Computing and Information Systems: Alive?

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Introduction

A computer is nothing more than a complex network of adding machines. Connecting multiple computers together changes nothing. However, the addition of two ingredients, instructions and data, make the simple computer a wondrous and amazing tool. The source of each of these ingredients is and forever has been ultimately humans. However, the current growth of computers is changing the rules, where computers now tell each other what to do and humanity fades into the background. In the coming future much is possible, and as a society we must be aware of what is taking place. We must maintain our awareness against the ebb and flow of technology so that we are not swept away or drown by its force.

A Brief History of Computers

The abacus was the first computer, developed thousands of years ago in ancient Asia. This began the development of artificial devices to increase the mathematical abilities of humans. The most widely recognized mechanical representation of a computer was designed, but never fully built by Charles Babbage, programmed by Augusta Ada King, Countess of Lovelace in 1822 and was called the Difference Engine. The next major use of mechanical computing was used by the United States for the 1890 census by using a punch card system developed by Herman Hollerith.

A handful of computers were developed that utilized electricity and some form of mechanical motion. The Mark I was developed to calculate charts for the US navy and used electromechanical relays. Other partially electric computers were developed such as the British code-breaking Colossus and the German Z3. These computers, along with subsequent advancements were primarily built for governmental and military use, especially as World War II erupted.

The first generation of true electronic computers began with the use of the vacuum tube also known as the electronic valve. This evacuated glass bulb contained elements where electricity could be used to directly control electricity. The first is the ENIAC, or Electronic Numerical Integrator and Computer, built 1946 at the University of Pennsylvania by John Presper Eckert and John W. Mauchly. The ENIAC used 18,000 vacuum tubes to perform up to 5000 addition operations per second. This was followed by other such computers as the EDVAC, UNIVAC I, and ABC.

The second and third generation computers were based on a new technology, the semiconductor. Second generation computers used transistors, while third generation computers were based on the microchip, thanks to Jack Kilby of Texas Instruments. These newer computers, although more complex in nature, could be programmed using languages that were simpler and easier to understand.

The fourth generation of computers began with very large scale integration (VLSI) microchips. VLSI allowed for most of the computing power to be packed onto one chip. The first VLSI chip used in the market was the 4004 by Intel in 1971. From then on forth generation computers have been with us, with the IBM Personal Computer released in 1981. However, a growing segment

of technology focuses on fifth generation machines, which are the ultra high end of ultra-fast computing. These computers approach the level of HAL 9000 from Arthur C. Clarke's 2001.

Current Computing Technology

The current fourth generation technology is still advancing. As of December 10th 2000, $2000 will buy a very powerful computer complete with monitor, printer, and software from a very reputable manufacturer. For example, a computer purchased from Dell will have a 1 GHz Pentium III processor, 256 MB RAM, 80 GB of disk space, various input and output options (sound and video) and a plethora of other features. By next week, the price will undoubtedly drop a few dollars. However, the fourth generation microprocessors have found their way further into today's market.

Many people today in the United States own either a desktop or laptop computer. What many people do not realize is that they most likely own many more computers. Most televisions, microwaves, telephones, clocks, refrigerators and even toys contain a microprocessor, the heart of a computer. Even daily interactions involve computers: cars, ATM machines and gas pumps. These computers can be very simple, however they are faster, smaller and more efficient than their previous analog counterparts. But these wonderful small computers are only the babies of a much larger family, where giant computers run the stock market, the banks, the government, and the hospitals. In essence, it is almost impossible to escape from computers and with their importance in our society, would anyone really want to?

When consumers used to visit the computer store, a salesman would greet them and help them pick out a wonderful bland gray box. Adventurous people interested in technology could even open the boxes and add more parts. Today, it is almost impossible to buy that bland gray box. A happy salesman is trying to sell the consumer a "grape" or "blueberry" one. Consumer electronic devices continue to include more and more features, with more colors and transparency. Shopping has moved online, where e-tailors sell their wares using flashy moving graphics in lieu of content. The favoring of form over function dominates the rosy picture that is today's technology market. One can now buy a personal computer, desk, iron, and vacuum cleaner that all match.

