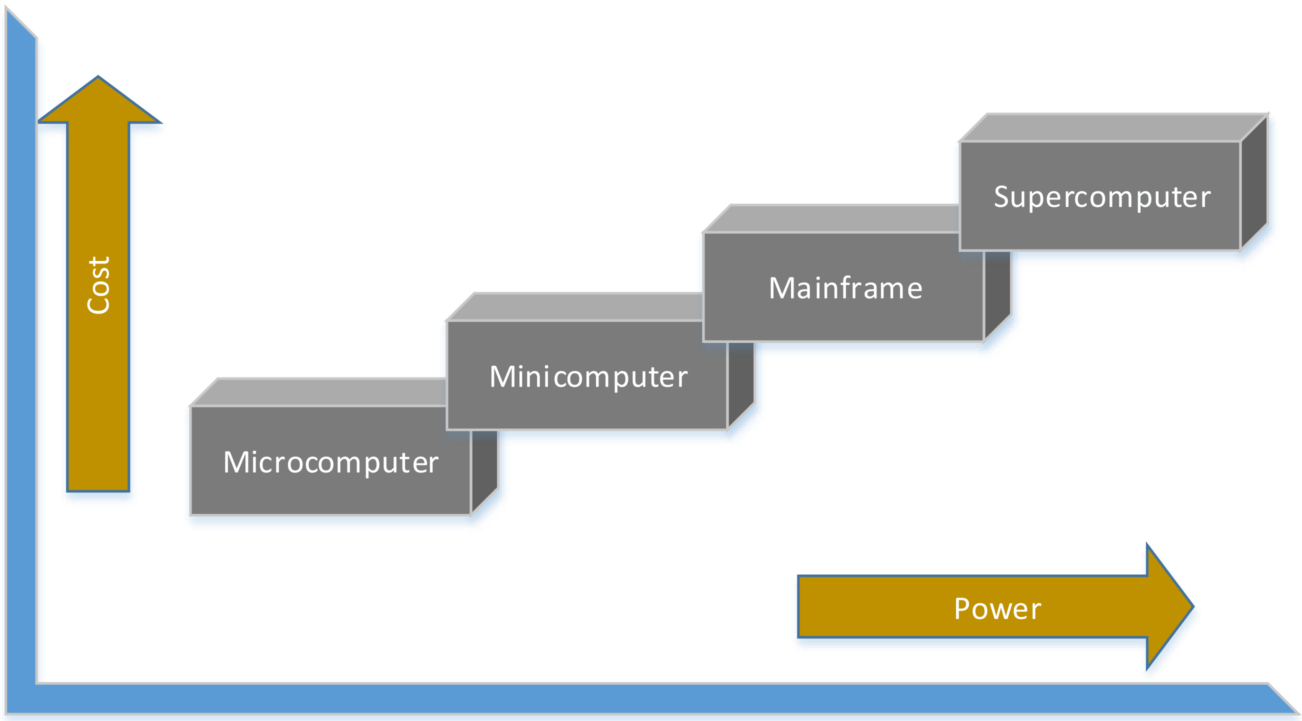


Figure 1.8a Digital Computer in terms of Cost and Power

Microcomputers

- Microcomputers are small, low-cost and single-user digital computer.
- They consist of CPU, input unit, output unit, storage unit and the software.
- Although microcomputers are stand-alone machines, they can be connected together to create a network of computers that can serve more than one user.
- IBM PC based on Pentium microprocessor and Apple Macintosh are some examples of microcomputers.
- Microcomputers include desktop computers, notebook computers or laptop, tablet computer, handheld computer, smart phones and netbook.

Microcomputers

Fig. 1.9 Microcomputers

Minicomputers

- Minicomputers (Figure 1.10) are digital computers, generally used in multi-user systems.
- They have higher processing speed and higher storage capacity than the microcomputers.
- Minicomputers can support 4–200 users simultaneously.
- The users can access the minicomputer through their PCs or terminal.
- They are used for real-time applications in industries, research centres, etc.
  - PDP 11, IBM (8000 series) are some of the widely used minicomputers.

Minicomputers ..

