Computing Outlook

Jim Mathews, MS, APF

The Futures Network, LLC
5035 Jazz Lane
Salt Lake City, Utah 84117, USA

+1 801 231-1702
jim@thefuturesnetwork.com

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the FUTURES network ™

The intent of this outlook is to give the reader an understanding of some of the major trends within the Computing domain by providing a framework for understanding some of the forces in operation. This is not a detailed analysis, and therefore does not contain footnotes or references. Readers who have been following developments in Computing will already be familiar with many of these trends.

Moore's Law

Moore's Law states that the number of components on an integrated circuit will double every eighteen to twenty-four months. What this means for Computing is that the computing power available on a chip doubles approximately every two years. This usually results in chips that are twice as fast and, ultimately, in computers that are twice as powerful. There is debate about whether the rate of doubling still holds, and how long it will continue, but the end result of this exponential progress is an embarrassment of riches for the Computing domain for as long as this doubling continues. For example, a significant part of the reason that mapping the human genome took ten years rather than the originally planned fifteen was the increase in computing power that was manifest during the course of the project.

Continuous doubling means exponential growth. There are other exponentials operating in or near the Computing domain. The performance of (chip-based) memory also doubles every eighteen to twenty-four months. Storage capacity and network bandwidth are currently doubling every twelve months. The result of all of this exponential growth is that processes that once seemed too large to perform economically become doable and then common place within a limited number of doublings.

The Singularity

As exponential growth continues, and the speed of the most powerful computers approaches the theoretical operational speed of the human brain (10,000 teraflops as estimated by Ray Kurzweil), there is speculation about what will happen when computers do reach that speed. One theory advocated by Kurzweil and Vernor Vinge is that there is a "technological singularity", an event horizon beyond which we can not see (like that surrounding a black hole) at the point where computers become intelligent. While certainly possible, the singularity is far from a certainty. Researchers do not yet know how a mind as complex as the human mind works. Can a single computer, a group of computers, or even the network become intelligent? No one knows, but developments in this area are definitely worth monitoring.

Convergence

As communications and entertainment become digital, they are moving onto the network. This will affect computing as devices evolve to support this convergence. Computers already support entertainment (music, movies, and games) and communications (eMail, telephony and document sharing) as well as traditional computer functionality. Now other devices are evolving to support multiple functions. PDAs are expanding their networking capabilities and adding telephony features. Cellular phones are expanding their PDA capabilities and adding data networking capabilities. Both of these device types are supporting various entertainment options.

Logic dictates that the number of devices delivering redundant capabilities will be reduced by marketplaces forces. In the long term, these devices will be subsumed into the outcome of the Ubiquitous Computing trend; in the meantime, there will be a chaotic marketplace for a varying array of handheld devices.

Topics in Computing

If we try to develop a taxonomy of the Computing domain, we can easily create a lengthy list of fuzzy, overlapping categories. Rather than that, we should concentrate on a few key categories while acknowledging that not every development will fit into them. Two categories, hardware and software, are the foundational layers that computing is built on; the other three, business, home, and games, are three key application areas.

Hardware

Hardware is what many people think of when they hear the word computer. Most people can identify several different types of computer hardware: server, desktop PC, laptop PC, PDA, etc. Two important ongoing hardware trends that you can expect to continue are miniaturization and more efficient power usage.

Hardware is the foundational layer of computing upon which the software rests. While hardware will not physically disappear, it will ultimately move behind the scenes (or at least behind a pervasive user interface) and become invisible to most computer users.

CPU

The impact of chip speed on Computing was discussed earlier, but decreasing cost is another important factor. While the latest chips are usually expensive, the cost drops dramatically within one or two years. Chips that were once found in top of the line PCs are now commodity items. This means that the incremental cost (as opposed to the initial development cost) of making an object “smart” can be relatively low. CPU chips become both faster (the new ones) and cheaper (the old ones) as time passes, so look for more everyday objects to have chips (and improved functionality) embedded in them. There are two conflicting trends in CPU development that are worth watching. The quest for ever faster CPU chips has resulted in higher power consumption for high performing CPUs. This means these chips give off more heat and require more cooling. On the other hand, CPUs are needed for low-power environments (PDAs, laptops, etc.) that require only a fraction of the power and that can vary their speed depending on power source.

Memory

Memory is also built on chips. That means that as the number of components that can fit on a chip doubles per Moore's Law, the amount of memory that will fit on a chip increases, the time in takes to store and retrieve information decreases (fast memory is necessary to leverage CPU performance improvements), and the price of memory chips will continue to drop rapidly. The amount of memory in a computer can dramatically affect performance. Non-volatile Flash memory, like that used in SD cards and camera memory sticks, can store data without requiring power to maintain it. This will ultimately result in technology like the sub-$100 computer – a price goal that is achievable because these computers will have almost no moving parts.