A government program called the Accelerated Strategic Computing Initiative or ASCI, was created as a safe method of computationally testing the United States' nuclear stock pile without physically detonating devices to comply with 1996 Comprehensive Test Ban Treaty. IBM delivered the most recent computer this year for about $110 million, called ASCI-White. This computer is now the most powerful machine on the planet, capable of over 12.3 trillion mathematical operations per second, which is over one thousand times more powerful than the chess-playing Deep Blue computer that beat Gary Kasparov in 1997. IBM has plans however, for a computer even grander named Blue Gene.

Near Future of Computing and its Pervasiveness

Blue Gene will be built by 2004 for about the same cost as ASCI-White. It will be capable of over one Pentaflop, meaning over one quadrillion operations per second. This is thought of as

only one order of magnitude below the theoretical operating speed of the human brain. The fantastic speed will be achieved by using 64 racks of 8 boards of 64 chips each housing 32 processors operating at one gigaflop each, making a total of over one million processors. The total available bandwidth to move data around is 300 terabytes per second, enough to download the entire Internet in less than a half second. Blue Gene will be used by researchers for advanced studies of protein folding. In this field, the mechanics of atoms in complex molecules will be studied, such as in genetic testing and drug synthesis, in a manner never before available. What is amazing, however, is the speculation by IBM and others that this power will be available to universities within ten to fifteen years, and to consumers soon after.

The personal computer may become a thing of the past in favor of a paradigm shift towards a more ubiquitous method of computing. The consumer will be affected by the explosion of more advanced computers into everyday life. However, he may not be able to see the computers. In the case of Blue Gene engineering new foods and medicines, consumers will benefit without seeing the computers. Advanced computers built into homes will help to regulate energy usage, maintain appliances, and provide entertainment.

The network computer (NC) is not a new concept but one from the beginning of computers. Many terminals, with little use or function individually would be connected to a massive central mainframe computer. Similarly, the NC does not have much to offer on its own, but connected to a larger system it provides many features. Following this trend is the current market of PC's, with happy colors and shapes, and all of the hardware permanently attached. Such computers as the Apple iMac, the Compaq Home Internet Appliance, and the 3com Audrey have pushed the limits of being called personal computers and advanced upon the newest generation of consumer computers. What sells these devices is the focus on the Internet. The 3com Audrey isn't even a full computer, but a wireless web terminal with only a screen and a touch pad. Interestingly enough, some colleges are following the trend with "tech-lite" educations that budding students are asking for. In the new fields such as computer information systems, heavy engineering practices and mathematical sciences are left behind for the newer fun style of technology, further removing the true workings of computers from those who use and now those who make them.

Internet and the Shift to Valuable Information

The Internet was built to share information, mainly between higher educational institutions and the government, but as it evolved it then became a versatile medium to share all sorts of information. As the infrastructure grew, so did its uses. Hence, we have the Internet as it exist today, with almost one hundred million registered hosts, or network providers, with millions of more users. The Internet is now used to share ideas, to conduct commerce, to listen to music, to cry out, and to be heard. The Internet can be a TV station and a store for every person who uses it, which is why it has such an impact on society. The internet is growing at such a high rate, the system for naming each computer known as IPv4 is being upgraded to IPv6 raising the possible number of host computers to about 10^14 from about 4 billion despite a completely new internet known as I2 being developed.

The reason for this growth is so that more computers, large and small can be connected to the Internet. The underlying and almost hidden goal is to get every person on the Internet in some

manner so they are always connected. The growing shift for consumer electronics devices is to include wireless technology and somehow the Internet: cell phones, pages, digital assistances and children's toys. The true need for this is almost nonexistent, but the consumer demand is insatiable and the industry is forging ahead at a breakneck pace. In the future, today's Internet could become a mental connection and contain the entire human knowledge. With over 6 billion people connected and countless computers, something could exist in that sea of information, something unexpected.