Figure 1.10 Minicomputer

Mainframe Computers

- Mainframe computers (Figure 1.11) are multi-user, multi-programming and high performance computers.
- They operate at a very high speed, have very large storage capacity and can handle the workload of many users.
- Mainframe computers are large and powerful systems generally used in centralized databases.
- The user accesses the mainframe computer via a terminal that may be a dumb terminal, an intelligent terminal or a PC.

Mainframe Computers

Figure 1.11 Mainframe

Mainframe Computers

- A *dumb terminal* cannot store data or do processing of its own.
- It has the input and output device only.
- An *intelligent terminal* has the input and output device, can do processing, but, cannot store data of its own.
- The dumb and the intelligent terminal use the processing power and the storage facility of the mainframe computer.
- Mainframe computers are used in organizations like banks or companies, where many people require frequent access to the same data.
- Some examples of mainframes are CDC 6600 and IBM ES000 series.

Mainframe Computers..

- Mainframe computers (colloquially referred to as "big iron") are computers used primarily by corporate and governmental organizations for critical applications, bulk data processing such as census, industry and consumer statistics, enterprise resource planning and transaction processing.
- The term originally referred to the large cabinets that housed the central processing unit and main memory of early computers.
- Later, the term was used to distinguish high-end commercial machines from less powerful units.
- Most large-scale computer system architectures were established in the 1960s, but continue to evolve.

Mainframe Computers..

- Modern mainframe design is generally less defined by single-task computational speed (typically defined as MIPS rate or FLOPS in the case of floating point calculations), and more by:
  - Redundant internal engineering resulting in high reliability and security
  - Extensive input-output facilities with the ability to offload to separate engines
  - Strict backward compatibility with older software
  - High hardware and computational utilization rates through virtualization to support massive throughput
- Their high stability and reliability enables these machines to run uninterrupted for decades.

Mainframe Computers..

- Mainframes are defined by high availability, one of the main reasons for their longevity, since they are typically used in applications where downtime would be costly or catastrophic.
  - The term reliability, availability and serviceability (RAS) is a defining characteristic of mainframe computers.
  - Proper planning and implementation is required to exploit these features, and if improperly implemented, may serve to inhibit the benefits provided.

Mainframe Computers..

- Software upgrades which usually require setting up the operating system or portions of it are done as non-disruptive operation using virtualizing facilities such as in IBM’s z/OS and Parallel Sysplex, or Unisys’ XPCL, which support workload sharing so that one system can take over another's application while it is being refreshed.
- In addition, mainframes are more secure than other computer types: the NIST vulnerabilities database, “US-CERT” rates traditional mainframes such as IBM zSeries, Unisys Dorado and Unisys Libra as among the most secured with vulnerabilities in the low single digits as compared with thousands for Windows, Unix, and Linux.

The Interfaces of Mainframes

- In the late 1950s, most mainframes had no explicitly interactive interface.
  - They accepted sets of punched cards, paper tape, or magnetic tape to transfer data and programs.
  - They operated in batch mode to support back office functions such as customer billing, and supported interactive terminals almost exclusively for applications rather than program development.
  - Typewriter and Teletype devices were also common control consoles for system operators through the 1970s, although ultimately supplanted by keyboard/display devices.

The Interfaces of Mainframes..

- By the early 1970s, many mainframes acquired interactive user interfaces and operated as timesharing computers, supporting hundreds of users simultaneously along with batch processing.
  - Users gained access through specialized terminals or, later, from personal computers equipped with terminal emulation software.
- By the 1980s, many mainframes supported graphical terminals, and terminal emulation, but not graphical user interfaces.
  - This format of end-user computing reached mainstream obsolescence in the 1990s due to the advent of personal computers provided with GUIs.
- After 2000, most modern mainframes have partially or entirely phased out classic terminal access for end-users in favour of Web-style user interfaces.

How Mainframe got its name

- Historically, mainframes acquired their name in part because of their substantial size, and because of requirements for specialized heating, ventilation, and air conditioning (HVAC), and electrical power, essentially posing a "main framework" of dedicated infrastructure.
- The requirements of high-infrastructure design were drastically reduced during the mid-1990s with CMOS mainframe designs replacing the older bipolar technology.
- IBM claimed that its newer mainframes can reduce data centre energy costs for power and cooling
  - And that they could reduce physical space requirements compared to server farms.

