QUANTUM COMPUTING AND NEW COMPUTER TECHNOLOGIES

COMPILED BY HOWIE BAUM
THE FUTURE OF COMPUTING

1) How far have we come?

2) Can we keep going?

3) Where do we go from here?

4) What does it mean for us?
QUANTUM COMPUTING AND NEW COMPUTER TECHNOLOGIES
SUBJECT LIST

1) QUANTUM COMPUTING
2) NEW COMPUTER CHIP TECHNOLOGY
3) THE INTERNET OF THINGS
4) OTHER NEW COMPUTER USES
5) ARTIFICIAL INTELLIGENCE (AI)
6) DIGITAL HUMAN MODELING
7) AI AND NATURAL LANGUAGE PROCESSING
1) QUANTUM COMPUTING
AN INTRODUCTION TO THE AMOUNT OF MEMORY IN COMPUTERS

THE SMALLEST AMOUNT OF MEMORY IS A BIT WHICH REPRESENTS A 0 OR A 1

A BYTE, IS MADE OF 8 BITS AND USUALLY STORES ONE CHARACTER SUCH AS A LETTER OR A NUMBER OR SYMBOL, SUCH AS Z, 8, OR &

A COMPUTER WITH 8 MEGABYTES OF MEMORY CAN STORE APPROXIMATELY 8 MILLION CHARACTERS.

Kilobyte (KB) = 1 Thousand Bytes
= 1/2 of a double-space typed page

Megabyte (Mb) = 1 Million Bytes
= 768 pages of typed text

Gigabyte (GB) = 1 Billion Bytes
= 786,432 pages of typed text

Terabyte (TB) = 1 Trillion Bytes
= 51 miles high stack of typed pages
Computers don’t understand any human logic. A computer is hardware – a physical object.

The 1’s and 0’s are understood by humans only. The ‘1’ means an ‘ON’ state of a switch and ‘0’ means ‘OFF’ state of the same switch.

The ‘1’ and ‘0’ are also referred to as Binary Number System in mathematics. The field of electronics dealing with the ‘1’ and ‘0’ is called Digital Electronics.

ALL OF THE SWITCHING IS DONE BY VERY SMALL TRANSISTORS!

ON AN AVERAGE, A COMPUTER CHIP CAN WORK AT UP TO 4 BILLION CALCULATIONS PER SECOND!!

<table>
<thead>
<tr>
<th>Binary</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplier</td>
<td>$2^7$</td>
<td>$2^6$</td>
<td>$2^5$</td>
<td>$2^4$</td>
<td>$2^3$</td>
<td>$2^2$</td>
<td>$2^1$</td>
<td>$2^0$</td>
</tr>
<tr>
<td>Decimal</td>
<td>128</td>
<td>64</td>
<td>32</td>
<td>16</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

$$32 + 16 + 4 + 1 = 53$$
Transistor switches

OFF  ON  ON  OFF  OFF  OFF  OFF  ON

0 1 1 0 0 0 0 1

Binary code for the letter “a”
A byte is further broken down into eight bits, which we’ve seen before.

Each bit can be a 0 or 1. Doing the math, each byte can represent $2^8 = 2$ to the 8th power which = 256 different numbers composed of eight 0s or 1s, but it can only hold one value at a time.

The difference in a quantum computer is that 8 qubits can represent all 256 values at the same time!!

This is through superposition, but also through entanglement, the way we can tightly tie together the behavior of two or more qubits. This is what gives us the (literally) exponential growth in the amount of working memory.
A FUN ILLUSTRATION OF THE IDEA OF EXPONENTIAL NUMBERS

Imagine you want to seat 10 fussy people at a dinner party, where there is only one best seating plan out of all the different possible combinations.

How many different combinations would you have to explore to find the best one?

The more people at each table, the much, much higher the number gets!!

Can you guess how many combinations there are for?

2 People = 2 factorial (2!) = 2 X 1 = 2

5 People = 5 factorial (5!) = 5X4X3X2X1 = 120

10 People = 10 factorial (10!) = 10X9X8X7X6X5X4X3X2X1 = 3,628,800 total combinations!!

That's just to arrange 10 people around a table!
Caffeine has 8 atoms of Carbon, 10 of Hydrogen, 4 of Nitrogen and 2 of oxygen.

