# Quantum Computing and Artificial Intelligence

**Quantum Computing in Big Data Analytics: A Survey**

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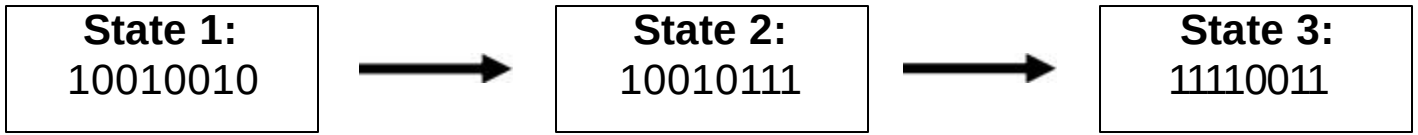
# What Is Quantum Computing?

- Quantum Computers (QCs) function in a different manner from regular computers
  - Should be able to solve *specific types* of problems in **seconds** that would take normal computers **thousands of years**

- QCs are currently in the domain of academic research. Google and IBM also have active research programs

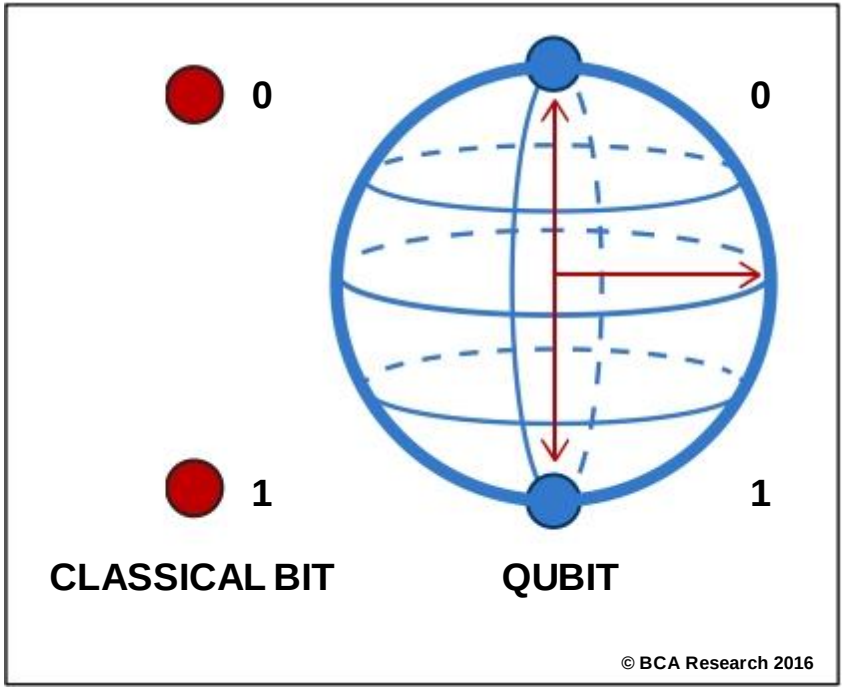
# Traditional Computers Vs Quantum Computers

- **Traditional computers** → *binary* system
  - Data is represented by binary digits (bits), which can be 1 or 0
  - Every element within the computer must be in a state of “1” or “0” at all times • The computer executes instructions by **transitioning** between different combinations of “1” and “0”, but only one combination can be active at a time



# Traditional Computers Vs Quantum Computers (cont)

- **Quantum Computers** → *superposition* of *quantum bits*
  - A quantum bit (Qubit) can be **both 1 and 0 at the same time**
  - This state is called **superposition**



# Advantages Of Quantum Computers

- A 16-bit binary number has only *one of* 65,536 possible values ($2^{16}$)
  - If searching for a particular combination of 1s and 0s, must go through in order until the desired combination is located (on average, would need to look through half, or 32,768 values)

- A 16 Qubit number has *all* 65,536 possible values at the **same time**
  - Can design an algorithm to find the desired combination in only **16** operations (one per Qubit)