Major Characteristics of Mainframe

1. Modern mainframes can run multiple different instances of operating systems at the same time.
   - This technique of virtual machines allows applications to run as if they were on physically distinct computers.
   - In this role, a single mainframe can replace higher-functioning hardware services available to conventional servers.
   - While mainframes pioneered this capability, virtualization is now available on most families of computer systems, though not always to the same degree or level of sophistication.

Major Characteristics of Mainframe..

2. Mainframes can add or hot swap system capacity without disrupting system function, with specificity and granularity to a level of sophistication not usually available with most server solutions.
   - Modern mainframes, notably the IBM zSeries, System z9 and System z10 servers, offer two levels of virtualization: logical partitions (LPARs, via the PR/SM facility) and virtual machines (via the z/VM operating system).
   - Many mainframe customers run two machines: one in their primary data centre, and one in their backup data centre—fully active, partially active, or on standby—in case there is a catastrophe affecting the first building.

Major Characteristics of Mainframe..

- Test, development, training, and production workload for applications and databases can run on a single machine, except for extremely large demands where the capacity of one machine might be limiting.
- Such a two-mainframe installation can support continuous business service, avoiding both planned and unplanned outages.
- In practice many customers use multiple mainframes linked either by Parallel Sysplex and shared DASD (in IBM's case), or with shared, geographically dispersed storage provided by EMC or Hitachi.

Major Characteristics of Mainframe..

3. Mainframe return on investment (ROI), like any other computing platform, is dependent on its

- ability to scale,
- support mixed workloads,
- reduce labour costs,
- deliver uninterrupted service for critical business applications,
- and several other risk-adjusted cost factors.

Major Characteristics of Mainframe..

4. Mainframes have execution integrity characteristics for fault tolerant computing.
   - For example, z900, z990, System z9, and System z10 servers effectively execute result-oriented instructions twice, compare results, arbitrate between any differences (through instruction retry and failure isolation), then shift workloads "in flight" to functioning processors, including spares, without any impact to operating systems, applications, or users.
   - This hardware-level feature is known as lock-stepping, because both processors take their "steps" (i.e. instructions) together.
   - Not all applications absolutely need the assured integrity that these systems provide, but many do, such as financial transaction processing.

Supercomputers

- A supercomputer (Figure 1.12) is the fastest type of computer.
- Supercomputers are very expensive and are employed for specialized applications that require large amounts of mathematical calculations.

Supercomputers..

Figure 1.12 Supercomputer

Supercomputers.. Common Uses of Supercomputers

- Supercomputers are used for highly calculation-intensive tasks such as problems involving quantum mechanical physics, weather forecasting, climate research, molecular modeling (computing the structures and properties of chemical compounds, biological macromolecules, polymers, and crystals), physical simulations (such as simulation of airplanes in wind tunnels, simulation of the detonation of nuclear weapons, and research into nuclear fusion), cryptanalysis, and many others.
- Some supercomputers have also been designed for very specific functions like cracking codes and playing chess; ***Deep Blue*** is a famous chess-playing supercomputer.
- Major universities, military agencies and scientific research laboratories depend on and make use of supercomputers very heavily.

Hardware design of supercomputers

- Supercomputers using custom CPUs traditionally gained their speed over conventional computers through the use of innovative designs that allow them to perform many tasks in parallel, as well as complex detail engineering.
- They tend to be specialized for certain types of computation, usually numerical calculations, and perform poorly at more general computing tasks.
- Their memory hierarchy is very carefully designed to ensure the processor is kept fed with data and instructions at all times - in fact, much of the performance difference between slower computers and supercomputers is due to the memory hierarchy.
- Their I/O systems tend to be designed to support high bandwidth, with latency less of an issue, because supercomputers are not used for transaction processing.