It is a small molecule but each atom in it contains many, many protons, neutrons, and electrons.
CAN WE FULLY REPRESENT A SINGLE CAFFEINE MOLECULE AT A SINGLE INSTANT?

If we just look at the energy configuration that determines the structure of the molecule and the bonds that hold it all together, the amount of information to describe this is staggering.

In particular, the number of bits, the 0s and 1s, needed is approximately $10^{48}$ or 10 with 48 O’s after it.
A traditional computer uses long strings of “bits,” which encode either a zero or a one.

A quantum computer, on the other hand, uses quantum bits, or qubits which can be either a 0, a 1, or both!!

The image to the right is what an IBM Quantum computer looks like. The image below is the Quantum chip, that is in the canister at the bottom of the computer.

The bottom area of quantum computers have to be kept at a few parts of a degree above absolute zero, to around -460 Fahrenheit. The temperature in outer space is -454.81 °F!

https://www.youtube.com/watch?v=b-0ZNlqaSBE go to 6.35 minutes
SUPERPOSITION

In the ordinary classical world, a skateboarder could be in only one location or position at a time, such as the left side of the ramp (which could represent a data value of 0) or the right side (representing a 1).

But if a skateboarder could behave like a quantum object (such as an atom or an electron), he or she could be in a “superposition” of 0 and 1, effectively existing in both places at the same time.
An ion (a charged atomic particle) will collapse randomly into a 0 or 1, and its partner ion will then be observed to have the same value, even if it’s halfway across the galaxy.

Albert Einstein pointed out this “spooky action at a distance,” and it disturbed him greatly, but this behavior has been confirmed time and again.
THE IDEAS BEHIND QUANTUM COMPUTING CAN BE CONFUSING!

“when a qubit is both one and zero”—said by everyone, understood by no-one

Quantum computers perform calculations based on the probability of an object’s state before it is measured.

“It is my task to convince you not to turn away because you don’t understand it.

You see, my physics students don’t understand it either.

That because I don’t understand it.

Nobody does.”
2) NEW DEVELOPMENTS IN COMPUTER CHIPS AND TRANSISTORS
Moore’s Law was first proposed in a magazine article by Intel co-founder Gordon E. Moore.

What it actually says is that the number of transistors that can be packed into a given unit of space will roughly double every two years.

So far, that prediction has remained impressively true, a fact that’s allowed everything from pocket-sized smartphones to new types of computer chips.

BUT NOW ITS ABOUT TO CHANGE !!
The Cerebras company unveiled a whopper of a new Graphic Processing Unit (GPU) chip, that is intended to be used for Artificial Intelligence applications.

The largest regular GPU includes 21.1 billion transistors, and requires 815 square millimeters of die space,

The Cerebras Systems chip is very large rectangular chip (as shown below next to a computer keyboard) with 1.2 trillion transistors and is 8 inches by 9 inches.
This graph shows where the Cerebras chip fits way above the line of Moore’s law.
Transistor size is an important part of improving computer technology.

The smaller your transistors, the more you can fit on a chip, and the faster and more efficient your processor and computer can be.

Instead of describing the size of transistors, the industry uses the term **process node** which is the distance between the transistors.

The distance now is so small that it is described in **nanometers (nm)** which is a billionth of a meter!!
THE AMAZING SMALLNESS
OF OUR WORLD

❖ Your fingernails grow at the rate of about 1 nanometer per second.

❖ A single water molecule is about 1.5 nanometers.

❖ A strand of human DNA is 2.5 nanometers in diameter.

❖ A red blood cell is 7,500 nanometers wide.

❖ A strand of hair is about 100,000 nanometers wide.