Double Exponential Growth

Moore's Law was based on an observation Gordon Moore in 1965, when he noticed that the speed and memory capability of semiconductors doubled about every eighteen months. His linear relationship to growth held true for about twenty years. However, in the early 1980s, the time of doubling decreased to only about twelve months. Previous to 1965, before solid-state computers existed, the growth was actually slower. Generalizing the trend to include major tools of humanity, the growth rate has been extremely low, until about the time of the industrial revolution, at which technology started to advance at a quicker and quicker rate. Using this viewpoint, the speed that technology advances is actually increasing in a manner known as double-exponential growth.

An interesting note is that in the evolution of human history, we have yet to level off. In any one technology, the capabilities increase rapidly and then plateau in a curve known as sigmoid. However, humans are unique in our ability to shift paradigms at the point of saturation to a new model. This is evident in computer technology: mechanical, electromechanical, vacuum tubes, discrete transistors, and integrated circuits. Integrated circuits have their limit as to speed and density based on the laws of physics. However, we are developing new technologies currently that will overstep two-dimensional integrated circuits by many orders of magnitude.

A view of the future is held again by IBM in a field called quantum computing. Quantum theory is not new, and neither is quantum computing. Isaac Chuang has working on quantum computers since the late 1980s. Recently, Chuang developed the one molecule 5-qubit quantum computer at IBM Almaden Research Center. A qubit is the quantum equivalent of a digital bit. Chuang's computer was built using five fluorine atoms in one molecule, each representing one qubit. It was built to solve order-finding problems, which are basically methods of decryption. In today's computers, even Blue Gene, order-finding problems are step-by-step algorithms. Although the method may change, it still takes much iteration to find the answer. However, in quantum mechanics, each qubit can occupy simultaneously all possible input values due to the Heisenburg uncertainty theorem. This means that any problem can be solved in only one step. Traditional algorithms must exponentially expand the needed computing power as the problem gets bigger, while the quantum computer uses only the number of atoms needed to encode the input and output values.

The result is a computer that can be built on the atomic scale, similar to nano-technology. In that light, the quantum computer can be used to control nano-technology, and in turn nano technology can be used to build more quantum computers. Computers are shrinking, computational power is increasing, and consumers' awareness of direct computing is decreasing

and the reach and use of computers is growing similarly to their power. Many prominent members of the technological and scientific community have theorized the results of this growth, some with positive outcomes, and some with negative outcomes.

Speculations: Ray Kurzweil

Ray Kurzweil, a serious inventor, technologist and futurist, is the author of The Age of Spiritual Machines: When Computers Exceed Human Intelligence. He has made some advanced prophesies into the future of not only computers, but also computer intelligence, nano-technology and genetics. Ray makes a very important point about predictions:

> ….technology, particularly the pace of technological change, has been advancing at least exponentially since the advent of technology. Thus, while people often tend to overestimate what can be achieved in the short term because there is a tendency to leave out necessary details, we typically underestimate what can be achieved in the long term because exponential growth is ignored.

By 2009, Ray expects computers to become ubiquitous to most users. He also expects high-resolution displays everywhere, operating on wireless networks and interfaced using speech instead of text or touch. A one thousand dollar computer should be capable of performance equivalent to a machine today of one Terahertz. Jumping Ahead to 2019, the thousand-dollar computer should be roughly equal to the human brain in capacity, but most computers are embedded into everything and never seen by the consumer. High-resolution 3D virtual reality machines include the capability to handle tactile information. Automated computing systems have advanced to the point where most transportation is no longer human controlled. A large number of claims are being made at this point of computers passing the Turing Test, meaning that humans cannot discern the artificial intelligence (AI) of the computer from real intelligence.

After this point, Ray's predictions begin to get a bit irrational. However, what *is* rational is that no matter who is predicting what, no one path has been set and anything is possible. An important reason for this is what ray refers to as the rate of paradigm shifts, which he claims are doubling approximately every decade. Sometime around 2029, Ray predicts that today's equivalent of a one thousand dollar computer will have the capabilities of one thousand human brains. There is almost no use of human labor for majority of manufacturing. The computers existing could be connected directly to humans via biotech implants and connections. The artificial intelligence of a complete, worldwide, and connected network of computers has created a new level of knowledge independent of human interaction. Therefore, growing legal issues are rising about what defines "human," where machines may even claim to be conscious. By 2099, the prediction for total integration of man and machine has blurred the lines of humanity.