Challenges of supercomputers

- A supercomputer generates large amounts of heat and therefore must be cooled with complex cooling systems to ensure that no part of the computer fails.
  - Many of these cooling systems take advantage of liquid gases, which can get extremely cold.
- Another issue is the speed at which information can be transferred or written to a storage device, as the speed of data transfer will limit the supercomputer's performance.
  - Information cannot move faster than the speed of light between two parts of a supercomputer.
- Supercomputers consume and produce massive amounts of data in a very short period of time.
  - Much work on external storage bandwidth is needed to ensure that this information can be transferred quickly and stored/retrieved correctly.

Supercomputer Operating Systems

- Most supercomputers run on a **Linux** or **Unix** operating system because these operating systems are
  - extremely flexible,
  - stable, and
  - efficient.
- Supercomputers typically have multiple processors and a variety of other technological tricks to ensure that they run smoothly.
- Until the early-to-mid-1980s, supercomputers usually sacrificed instruction set compatibility and code portability for performance (processing and memory access speed).

Supercomputer Operating Systems..

- For the most part, supercomputers had vastly different operating systems.
  - The Cray-1 alone had at least six different proprietary OSs largely unknown to the general computing community.
  - Similarly different and incompatible vectorizing and parallelizing compilers for Fortran existed.
- In the future, the highest performance systems are likely to use a variant of Linux but with incompatible system-unique features (especially for the highest-end systems at secure facilities).

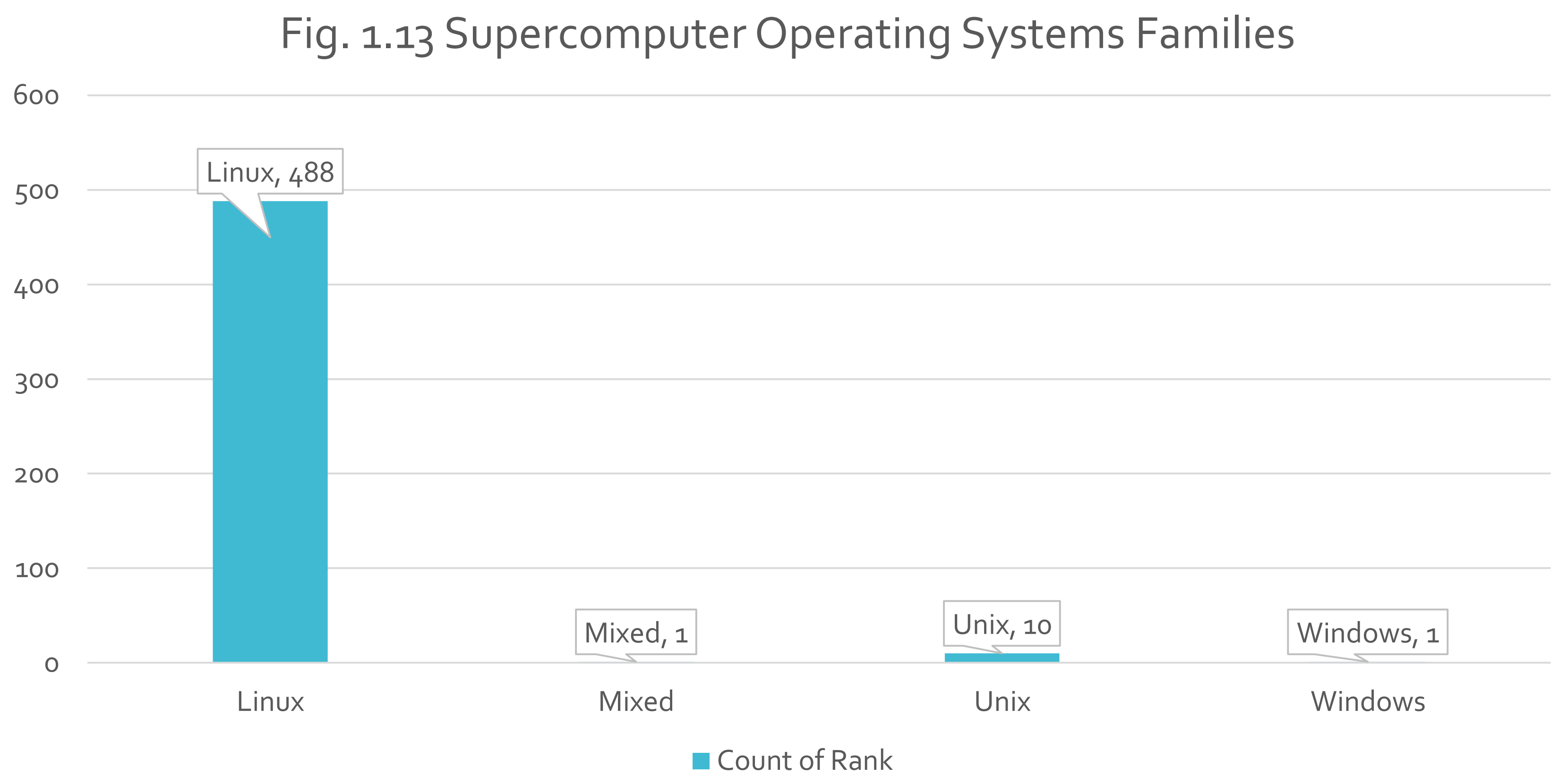
Rank	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	**Summit** - IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband , IBM DOE/SC/Oak Ridge National Laboratory United States	2,282,544	122,300.0	187,659.3	8,806
2	**Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway , NRCPC National Supercomputing Center in Wuxi China	10,649,600	93,014.6	125,435.9	15,371
3	**Sierra** - IBM Power System S922LC, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband , IBM DOE/NNSA/LLNL United States	1,572,480	71,610.0	119,193.6	
4	**Tianhe-2A** - TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000 , NUDT National Super Computer Center in Guangzhou China	4,981,760	61,444.5	100,678.7	18,482
5	**AI Bridging Cloud Infrastructure (ABCI)** - PRIMERGY CX2550 M4, Xeon Gold 6148 20C 2.4GHz, NVIDIA Tesla V100 SXM2, Infiniband EDR , Fujitsu National Institute of Advanced Industrial Science and Technology (AIST) Japan	391,680	19,880.0	32,576.6	1,649

