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Part A:

What is quantum computing?

According to the Wikipedia article on quantum computing, the term is used to describe computation using “quantum-mechanical phenomena, such as superposition and entanglement.” In class we discussed that Quantum Computers have the potential to become the fourth generationcomputers although that future is not set in stone.

In order to understand quantum computing, one must first understand the workings of the current third generationof computers that are based on the Von Neumann Architecture. The current model is based on computers that are based on the workings of transistors**.** All data and operations are encoded into unique binary codes (0’s and 1’s). In the architecture, programs and data are held in memory. The processor and the memory are held in separate locations. In every computation, signals must travel back and forth across a bus. Thus, every computation is limited by the speed of the slowest process. The problem described above is known as the “Von Neumann Bottleneck”.

Quantum computing breaks from the tradition of using 0’s and 1’s to represent data. Quantum Computers will use qubits (quantum bits) to represent data. Quantum computing is currently a hot area of research because it uses the basic principle of superposition to justify its usefulness. The principle of superposition states that in all linear systems, the “net response caused by two or more stimuli is the sum of the responses that would have been caused by each stimulus individually”. The principle governs the behavior of the qubits. A simple observation of electrons and protons leads to the conclusion that on the microscopic level, the particles take on states that would seem contradictory if it were not for equations such as Schrodinger’s Equation. Qubits are not limited to the behavior of digital signals since qubits can take on the values of 0, 1, or both simultaneously.

In Quantum computing, there is an interesting property know as *entanglement.* In a system with two qubits, one can immediately determine the value of a cubit if one knows the value of another qubit, regardless whether the value of the cubit is a 0 or 1. In order to describe such a system with at least two qubits, one now needs to list and document all the *correlations* between the various qubits. For n qubits there will be a total of 2^n correlations. The appeal of a quantum computer is that it would be able to compute problems that a regular computer could never even dream of computing. The main drawback is that unlike generation 3 computers following the Von Neumann architecture that take in a binary string as an input and output either a 0 or 1, a quantum computer provides information that is incomplete (See Schrodinger’s Uncertainty Principle). The current goal is to come up with ways to gain as much information that is currently unobservable. One important drawback of quantum computing is that there is currently no way to make the computers available for mass production. In addition, there is no way to guarantee that quantum computers will be faster than third generation computers.

Quantum computers have been created by companies such as IBM, Google, and a Canadian company called DWave. Quantum computers can solves problems in chemistry such as being able to predict the properties of molecules and materials. Currently research is being done on a molecule called nitrogenase could revolutionize food production. Unfortunately, our biggest supercomputers cannot analyze this molecule, but a quantum computer could.

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Part B:

What are Fuzzy sets?

A Fuzzy Set was an idea that was proposed by a mathematician called Lofti A. Zadeh in a 1965 paper. In order to understand what a fuzzy set is, one must first understand the concept of fuzzy logic. Today’s computers operate on Boolean algebra. Fuzzy logic attempts to mimic the human thought process in order to help deal with the following phenomenon: “Any event, process, or function that is changing continuously cannot always be defined as either true or false”. In Fuzzy logic a function takes on a value between 0 and 1 inclusively. In classical mathematics, a set is an unordered collection of elements. Fuzzy sets are considered a “dumbed-down version” of classical sets in mathematics. Unlike classical sets where elements are defined as belonging to a set or not, fuzzy sets allow for partial membership. As a result, the elements have degrees of membership that are represented by a number between 0 and 1.

One can perform the following operations on fuzzy sets: Union/Fuzzy ‘OR’, Intersection/Fuzzy ‘AND’, and Complement/ Fuzzy ‘NOT’. The set operations are very similar but rely on completely different notation. Membership functions are used to describe the “fuzziness” of real-world situations. Every membership function has the following features: Core, Support, and Boundary, where the core is the region of the universe with full membership in a set, support is the region with non-zero membership, and boundary is the region where membership is incomplete.

Fuzzy sets can be used in Traffic monitoring systems, Commercial Appliances, Gene expression data analysis, and Facial Pattern Recognition. To provide a specific example, let us examine how fuzzy sets are used in Japan’s Sendai Subway System. In a normal engine, the speed overshoots the target speed or arrives through a series of fluctuations. In Japan’s system, the fuzzy controller that is responsible for acceleration, deceleration, and breaking has reduced energy consumption by 10%.

Despite the numerous benefits of fuzzy logic, the biggest issue is that it cannot be verified, which is why many mathematicians and statisticians reject it. Because the conclusions and predictions that fuzzy logic makes are vague, it is unviable for many tasks that need precise and efficient definitions. In addition a fuzzy logic controller takes significantly more time to set up and requires more hardware.

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Part C:

CISC, RISC, and MIPS

In modern “Generation 3” computers, the CPU (Central Processing Unit) operates on either CISC (Complex Instruction Set Computer) or RISC (Reduced Instruction Set Computer) architecture. The two architectures essentially govern how logical, arithmetic, and control operations occur in a computer.

The Complex Instruction Set Computer Architecture attempts to perform an assembly task using as little code as possible. Thus, a single instruction in CISC could execute a load operation from memory and an arithmetic operation in one step. Unlike the CISC architecture, the RISC architecture uses simple instructions that are meant to be executed within one clock cycle. CISC has the following characteristics: a strong emphasis on hardware, multi-clock complex instructions, memory-to-memory LOAD and STORE Operations, high cycles per second, and uses transistors for storing complex instructions. A RISC architecture has a different set of characteristics with a strong emphasis on software, single clock reduced instructions, register-to-register LOAD and STORE as independent instructions, and transistors used mostly for memory registers. One big advantage of a RISC-style architecture is that an entire program can be executed in the same amount of time as a single MULT(multiply) command in a CISC program. Despite the major advantage of RISC, the fortune 500 company Intel that is responsible for a significant percentage of chips used in today’s personal machines, aggressively used its resources to push chips that relied on the CISC architecture. However, the tides are turning, as the price of RAM has fallen significantly, so that RISC’s heavy emphasis on RAM and software makes it a better choice.

In our course, we are covering the RISC-style architecture MIPS( Microprocessor without interlocked pipeline stages). Introduced in 1985, MIPS was designed for general purpose computing and was used by companies such as Digital Equipment Corporation, MIPS Computer Systems, NEC, Pyramid Technology, SiCortex, Siemens Nixdorf, Silicon Graphics, and Tandem Computers. In the game industry MIPS was used in the Nintendo 64, Sony PlayStation, PlayStation 2, and PlayStation Portable. Right now, MIPS is still being used in embedded systems such as residential gateways and routers.

Since our course only covers the 32-bit architecture, I will only discuss the architecture of MIPS I created for the R2000 microprocessor. In MIPS I, instructions are categorized into one of three types: R, I, and J where I stands for Register, and J stands for immediate, and J stands for Jump. In all three instructions, the first 6 bits are used to encode the opcode. In both R and J instructions, 5 bits are used to encode the register numbers of the two source registers. In an I instruction, the last 16 bits are used to encode the immediate value, while and R instruction uses 5 bits for the destination register, 5 bits for the shift-amount, 6 bits for funct. In a J instruction, the last 26 bits are used solely to encode the address. MIPS contains 32 registers. MIPS has 12 instructions that are used for Load/Store operations, around 20 instructions that are used for ALU operations, 6 instructions for shifting, 8 instructions for division, 12 instructions for JUMPS, and 2 Instructions for Exceptions. In addition, MIPS supports FPU instructions.

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