Ray Kurzweil paints a picture of the assimilation of the computer into our own humanity as almost inevitable. However he does raise the issue of the safety and use of technologies. Bill Joy, the cofounder of Sun Microsystems labels the new technologies of genetics, nano-technology and robotics (i.e. artificially intelligent computers) as dangerous. Ray says he is often found defending Bill Joy's theories on the feasibility of these technologies, in the ability of man to build. However, in contrast Joy, who favors the complete abolition of certain technologies and sciences to prevent the destruction of humanity, Ray is certain that careful planning and regulation is more appropriate and the only sane way to proceed.

Speculations: Isaac Asimov

Isaac Asimov has always been a favorite to almost any science fiction buff. However, being a scientist, Asimov has also written many non-fiction books. In 1939, Asimov wrote a science fiction book I, Robot. In it, the robots are different from the robots of today by the nature of their brain. Asimov's robots are controlled by a positronic brain, extremely complex and powered by the simultaneous destruction and creation of subatomic matter. His robots have an artificial intelligence that is very similar to humans but controlled by the Three Laws of Robotics to prevent the dangerous scenarios proposed by Bill Joy: 1) a robot may not injure a human being or through inaction, allow a human being to come to harm 2) A robot must obey orders given it by human beings except where such orders would conflict with the First Law 3) A robot must protect its won existence as long as such protection does not conflict with the First or Second Law. Interestingly enough, although Asimov's robots were usually very compact and at least somewhat intelligent, the computer did not exist outside of ultra large machines. In certain stories, giant planet wide computers with names such as MultiVac and UniVac took in all data and processed it for humanity, following the Three Laws. In one story, the computer MultiVac predicted the outcome of the presidential election by just the vote of one person, a far cry from the recent stagnation in Florida.

In 1987, Asimov gave two speeches at the College of William and Mary about his predictions. On the topic of the feasibility of his worlds, he agreed that although far fetched at present, that the existence of artificial intelligence was not only possible but also being worked on and he was currently authoring non-fiction material on the need for the Laws of Robotics. However, the ability for humanity to create the technology he writes about requires the drive to do so. If as a society, we choose not to colonize Mars, Mars will never be colonized. Similarly, we could choose self-destruction, for only by choosing to survive will we be able to. A short time before this talk, Asimov spent a lot of time prophesizing the destruction of humanity through almost any means, with a growing concern for technology. But, the response has been to meet the challenges of the long term with care, and to worry less about the short-term political conflicts that seem to take all the news time today.

An important concern is raised by many groups and individuals about the necessity of man post technology. In a world run by computers and robots, the utopian view is that humanity will have the chance to focus on what they like best and time to explore new realms. While the dystopian view envisioned humans dying out for lack of drive and purpose. Asimov addresses this issue by reminding us that humans have free will. Despite the use of robots, we individually will still have the choice to do whatever task we find fulfills our life. But interesting and scary scenarios exist in Asimov's future world with thinking robots.

It is possible for, as Ray also suggests, computer intelligence to become indistinguishable from humanity. Once a consciousness recognizes its own existence, does that make it sentient and therefore worthy the same benefits of humanity? Similar plots are played out in Asimov's stories "Evidence" and "Reason." Or furthermore, what happens when the artificial consciousness believes that it is superior to its human counterparts? In "Little Lost Robot," this scene is played out, but is resolved by human ingenuity and the Three Laws. Such occurrences

could become possible in the near future as computers grow in power and artificial intelligence software and systems grow in ability.