Figure 1.16 Top 10 Supercomputers (Source www.top500.org), 2018

Rank	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
6	**Piz Daint** - Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect , NVIDIA Tesla P100 , Cray Inc. Swiss National Supercomputing Centre (CSCS) Switzerland	361,760	19,590.0	25,326.3	2,272
7	**Titan** - Cray XK7, Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x , Cray Inc. DOE/SC/Oak Ridge National Laboratory United States	560,640	17,590.0	27,112.5	8,209
8	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom , IBM DOE/NNSA/LLNL United States	1,572,864	17,173.2	20,132.7	7,890
9	**Trinity** - Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect , Cray Inc. DOE/NNSA/LANL/SNL United States	979,968	14,137.3	43,902.6	3,844
10	**Cori** - Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect , Cray Inc. DOE/SC/LBNL/NERSC United States	622,336	14,014.7	27,880.7	3,939

Figure 1.16 Top 10 Supercomputers (Source www.top500.org, 2018)..

Supercomputer Operating Systems..



Supercomputers in Different Segments

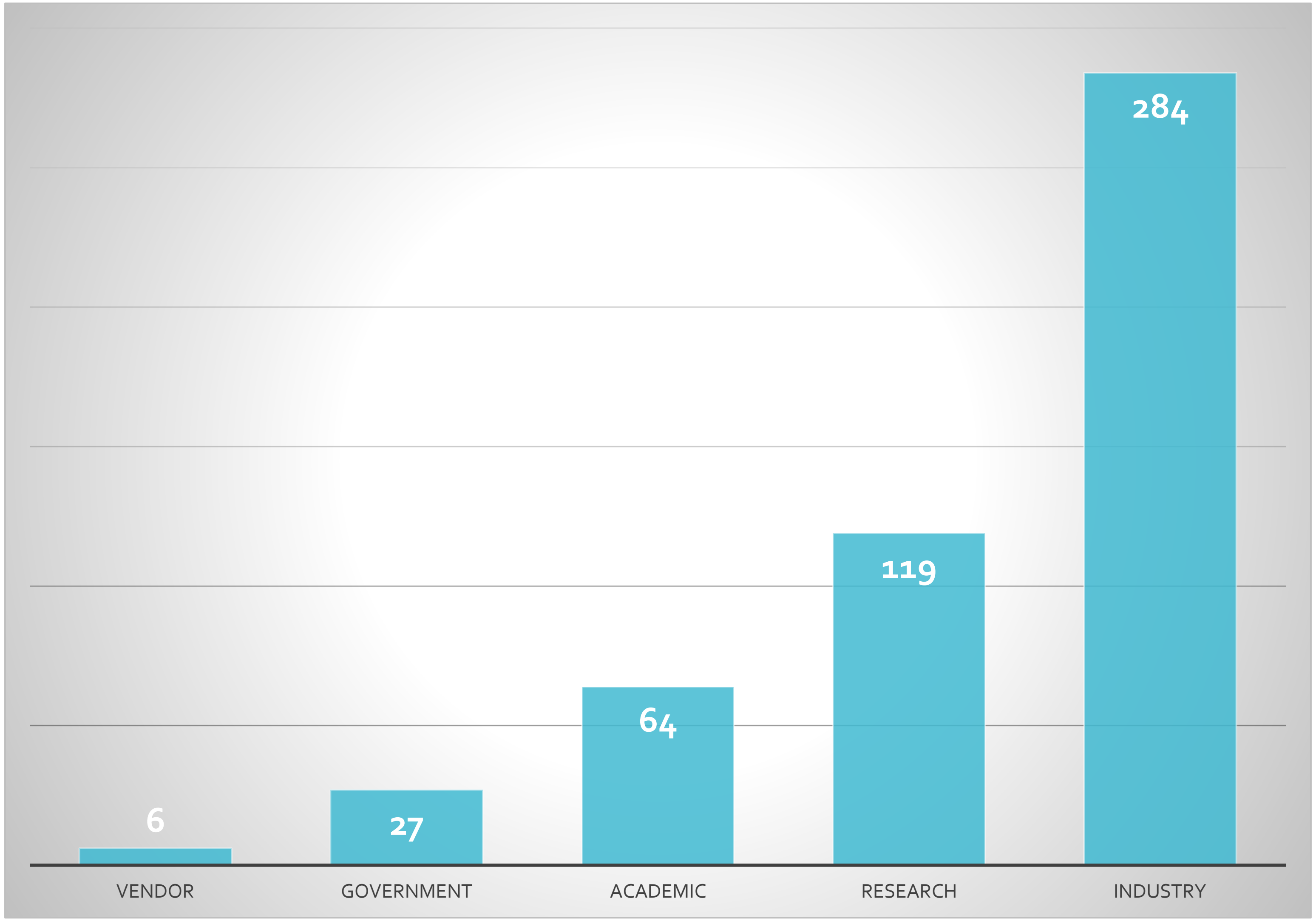


Fig. 1.14 Supercomputers in different Segments

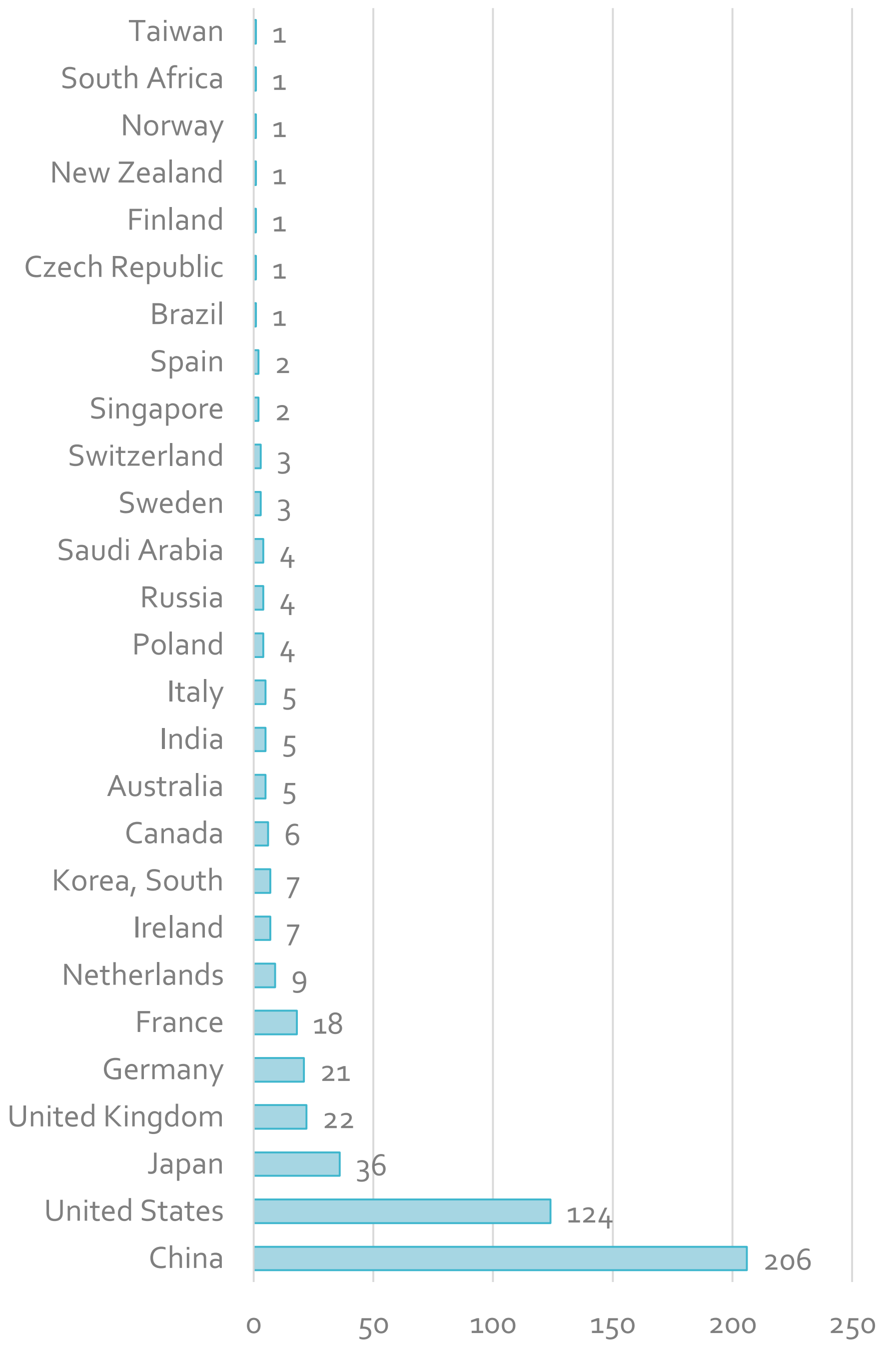


Fig. 1.15 Supercomputers by geographical spread

Supercomputer Programming Languages

- The base language of supercomputer code is generally **Fortran** or **C**
  - Special libraries are used to share data between the nodes.
- Software tools for distributed processing include standard application programming interfaces (APIs) and open source-based software solutions which facilitate the creation of a supercomputer from a collection of ordinary workstations or servers.

Processing Speed of Supercomputers

- Supercomputer computational power is rated in **FLOPS** (Floating Point Operations Per Second).
- The first commercially available supercomputers reached speeds of 10 to 100 million FLOPS.
- The next generation of supercomputers is predicted to break the petaflop level.
  - This would represent computing power more than 1,000 times faster than a teraflop machine.
  - A relatively old supercomputer such as the Cray C90 (built in the mid to late 1990s) has a processing speed of only 8 gigaflops.
  - It can solve a problem, which takes a personal computer a few hours, in .002 seconds!
  - From this, we can understand the vast development happening in the processing speed of a supercomputer.

Supercomputer Architecture

- Supercomputer design varies from model to model.
- Generally, there are vector computers and parallel computers.
  - Vector computers use a very fast data “pipeline” to move data from components and memory in the computer to a central processor.
  - Parallel computers use multiple processors, each with their own memory banks, to 'split up' data intensive tasks.
  - A vector computer solves a series of problems one by one in a consecutive order whereas a parallel computer solves all the problems in parallel as it is equipped with multiple processors.
  - Hence, the parallel computer would be able to solve the problems much quicker than a vector computer.