Computer development analysis based on Von Neumann Architecture

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Abstract: This paper discusses the constraints to modern computer further development, points out the limitation of integrated circuit production technology to computer hardware and the defects of Von Neumann architecture. It demonstrates the necessity of breaking through Von Neumann architecture. At the same time, the leading research fields of non-Von Neumann architecture computers are introduced in the paper, such as photon computer, quantum computer and Sixth generation computer.

1. Overview of Von Neumann Architecture

As we all know, ENIAC which was born in 1946 is the first computer in the world, and its developer Professor Von Neumann proposed three basic rules of computer manufacturing, known as the Von Neumann architecture. To sum up, the von Neumann architecture is that the computer uses binary logic, program storage execution, and the computer consists of five parts (arithmetic unit, control unit, storage, input device, output device) [1]. This theory has been guiding the development of computer science for more than 70 years, any breakthrough and development of von Neumann architecture can be regarded as a milestone in the history of computer science development.

2. Limitations of Computer Development in Von Neumann Architecture

2.1 Constraints from IC production technology.

Since the first computer came out, the development of computer has gone through four generations in manufacturing components. The evolution of these four generations can be attributed to the era of electronic tube, transistor, medium and small scale integrated circuit, large scale and super large scale integrated circuit. With the development of manufacturing components, the storage ability of computers is constantly enhanced, and the computing ability is constantly improved, which has become the most widely used technical support and the most powerful intellectual support in modern science and technology. The traditional storage mode of Von Neumann architecture makes Von Neumann computer rely heavily on memory, CPU the speed of accessing memory determines the running speed of computer system, and the technical level of integrated circuit IC chip determines the performance of memory and other hardware. Some chip manufacturing enterprises have invested a lot of manpower, material and financial resources in the production of integrated circuits, paid great efforts, but also gained remarkable results. According to the description and understanding of Moore's Law, it is not difficult to know that the integration of IC chips now doubles every 18 months, with performance doubling and product prices halving. However, the basic limitations faced by electronic products are objective, mainly from two aspects, the speed of information transmission and the atomic characteristics of computer materials.

First of all, the most important point, the speed of information propagation ultimately depends on the flow speed of electrons in the transmission medium. The flow of electronic signals in the transmission medium will be distorted by time delay, frequency instability and other irresistible factors, so the speed of signal transmission in the transmission medium can not be increased indefinitely until the speed of light reaches. secondly, the electronic signal of the computer is stored

on the transistor with silicon crystal as the representative material. the great improvement of the integration degree is based on the transistor becoming smaller, but this process and change is not unlimited. along with the semiconductor technology gradually approaching the limit of silicon process size, the Moore law may no longer be applicable. so far, the distance between two transistors in an integrated circuit is equivalent to the size of 100 silicon atoms, about 22 nanometers. it can be speculated that the IC technology represented by silicon materials will reach the limit by 2030. Therefore, the development of computer hardware will be seriously restricted, when the material science, basic physics and other aspects of the need to reconsider the composition of computer hardware, more need to break through the von Neumann architecture, change the computer's strong dependence on memory.

2.2 Defect Analysis of Von Neumann Computer Architecture.

a) Memory is useful for storing and executing machine language instructions, suitable for numerical calculation, but high-level language is called by variable name, not by address access, which is the "von Neumann semantic interval" between machine language and high-level language;
b) Instruction is stored in memory in the order of execution, so instruction execution is serial, which seriously affects the speed of system execution;
c) Instruction and data are stored in the same memory, which results in a strong dependence on memory, and the limited development of memory will inevitably affect the development of computer;
d) The Von Neumann system computer develops slowly in the non-numerical application field;
e) The traditional Von Neumann system is a control drive mode, which is insufficient in dealing with some fuzzy events in modern times. We hope that computers can be self-made machines rather than just automatic machines [2].

3. Non-Von Neumann Computer Architecture

3.1 Popular Non-Von Neumann Architecture research routes

In recent years, as the semiconductor process has gradually approached the limit of silicon process size, people have become more and more aware of the urgent need to break through the limitations of the von Neumann system, and various non-vonne studies have been carried out one after another, the main research routes can be summarized as follows:

a) Multiple processors are used to form a parallel algorithm structure supported by multiple instruction stream data stream;
b) Completely negates the Von Neumann system computer control flow drive way, creates the real sense non-vonne machine, namely uses the data flow drive computer, such as the neural computer;
c) The traditional Von Neumann computer is improved, and its serial execution is changed to pipeline processing, which relies on time overlap to improve processing efficiency;
d) Out of the electronic category, prospective studies using other substances as information carriers and executive components.

3.2 Some Representative Non-Von Neumann Computers

3.2.1 Quantum Computer

Quantum computers are a class of physical devices that follow the laws of quantum mechanics to perform high-speed mathematical and logical operations, store and process quantum information. When a device processes and computes quantum information and operates a quantum algorithm, it is a quantum computer. The concept of quantum computer originates from the study of reversible computer. The purpose of studying reversible computer is to solve the problem of energy

consumption in computer. The characteristics of quantum computer mainly include fast running speed, strong ability to dispose information and wide application range. Compared with ordinary computers, the more information processing is, the more favorable it is for quantum computers to perform operations, and the more accurate they are.

3.2.2 Photon Computer

Photon computer is a new type of computer which is composed of optical signals for digital operation, logic operation, information storage and processing. It is composed of laser, optical mirror, lens, filter and other optical components and equipment, and the laser beam enters the array composed of mirror and lens for information processing, replacing electrons with photons and electric operation with optical operation. The parallel and high speed of light naturally determines the parallel processing ability of photonic computer is very strong and has super high operation speed. has great potential in image recognition, artificial intelligence and other fields[3].

3.3.3 Biological Computer

Biological computer, also known as the sixth generation computer, its main raw material is protein molecules produced by bioengineering technology (especially protein engineering), which is used as a bio-integrated circuit -- biochip. In biochips, information is transmitted in the form of waves. When the wave propagates along the protein molecular chain, it will cause the change of the single bond and double bond structure order of the protein molecular chain. Its function imitates the human brain judgment ability and the adaptability, and has the neural network computer which can process many kinds of data function in parallel. Different from the fifth generation computer, which is mainly logic processing, it can judge the nature and state of the object itself, and can take corresponding actions, and it can simultaneously process a large amount of data with real-time changes in parallel, and draw conclusions. The previous information processing system can only deal with the clear, clear meridian data. And human brain activity has the flexibility to handle fragmentary, ambiguous information, and the sixth generation of computers will resemble human brain intelligence and flexibility.

4. Conclusion

The development of Von Neumann computer hardware is restricted by the integrated circuit production technology, the way of storage control task flow drive on the structure system can’t meet the needs of people for more high-speed and intelligent computer, and the road of system improvement is in a bottleneck. The breakthrough of von Neumann's system has made us see a promising field of computer research, and the research of Non-Von machine is booming, which will also bring about revolutionary changes in computer architecture, so that computers can better adapt to and meet the needs of productivity development, and become the most powerful technical support and application tool of modern science and technology.

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