Storage

There are many types of storage. Memory (see above) is one of them. Types of persistent storage, needed to store mass quantities of information for the long term, include magnetic storage (hard and floppy disks), optical storage (CDs and DVDs), and Flash memory. As mentioned earlier, storage capacity as expressed in terms of constant cost doubles every twelve months. Unfortunately, the quantity of information that needs to be stored is growing at a similar rate. Storage and retrieval speeds (when compared to CPU and dynamic memory speed) have always been an issue for persistent storage; projected future developments, like holographic storage, are intended to alleviate this problem while greatly increasing capacity. As people begin recording video and sound for all of their daily experiences (people are already promoting this), huge amounts of storage will be needed.

Software

Successful computing requires hardware and software to work in tandem. Software "virtualizes" hardware; it enables hardware to be repurposed for many uses. Faster hardware and networks enable more complex software to be run to deliver more advanced functionality in a reasonable amount of time. The unkind say that software always eats up the performance improvements delivered by hardware. Expect this to continue for the foreseeable future…

Operating System (OS)

We currently see much more of the Operating System running our computers than we will in the future. The OS provides the foundation for the other software, coordinating access to any required hardware functionality, and currently determines (limits) what applications can run on your computer. OSs that consumers hear most about are Windows (Intel platform), OSX (Apple platform) and possibly LINUX (Intel platform – more on this later). The OS is another layer of computing that should be invisible to users, is not now, but will be some day when we have "instant on" computers that require no time to boot.

User Interface (UI)

The User Interface is how we communicate with the computer to request services. There has been progress over the last twenty years, but current UIs are crude, have limited bandwidth, and are tightly coupled to the OS. Advances in speech, and facial expression and gesture recognition, coupled with an immersive computing environment, should result in more intuitive human to computer interaction, but these changes will be gradual. Future possibilities that might result in revolutionary improvements include chips implanted in our brains and interfaces that sense brain waves.

Applications

Applications make up the layer of computing that does things for us using the capabilities provided by the other layers. They do things like creating documents, data analysis, authoring DVDs, or playing music. As Hardware and Operating Systems become more powerful, applications become more sophisticated. New applications are needed to support new business models, and the two often feed each others' development. Future applications will do more for us, anticipating our needs. They will appear intelligent, and someday may actually deliver non-human intelligence.

Business

Businesses will be impacted in positive and negative ways by the developments in this domain. The emphasis will be on adaptability. Businesses will (as usual) have to take advantage of positive developments and minimize the problems caused by negative ones. Open Source software is changing the economics of the software business for both vendors and customers, expect software price per performance to drop for the next ten years. That's good news unless you're in the software business. There is even greater potential for change in the move toward Service Oriented Architectures; this may be the new software platform that the industry has been seeking for the last twenty years or more. SOA will require redesign and retooling of the entire software base to be utilized effectively, but is already enabling new business models in Web 2.0.

Businesses will be impacted by the Info Glut, too. They are already feeling this impact due to regulatory requirements to retain more data and records, but the additional data flow from RFID tagged inventory may become overwhelming. In general, but with some exceptions, business users are not a major market for high end processors and graphics cards. Hardware vendors must depend on new, improved, resource intensive software to drive demand for new hardware.

Home

There is a lot of hype about the digital home coming from hopeful vendors and development labs. The digital home will arrive some day, but there must be an intuitive User Interface before there is very much market penetration. Computers in the home are being networked now as the cost of wireless networking drops dramatically. Technically savvy users are networking their Tivo DVRs. Demand for higher end machines in the home is being driven by entertainment applications and digital and video cameras that require large amounts of storage and fast processors for images, music, and videos. The day where everything you buy has embedded intelligence that your digital home can access via RF is still a few years off, but there will be great opportunities for businesses to introduce wildly innovative products.

Games

Players of computer games have always been a key market for high end processors and graphics cards. Realistic web-based multi-player games help drive this demand, as do 3-D applications. Some game companies are trying to maintain dedicated, proprietary platforms to protect their IP, but their long term success with this strategy is in doubt due to the continued doubling of PC power, which should enable ever improving emulation of their game environments.

Current Trends to Watch

There are many trends to watch in Computing. Some of the more important ones are listed here, but there is evidence of many more in the news concerning the Computing domain that can be found on the web.

Ubiquitous (Pervasive) Computing

This trend is still early in its development. Today your computing is ubiquitous only to the extent that you can carry it with you. There is much more to true Ubiquitous Computing than being able to access the web from different locations using a laptop or a PDA. The Wireless & Mobility trend is a major precursor trend for this one. As computers and the network fade into the background, we will have truly ubiquitous computing in economically advanced but geographically limited areas. (Worldwide penetration will take much longer.) Permanent objects in your office and home will be smart (chip enabled) and be networked via RF; temporary objects (consumables) will be idiots, able only to respond to RF probes with their identity and current status. Your workspace will be wherever you are, moving with you as the web traces your movements. This will have advantages and disadvantages. Much of the world will take longer to get to the point of joining this infosphere; there will be much resistance to it, and many bumps along the way.