Speculations: Vernor Vinge

Vernor Vinge of the Department of Mathematical Sciences at San Diego State University painted a more sinister picture in a paper called "The Coming Technological Singularity: How to Survive in the Post-Human Era." The main point is the coming technological singularity. Using the double acceleration of technologies on all fronts, not just computers, Vinge hypothesizes that in the near future, the power of technology will overtake human understanding at even the most fundamental level. He suggests that the three most powerful occurrences that would be the signifiers of such a singularity: a computer system is developed to be awake and intelligent, large computer networks wake up as an intelligent entity, computer/human interfaces become so advanced, the two parts no longer are separable. Using his own predictions and those of others, Vinge believes one of these will occur no later that 2030 and soon after 2005.

The term singularity is used to illustrate that the entire method of life must be thrown out to sustain life in a new era of intelligent machines. Vinge makes reference to a statement in 1960 by I. J. Good. Good says that once we create a machine that surpasses our abilities as humans, we no longer have to build anything, as the machine will be capable of creating an even more intelligent machine on an even shorter time span. Within a few generations, the new machines would be free of any restraints we had put on the original and we would be at the mercy of the computers. The introduction of safeguards and rules into the technology would, according to Vinge, have no effect other than to bring the work of things more dangerous or forbidden underground. Vinge even attacks Asimov as saying that despite safeguards, human competition alone would ensure the coming of the singularity

What is more significant now is the theory of Intelligence Amplification (IA), whereby a computer is connected to a human in a form of assistance. To Vinge and many others, this is even closer to reality than autonomous artificial intelligence. It starts with ubiquitous computing; where the users don't even have to know they are interacting with a computer. As the system networks into a worldwide and then integrated system, it is the system as a whole, which is then the group mind of humanity.

Dependence on Computers and the Digital Divide

Before the issue of artificial intelligence even begins to be an issue, the dependence on the computer as a tool is a problem in itself. Today, the immediate elimination of computers throughout the world would cripple everyone. There would be no food to buy, to car to drive to buy it, no money to pay for it, no stock market to determine the value of it, and almost no government to watch over it all. The elimination of computers today would push us back farther than the 1930s. The entire value system of the major economies of the world are based on technology, and negotiated over technology. Recently, the year 2000 bug passed without major incident, and the world breathed a sigh of relief. However, the damage that could have been done is enormous but only based on a few programming decisions in the 1960s. The effects of this will only get worse as time progresses and the dependence on technology grows even

further. For example, today computer viruses exist, but when they strike we have an infrastructure set up to handle them with some efficiency. A virus attack usually will not cause overall significant damage across society but is more a nuisance. However, as computers and networks expand, viruses may grow in power and danger as their effect will be able to grow.

In addition to transferring, controlling, and regulating money, computers cost money. A person with a computer today can find information faster and more efficiently, distribute thoughts and materials faster than a person who doesn't have a computer. Those with computers can sell and buy goods and services online via the Internet and in the process save money, in the end profiting from the purchase or use of the computer. The result is the displacement of those people unable to purchase a computer, or unable to use one. This displacement is known as the digital divide and will grow with the dependence on technology. Today, you must understand at least how to operate a simple computer even if working in McDonalds. What does that leave those without computers or computer skills in the near future?

The Luddite movement and the anti-tech movement

Both Bill Joy and Dr. Theodore Kaczynski support the renunciation of advanced technologies, especially genetic, nano-technology, and artificial intelligence. However, their methods of relinquishment differ significantly. Kaczynski was the infamous Unabomber of only a few years ago. Kaczynski is part of a faction of people that believe in the resistance or refusal of technology in favor of completely manual labor. Kaczynski is one of the most well know for writing a manifesto against technology, but many others have, also. Rosalind Williams from Massachusetts Institute of Technology said, "The fact that people are writing manifestos now means we are in the midst of something really important. It's inspiring people to write declarations that rethink social connections entirely." What makes this significant is that for all recent speculation, even conservative speculation, the current trend is not slowing. What scared Kaczynski and others the most was the possibility that humans won't directly give up control, but slowly come into a position where we are no longer able to turn away from machines decisions because doing so would be complete self-destruction. What is the most interesting is the differing levels of fear and technological repulsion luddites have. There are numerous websites online that exist only to share and distribute anti-technology information. Clearly, even these people realize the sweeping communication power of the Internet, just as the evangelists have done so with the television.