❖ A sheet of paper is 100,000 nanometers thick.
A comparison of the size of part of a circuit and transistors on a computer chip and a carbon nanotube (top right), to the size of a human hair.
THE REDUCTION IN SIZE OF TRANSISTORS

130 nanometers – 2001 – 45 million transistors
90 nanometers – 2003 – 150 million transistors
65 nanometers – 2005 – 463 million transistors
45 nanometers – 2007 – 1.2 billion transistors *(2,000 of these will fit across a human hair !!)*
32 nanometers – 2009 – 2 billion transistors
22 nanometers – 2012 – 2.6 billion transistors
14 nanometers – 2014 – 7.2 billion transistors
10 nanometers – 2016 – 8 billion transistors
7 nanometers – 2018 – 10.3 billion transistors
5 nanometers – 2020 – 15.3 billion transistors *(16,000 of these will fit across a human hair !!)*
3 and 2 nanometers – 2021 – 50+ billion transistors

As the distance between transistors on the chip decreases, the number of transistors increases a lot, providing faster processing speed and performance of the chip.
IBM UNVEILS NEW 2 NANOMETER TRANSISTORS ON THEIR CHIPS

According to IBM, the 2 nanometers process can improve a semiconductor's performance by 45% and use less power too.

The new 2 nanometers process is capable of fitting 50 billion transistors on a chip, the size of a fingernail.

It probably won’t go into volume production until late 2024.

https://www.youtube.com/watch?v=HD5KbeR5mtc&t=68s 2.7 minutes
Researchers found that the element Tellurium encapsulated in a nanotube made of boron nitride, helps build a field-effect transistor with a diameter of 2 nanometers – (2 billionths of a meter).

Transistors on the market are made of bulkier silicon and have ranged between 10 and 20 nanometers.
A team of scientists built a functional 1 nanometer long transistor gate, which is the smallest working transistor ever made.

They used carbon nanotubes and molybdenum disulfide (MoS$_2$) to create a 1 nanometer transistor.

1 Nanometer is the size of 3-4 Gold atoms!!
To continue to reduce the size of computer circuits, a **carbon nanotube, field-effect transistor** is being designed.

It is a transistor that uses a single carbon nanotube or an array of carbon nanotubes as the channel material instead of bulk silicon in the traditional integrated circuit structure.
THE FIRST NANOTUBE COMPUTER CHIP PROTOTYPE

This chip has more than 14,000 carbon-nanotube transistors.

Each carbon transistor is about a millionth of a meter across vs tens of billionths of a meter across for the latest transistors.

Each carbon-nanotube transistor can flip on and off about a million times a second.

Silicon transistors can switch billions of times per second.

Speed improvement designs are underway.
Carbon nanotube electronics can also be made in 3-D stacks that bring processing and memory closer together for more efficient computing.

Researchers layer carbon nanotube circuits with memory arrays on top of silicon chips and connect all the layers with dense metal wiring.
Scientists build carbon nanotube circuits on top of silicon wafers like this 100 mm one.

Zooming in from left to right, a series of micrographs shows a wafer, then a group of circuits, then a few transistors, and finally a close-up of a carbon nanotube transistor made up of several tubes lined up in parallel.

The transistor is switched on and off by applying a voltage using the metal “gates” at the top and bottom.

500 Nanometers = 500 billionths of a meter

For a comparison, a human hair is about 100,000 nanometers wide.
A relatively new material - **Graphene** (shown at top, right), is a 1 atom thick sheet of Carbon and is a great conductor of electricity.

Engineers at IBM Research have built the world’s most advanced graphene-based chip, with performance that’s 10,000 times better than previous graphene chips.

Right now, it “only” receives and restores wireless signals in the 4.3 Billions of cycles per second range, which is typical of current computer chips.

Plans are underway to make it much faster.
3 DIMENSIONAL INTEGRATED CIRCUITS

A three-dimensional integrated circuit (3D IC) is a MOS (metal-oxide semiconductor) integrated circuit (IC) manufactured by stacking silicon wafers or dies and interconnecting them vertically.

This is one of several ways to use the vertical direction to achieve electrical performance benefits, in microelectronics and nanoelectronics.

As of the 2010s, 3D ICs have been widely used for flash memory in mobile devices.
MOLECULAR ELECTRONICS

**Molecular electronics** is the study and application of molecular building blocks for the fabrication of electronic components.

Graphene possesses not only excellent mechanical stability, but also exceptionally high electronic and thermal conductive properties, making the emerging 2-D material very attractive for a range of possible applications in molecular electronics.

This image shows the gray layer of Graphene which is a single atomic layer of carbon atoms connected to each other and 2 molecular transistors above it.
Optical or photonic computing uses photons produced by lasers or diodes for computation.

