CS8625 Quantum Computing

CS8625 High Performance and Parallel Computing
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Class

Will

Start

Momentarily…

Quantum Computing

- A new and “bizarre” way to do computing.
- Counter-intuitive: The way we think about the world which we experience, does not apply.
- The revolution in quantum mechanics is just as big a paradigm shift as relativity was.

Hierarchy of nested understanding of reality

- Our experience, Newtonian physics
  - Understanding of atoms and particles
    - Relativity
      - Quantum physics
        - » Perhaps string theory or something else

Recent Breakthroughs

- Faster than light!
- 8 years or so ago, made all the papers
- Experiment confirmed by researchers worldwide
- A particle/quantum information was transmitted through a quantum experiment, from transmitter to detector.
- It reached the destination so quickly that it would have had to travel faster than light, *in fact, for part of the transit, travel backwards in time*! ***If*** it had traveled in our normal universe.
- The particle “left” the universe of 4 dimensions that we experience (x,y,z and time), or perhaps utilized other dimensions we don’t experience, to make the transit.

- How can this be?
- A joke?

- No joke. The problem is not the experiments, but our expectations.

- Reality/the universe, is more interesting than what we personally experience.

- Our experience teaches us to think using an in-appropriate paradigm.

Wrong Paradigm

- The paradigm problem is that we are talking about a particle as if it were a very small ball, that we can fire with a direction and velocity, so this result seems unbelievable, based on our intuitive understanding of balls and Neutonian physics.

- We are trying to apply our “macro level” experience to a quantum event.

- Quantum mechanics violate our intuitive or experience-based understanding of reality.
- Quantum mechanics works by different rules.

Wave-Particle Duality

- Is it a particle, or a wave???
- Yes!

- That is, it is both at the same time,
- or perhaps, neither, with attributes of both.

- **Better still**, don't try to understand quantum behavior by relating it to our every-day understanding of the world.

- Take it as it is, don't try to make analogies to our personal level of experience of reality.

Other bizarre results

- Information as quantum states transmitted in zero time.
- Think ‘Star Trek communicator’, where you can communicate over vast distances in real time.

- Spontaneous creation and destruction of matter: individual quantum “particles” are constantly fluxing in and out of our universe.

- Superstring theory: our universe is but one of a perhaps infinite number of universes in 11 dimensions. Most of these universes are curled upon themselves, only a few, like ours, has the right cosmic parameters to allow for (an/our) existence.

Teleportation?

- I recently saw the first media article relating the transportation of information through this quantum mechanism as similar to teleportation.
- Transmitting bits of information is different from transmitting matter.
- But the article says that some physicists are now thinking building a “Star Trek Transporter” might be possible some day.
- I remain skeptical about this idea.
- The number of bits of matter in the human body and capturing the “state” of a living human is astronomically complex.

IBM work

- Recently constructed an electron pump, based on quantum mechanics.
- Heisenberg Uncertainty Principle: Should not be able to know both the velocity, and location of a particle at the same time, but this pump has demonstrated that possibility.
- “Forces” a particle to be in one specific location at an instant, by “collapsing” all other possibilities.

- Possibility of much greater information densities, power requirements, and computing speed.

- So what is quantum computing?

- In conventional computing, we use electronic bits (**bi**nary digi**ts**), that exist as electric charges on capacitors, voltage levels, or electric waves or pulses traveling down a wire.
- Quantum bits (qubits) function at a level below electronics. (also quaternary bits, 4 states rather than two)
- A wave-particle can exist in many states or locations at the same time. Its actual location/state is determined by the process of testing to determine its location.
- Makes no “sense” of course, but is true.

- **Small advantage** to having 4 states rather than two – greater information density.
- **Substantial advantage** in representing a bit with just a few particles, rather than a large scale electric charge of many electrons.

- **The big advantage** – a quantum number exists as many possible values at the same time. Testing or sampling the quantum number determines the actual value that it "settles on".
- Immensely parallel!
- Makes no sense are our level of experience of reality, but is true, and has been validated.

- Hugely parallel computations.
- Think of our recent lecture on the problem with too many solutions to examine – we used a genetic algorithm to get close to the maximum solution.
- A quantum calculation can explore all possible answers simultaneously.
- Each possible input is represented by a single quantum input, that can represent all valid values for that input at the same time. (doesn't make sense, but is true non-the-less).
- A single calculation time interval, can explore all possible solutions, and return the answer.

- Problems:

- Input and output into the quantum calculator. How to place quantum attributes on particles. Use three particles to represent a qubit, and utilize aspects of quantum interference (not explained here) to help sustain the values.
- How to read the output.

- Progress is being made. Perhaps 10-15 years will see a practical quantum computer.
- Experiments have confirmed the ability to do quantum computing in just a very few qubits.
- Progress on converting inputs to quantum states and reading the desired result is being made.
- What will computer science be like with a quantum computer? Certainly org and arch, and parallel processing will be dramatically different. Programming?

End of Lecture

End

Of

Today's

Lecture.