Artificial Intelligence, the Individuality, and the Authority of Man

Artificial Intelligence (AI) appears to be an attainable goal within the next 30 years. It also is a technology that brings much confusion. If possible, what would prevent the AI from being more advanced than humans and therefore assume a role of control? There are no laws, no rules, and no standards on how to deal with an AI should one be developed, save Asimov's Three Laws. Should AI be able to reason and think on its own, it could choose to question its existence and its purpose just as humanity has for thousands of years. But in that time, humanity has had many conflicts over who or what is right and wrong, and the uncertainty exists that we may have no control of the thoughts and actions of an intelligence created.

Furthermore, if an AI is capable of conscious and creative thought, does that make it human, or if not does that make it equivalent in some way to deserve the same as humans. Science fiction writers and scientists alike have analyzed the possibilities to no end and there is still no conclusive answer. Using Vinge's theory on intelligence amplification, how do the rules change, exactly how much human is needed to remain human? Asimov says that if we survive our evils and nature, there is little likelihood of significant change to humanity for hundreds of thousands of years. Yet, what if we create a new humanity?

Engineering Our Future

The possibilities for a very computerized society are very high; any other future is almost improbable. However, it is not known where the computers will take us, whether we as humans will be in control or the computers will hold the reigns of society. For this reason it is very important that the engineers in the field are careful and cautious. Furthermore, it is very likely that if a computing system existed that so deeply impacted humanity, the engineers would know about it far in advance of the politicians, the lawyers, the social scientists, and the public. On the other hand, the engineers may be so involved with their own handiwork that they may not see the dangers of their own work.

Although an engineer cannot be responsible for the final use of their design, they should be aware of the benefits and risks on a broad scale. Engineering is a profession in addition to being a job, because an engineer has control of very specialized knowledge that is not held by the general public. This is much the same as physicians are regarded as professionals. However, becoming and engineer requires only four years at an undergraduate college, which separates engineering from other professions. It is even more important then that engineers follow a code of ethics because their knowledge is capable of doing as much harm as good. As such, it is the responsibility of the engineer to not only make certain that the their design is efficient and fits the design requirements, but also to make sure it is a legal and ethical product. Despite the cadre of lawyers that tend to follow everyone around waiting for a slip or to make a judgment, it is still up to the engineer in the end. The engineer must be aware of the uses and reasons for the technology he may be developing.

Today in colleges, there is a push for teaching what is known as the engineering design circle. The main steps are: definition of the need and problem, research, constraints/criteria, analysis, specification and then repeat. By repeating this process continuously during the design and manufacture of a product, all the little kinks and hiccups can be ironed out. But it also gives the engineer a chance to review and check on the implications of their work. This is the time for the ethical decision for a go or a no go, either to ones self or to the proper authority.

Despite the fact that most engineers, especially in the realm of advanced computer science, will be working for a company or the government, it is paramount that the engineer's responsibility is placed properly. The safety and protection of the public should be first and foremost, followed by the interests of his or her employer, fellow professionals, science, and himself. This very important in such a case where a company may ask an engineer to develop a computer technology that would harm the public directly. It would be the engineer's responsibility to blow the whistle, either to fellow professionals or the company, and if that does not work, then finally

to the public. However, it is also up to the engineer to be a whistleblower on his or herself if the situation would call for it.

Unfortunately, while the method of making ethical engineering decisions is being taught throughout the country, the system does not help without the open discussion of peoples' personal ethics and morals. It is very difficult and even shunned for people to report against others in their field or against a company they may be very loyal to. However, it is very important if we are to prevent the surprise takeover by machines as has been theorized by many people.

Conclusion

The future holds a plethora of opportunities. One of the greatest and possibly most profound is the ability to remove the need for humans to control certain aspects of our life through computerization and artificial intelligence. It is possible that the technology will develop very rapidly, and so as a society, and as engineers, we must maintain vigilance and practice care and reason to ensure we survive as a species. The question we should no longer ask ourselves is, "can we do it," but rather, "should we do it". In this way, we can let the benefits of these amazing technologies enrich our lives.

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