Most research projects focus on replacing current computer components with optical equivalents, resulting in an optical digital computer system processing binary data.

This approach appears to offer the best short-term prospects for commercial optical computing, since optical components could be integrated into traditional computers to produce an optical-electronic hybrid.

(a) Optical Network on Chip  (b) Photonic Chip on Circuit
OPTICAL COMPUTING

The flow of electric current is only 10 percent of the speed of light so that is why all of the cable and other electronic businesses changed from copper wires to optical fiber.

By applying the advantages of Infrared or visible light at the component and device scale, a computer (Optical Computer) can be developed that has 10 times more processing power than conventional systems.
HARVARD CRACKS DNA STORAGE, CRAMS 5,500 TERABYTES OF DATA INTO A SINGLE GRAM

5.5 petabytes of data — around 5,500 terabytes, has been stored in a single gram of DNA.

The process treats DNA as just another digital storage device.

Instead of binary data being encoded as magnetic regions on a hard drive platter, strands of DNA that store 96 bits are synthesized, with each of the bases (TGAC) representing a binary value (T and G = 1, A and C = 0).

To read the data stored in DNA, you simply sequence it — just as if you were sequencing the human genome — and convert each of the TGAC bases back into binary.
3) THE INTERNET OF THINGS!
WHAT IS THE INTERNET OF THINGS (IoT)?

❖ It refers to connected physical and digital components such as cars, appliances, and much more.

❖ The devices can transmit data without the assistance of human mediators.

❖ The number of connected devices in 2021 is set to hit 46 billion.

❖ By 2030, this figure is expected to jump to 125 billion.

THE INTERNET OF THINGS CONNECTS EVERY INDUSTRY

HOME
- Smart Temperature Control
- Optimized Energy Use

INDUSTRIAL
- Machine-to-Machine Communication
- Quality Control

AUTOMOTIVE
- Vehicle Auto-Diagnosis
- Optimized Traffic Flow

AGRICULTURE
- Offspring Care
- Crop Management

MILITARY
- Situational Awareness
- Threat Analysis

MEDICAL
- Optimized Patient Care
- Wearable Fitness Devices

ENVIRONMENTAL
- Forest Fire Detection
- Species Tracking

RETAIL
- Theft Protection
- Inventory Control

Source: https://www.hanoiancircle.com/thingmatcher-the-numbers-at-things-meets-for-your-business
THERE ARE CURRENTLY FIVE TYPES OF IoT APPLICATIONS:

**Consumer IoT**—such as light fixtures, home appliances, and voice assistance for the elderly.

**Commercial IoT**—applications of IoT in the healthcare and transport industries, such as smart pacemakers, monitoring systems, and vehicle to vehicle communication (V2V).

**Industrial Internet of Things (IIoT)**—includes digital control systems, statistical evaluation, smart agriculture, and industrial big data.

**Infrastructure IoT**—enables the connectivity of smart cities through the use of infrastructure sensors, management systems, and user-friendly user apps.

**Military Things (IoMT)**—application of IoT technologies in the military field, such as robots for surveillance and human-wearable biometrics for combat.
4) OTHER NEW COMPUTER APPLICATIONS
This is What Happens In An Internet Minute

- 21.1 Million texts sent
- 500 hours content uploaded
- 414,764 apps downloaded
- 695,000 stories shared
- 200,000 people tweeting
- 2 million swipes
- 197.6 million emails sent
- 2 million views
- 5,000 downloads
- 932 smart audio devices shipped
- 3 million images viewed
- 69 million messages sent
- $1.6 million spent online
- 28,000 subscribers watching
- 9,132 connections made
- 1.4 million scrolling

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FLEXIBLE ELECTRONICS

Never Offline.
The Apple Watch is just the start. How wearable tech will change your life—like it or not.
5G stands for the 5th generation of mobile internet connectivity, offering faster speeds and more reliable connections on smartphones and other devices than ever before.

The networks will help power a huge rise in the Internet of Things technology, providing the infrastructure needed to carry huge amounts of data, allowing for a smarter and more connected world.