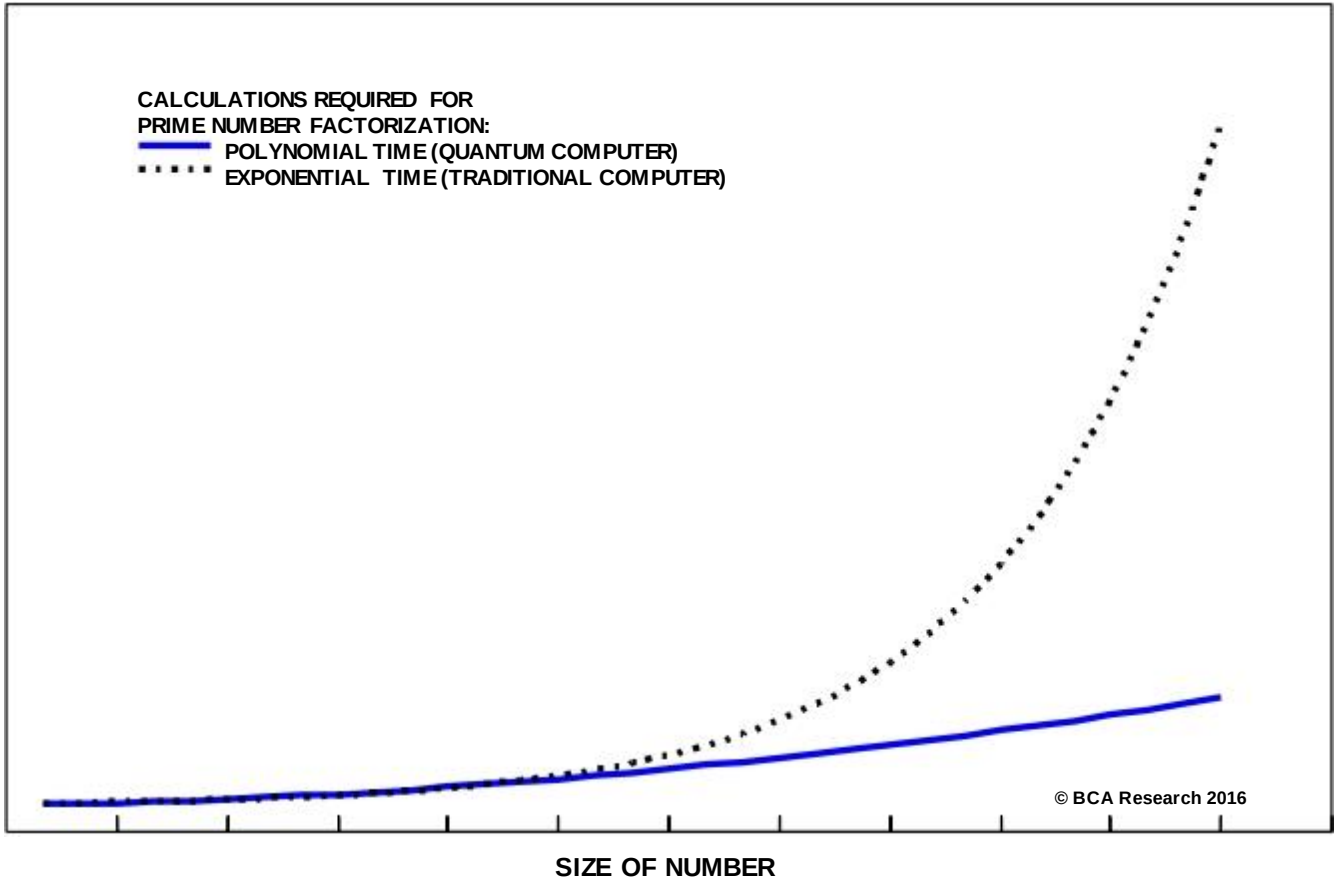
**A quantum computer can do in *16 operations* what takes a traditional computer *thousands* of operations**