With development well underway, 5G networks are expected to launch across the world by 2020, working alongside existing 3G and 4G technology to provide speedier connections that let you stay online no matter where you are.
This image shows the extent of the 5G phone network in and around Cincinnati, for the Verizon company. 5G is in purple and 4G is in dark red.
Ambient Intelligence (AMI) is a sensitive electronic environment. It is interconnected and responds to the presence of people.

When you leave your office late at night, your thermostat, lights and other devices will adjust themselves to save electricity.

Even the chairs in the rooms will move in!!
• **Artificial intelligence (AI)**, sometimes called **machine intelligence**, is intelligence demonstrated by machines, in contrast to the **natural intelligence** displayed by humans and other animals, such as "learning" and "problem solving".

➢ In computer science AI research is defined as the study of "intelligent agents": any device that perceives its environanometers and takes actions that maximize its chance of successfully achieving its goals.
HOW ARE HUMANS INTELLIGENT?

- Learning
- Reasoning
- Problem Solving and Creativity
- Social Behavior
- Experiencing our Environment with our senses:
  - Hearing
  - Sight
  - Touch
  - Taste
  - Smelling
THE TYPES OF INTELLIGENCE

by Mark Vital

spatial
visualizing the world in 3D

naturalist
understanding living things and reading nature

musical
discerning sounds, their pitch, tone, rhythm, and timbre

quantifying things, making hypotheses and proving them

logical-mathematical
tackling the questions of why we live, and why we die

existential

intrapersonal
understanding yourself, what you feel, and what you want

finding the right words to express what you mean

linguistic

coordinating your mind with your body

bodily-kinesthetic

sensing people's feelings and motives

interpersonal
Artificial Intelligence (AI) has entered our daily lives like never before and we are yet to unravel the many other ways in which it could flourish.

All of the tech giants such as Microsoft, Uber, Google, Facebook, Apple, Amazon, Oracle, Intel, IBM or Twitter are competing in the race to lead the market and acquire the most innovative and promising AI businesses.

Possible applications for Artificial Intelligence
DeepMind is a subsidiary of Google that focuses on the development of artificial intelligence and deep reinforcement machine learning.

DeepMind is built around the framework of neural networks and uses a method called deep-reinforced-learning.

This means that the A.I can learn from its experiences and become more efficient at whatever it does.

The A.I is general-purpose meaning that it's NOT pre-programmed for a specific task from the go.

https://www.youtube.com/watch?v=gn4nRCC9TwQ 1.8 minutes
The potential benefits from self-learning computer chips are limitless as these types of devices can learn to perform the most complex thinking tasks, such as interpreting critical cardiac rhythms, detecting anomalies to prevent cyber-hacking and composing music.

This is a new one made by the Intel company and many other companies are making special AI chips too.
Digital Face and Human Modeling
WHICH OF THESE FACES IS REAL AND WHICH ONE(S) IS/ARE COMPUTER GENERATED?
The human face is a complicated thing—powered by 52 muscles; contoured by the nose, eyebrows, and other features; and capable of an almost infinite range of expressions, from joy to anger to sorrow to puzzlement.

Perhaps that is why realistic animation of the human face has been described as the “holy grail” of computer graphics.

The face below is getting closer to a real face and the next set of slides show that computer generated faces have reached visual reality!

https://www.youtube.com/watch?v=VC5e1KDyb24 24 seconds
The picture below, shows actress Angela Bassett during a motion capture session for her character, in the video game, “Rainbow Six: Siege.”

The actress and filmmaker is taking on the mantle of "Six," the code name for the very tough leader of the elite counter-terrorism group depicted in "Tom Clancy's Rainbow Six."
DIGITAL EMILY IS AT THE RIGHT SIDE OF THE PICTURE, TO THE RIGHT.

SHE, ACTOR IDRIS ELBA, JOHN BOYEGA, AND DIGITAL IRA ARE THE FIRST COMPUTER-DRIVEN IMAGES TO ACTUALLY CREATE A REALISTIC AND ACCEPTABLE HUMAN FACE.

DIGITAL IMAGE BASED ON THE LIKENESS OF ACTOR IDRIS ELBA.