# Advantages Of Quantum Computers (cont)

- Using Traditional Computers, many types of problems become *exponentially* more difficult as the inputs increase
  - Travelling Salesman problem
  - Finding the prime factors of a number (used in encryption)

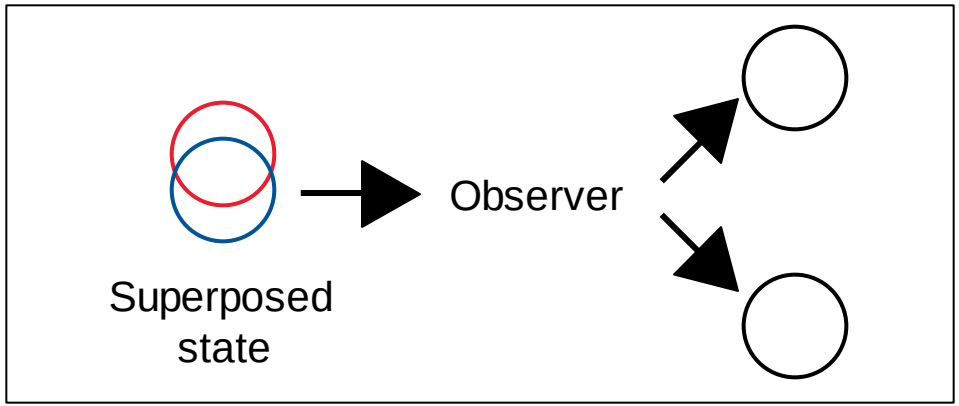
- Quantum computers can solve certain types of these problems in *polynomial* time (dramatically faster)
  - **Implication:** A quantum computer can determine the prime factors of a large number as fast as a classical computer can **multiply** two numbers!

# Polynomial Time Vs Exponential Time



# Limitations Of Quantum Computers

1. QCs require expensive, specialized equipment to avoid **decoherence**
   - *Decoherence* is when Qubits go from a state of superposition (*both* 1 and 0) to *either* a 1 or 0 as a result of interacting with the environment
   - Avoiding *decoherence* requires a cryogenic environment, lasers, and magnetic fields • The best QCs today can keep Qubits in superposition only for a very short time
   - **Implication:** QCs will not fit on a desktop. They are bulky and expensive to own and operate



# Limitations Of Quantum Computers (cont)

2. Benefits of QCs will outweigh the costs only in very specific applications

- Classical computers can provide "pretty good" solutions to many problems
  - The value of QC would be in moving from **pretty good** to ***optimal***, which is not worth the cost in many cases
- **Implication:** for a long time after development, QCs are likely to be used only in government labs (decryption), scientific experiments, and potentially for very complex commercial applications.

# Limitations Of Quantum Computers (cont)

3. Difficult to find developers for QC algorithms

- Relatively easy and quick to learn how to program a classical computer
- QC is at the intersection of two difficult fields: advanced mathematics and quantum theory
- **Implication:** developing quantum algorithms requires extremely specialized skills, and is currently the domain of high-level researchers
  - Very few algorithms have been developed that have any practical application at this time

# Investment Implications

- QC research is at an early stage, and remains in the domain of research scientists working in labs
- D-Wave is the only company that claims to manufacture a QC
- In order to be commercially viable, a QC would need to solve relevant problems significantly faster than the fastest classical computers
    - D-Wave is yet to demonstrate this, and no evidence that we are close to being able to do this yet

# Investment Implications (cont)

- Google recently announced potentially the first QC development that could have commercial relevance
  - Companies that profit most from technological breakthroughs historically have not been those that funded the research

- Investment in any QC company is **highly speculative** at this time

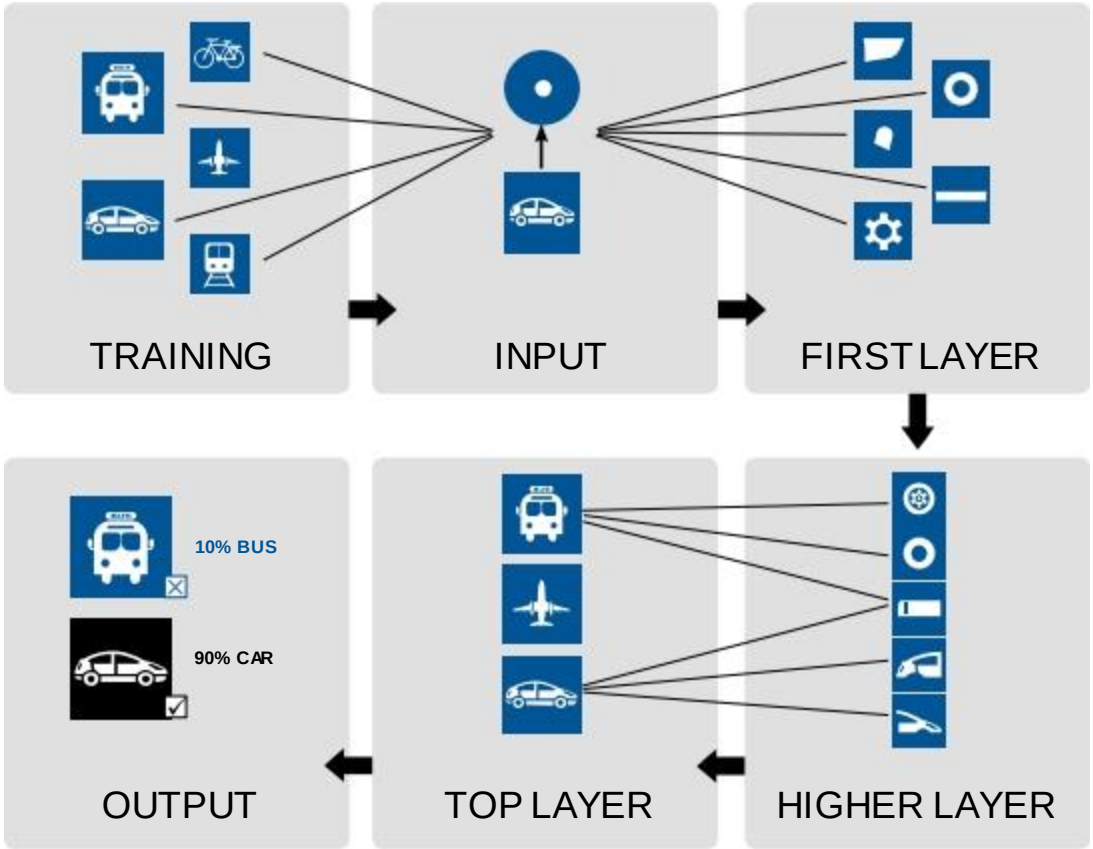
# Artificial Intelligence: What Is It?

- Artificial Intelligence (AI) ≠ “self-aware” machines
- AI, as understood by computer scientists, refers to:

*Software that incorporates **prior training**, and improves with each training session.*

- **Deep Learning** is responsible for many recent advances in AI

# Deep Learning And Neural Networks



# Investment Implications Of AI

- Deep Learning requires massive amount of computing power
  - AI development will likely rely on **cloud service providers**. This is positive for the dominant players: Amazon, Google, Microsoft
- Most applications of AI will require a high degree of human supervision
  - Employment will be affected, but AI will not replace doctors
- Any competitive advantage from superior AI algorithms likely to be temporary
  - Certain companies may emerge that have expertise in specific domains, for example medical

# Quantum Computing And AI

- Some futurologists believe that QCs will lead to significant advances in AI, but this is unlikely

- No indication that QC will be generally applicable to AI
  - QCs may speed up **certain tasks** useful in AI development, such as searching for information