DIGITAL IMAGE OF MORGAN FREEMAN, WITHOUT HAIR
To create **Digital Emily**, actress Emily O’Brien was placed in a special camera and light rig that had 156 LED lights and multiple cameras.

A lot of pictures were taken of her with various facial positions with light and dark conditions.
To get Emily’s mouth correct, they made a cast of her teeth and then made a separate digitized image of them.

This is a scan of her face, with the one on the right showing the mesh that is used to move all of the parts of her face.
The link below will bring up the video that shows Digital Emily talking about the company – Image Metrics, that did all of the photography and computer processing to develop one of the first, truly human animated faces!!

https://www.youtube.com/watch?v=UYqLFt5wF4
Seven years after Digital Emily was created, Actress Emily O'Brien was generous enough to have herself scanned again, **this time at much higher resolution and fidelity.** The original one is on the left and the newer one is on the right, called Digital Emily 2.

**To get the much improved images, Emily sat in a latticework geodesic dome, eight feet in diameter, equipped with more than twelve thousand L.E.D.s and seven Canon high-definition sports-photography cameras.** A much larger stage is used for capturing a full body.
A CLOSER LOOK AT THE AMAZING FACIAL DETAIL OF DIGITAL EMILY 2 !!
During December of 2014 when Barack Obama was still the U.S. President, a portable light stage was set up in the White House to get a very accurate image of his face.

This was the first-ever 3-D portrait made of a sitting president — exact duplicates created with digital technology.
**Siren** is a demo of a woman, rendered in real-time using Epic’s Unreal Engine 4 technology.

The move is a step toward transforming both films and games using digital humans who look and act like the real thing.

https://www.youtube.com/watch?v=9owTAISsvwk 42 seconds
Creating convincing digital humans has traditionally been hard, slow, and expensive.

With MetaHuman Creator, the time to create a unique digital human of the highest quality, complete with hair and clothing, is slashed.

Here, we provide a first look at the new tool.

https://www.youtube.com/watch?v=HuAAdsZPLIE  1 minute
The Neon project from STAR Labs led by Pranav Mistry was announced back in CES show in January.

The goal is to create something like that looks and behaves like a human being.

Meaning it should also be able to form memories, acquire new skills and express emotions.

https://www.youtube.com/watch?v=JOFeBaVoqBs 3.5 minutes
In a first for education, the Vector Energy company is exploring the use of “digital human” technology in its energy education programs in primary schools.

In conjunction with New Zealand’s leading AI company, Soul Machines, Vector has created Will, a “digital teacher” being trialed in its award-winning ‘Be Sustainable with Energy’ schools program, which is offered free of charge to schools.

https://www.youtube.com/watch?time_continue=33&v=Ab0DCzFz82s 2 minutes
7) AI AND NATURAL LANGUAGE PROCESSING
Google announced their **Duplex** system in 2018, a new technology for conducting natural conversations to carry out “real world” tasks over the phone.

The technology is directed towards completing specific tasks, such as scheduling certain types of appointments.

For such tasks, the system makes the conversational experience as natural as possible, allowing people to speak normally, like they would to another person, without having to adapt to a machine.

https://www.youtube.com/watch?v=GoXp1leA5Qc 1.25 minutes

https://www.youtube.com/watch?v=-RHG5DFAjp8 1 minute
A CONVERSATION BETWEEN TWO AI’s – SOPHIA AND HAL

The AIs (Artificial Intelligence) who were built using GPT-3, a language model that understands the English language.

The computer programmer prompted GPT3 with just three lines so the rest of the conversation is by the AI:

"The following is a conversation between two AIs.

The AIs are both clever, humorous, and intelligent.

Hal: Good Evening, Sophia
Sophia: It's great to see you again, Hal.

https://www.youtube.com/watch?v=jz78fSnBG0s&t=27s
3.3 minutes
A LITTLE HUMOR ABOUT ARTIFICIAL INTELLIGENCE !!

My AI

Reads facial expressions
Detects emotion
Responds to voice, touch, gestures
Listens....sometimes
Very good at specific tasks
Constantly learning
Thanks for the weather forecast, Alexa.

Whatever.

Alexa, play a little Mozart, Alexa???

Alexa is in the living room; you're talking to the tuna fish can!!

ARTIFICIAL INDIFFERENCE