RF and RFID Chips

RFID chip technology will lead to transformation of all aspects of the supply chain in both businesses and in the home. As the chips proliferate, they will infiltrate all levels of a shipment, beginning with pallets and migrating down into cartons and then individual items. Chips will be (this is still years off for most goods) added to individual products both for inventorying (almost anything sold) and as an anti-counterfeiting measure (e.g. currency and pharmaceuticals). When RFID chips with sensors are included in all purchased food items, the oft maligned "internet refrigerator" will become a reality. Ultimately, smart objects in our homes will be networked using RF chips. It is important to note that there is a potential for a negative backlash against RF and RFID if the powerful and ubiquitous radio waves necessary to activating the chips and unloading the information are shown (or convincingly rumored) to be harmful to humans.

Info Glut

The Info Glut is being driven by the Convergence (see above) as all media go digital and there is increased demand for storage capacity and network bandwidth. The Metadata Tagging trend evidences an attempt to organize the glut. Social trends may help drive this trend if people decide to record more and more of their daily lives and put the record online for their friends to view. The emergence of RFID will be a major contributor. The linking of GPS information to RFID tags to track location will help drive this trend. Look for this trend to drive ever increasing storage demands.

Autonomic Computing

This slow moving trend requires that elements of the computing environment (computers, storage servers, network routers, etc. – also see Grid Computing) be able to sense problems and repair them with little or no human involvement. Redundant disk arrays already do this, but Autonomic Computing means this self diagnosis and repair is done at a much higher level. Note that this capability does not imply Artificial Intelligence.

Grid Computing

The term Grid Computing has been used to describe several different developments, including using an array of inexpensive PCs to emulate a supercomputer. This trend is really something more than that. It has been likened to the creation of a computing fabric that can be used as a utility, like electricity. A grid of servers and storage devices will provide computing services on demand, expanding and contracting as needed. Little software has been written that is able to utilize this type of configuration, so early deployments of grids are in company datacenters or possibly shared datacenters. Security and privacy are major concerns, so expect a public grid utility (a prerequisite for true Ubiquitous Computing) to be slow to develop.

Service Oriented Architecture

SOA is a major trend whose benefits are needed so badly that it is experiencing rapid adoption in spite of immature software and standards. SOAs use loosely coupled, message-based software to deliver well defined IT services to consumers (other businesses or end users). Web services are one implementation of an SOA. SOAs ultimately reduce complexity while delivering standardized functionality, resulting in simplification and economies of scale. They are a higher level abstraction of current software implementations, and will revolutionize the way software is developed and distributed. Web services and many Web 2.0 products manifest SOA developments.

Open Movement

Open Source software is the most well known manifestation of the Open Movement. The software is developed by a volunteer community that decides what new functionality will be provided, fixes bugs, etc. The LINUX operating system is one of the best known examples of open source software, the FireFox web browser is another. Use of the software is free subject to a public use license. Similarly, open standards are developed and reviewed by communities of volunteers. This is a radical departure from the past, when both software and standards tended to be proprietary, and is expected to dramatically change the face of the software industry within the next ten years.

The Wikipedia, a web-based encyclopedia written and maintained by a community of users, is another important manifestation of the Open movement. It differs in that content, rather than functionality, is being delivered. Contributors do not have to be highly skilled programmers, as in open source, but just have to be knowledgeable.

Emerging Trends

There are many trends in Computing that are in early development in research labs. These may not yet commercially viable, but any one could lead to a wildcard development. They include Biological Computing, Chemical Computing, Quantum Computing, and direct brain to chip communication (as opposed to sensing).

Biological Computing

Biological and Chemical Computing are often taken to be the same thing. They may, however, be differentiated because one operates at the molecular level (Chemical) and the other operates at the cellular level or higher (Biological). Biological computing has great potential for interfacing with living systems, including our own brains. It also has potential ethical pitfalls. For example, at what level is it acceptable to use living things as computational devices? While a single neuron is not sentient, how many neurons does it take to reach the threshold for sentience?

Chemical (DNA) Computing

Chemical Computing uses molecules, usually DNA, to do computing. Although huge amounts of information can be stored at the molecular level, and the actual computation can be completed at very high speed, serious bottlenecks exist in the areas of creating programs, encoding input, and decoding output. These bottlenecks will ensure that development in this field is slow for many years, but general developments in Computing will be applied to solving these problems and may result in either faster than expected progress or a wildcard breakthrough.

Quantum Computing

Although Moore's Law continues to hold, some say the rate of doubling is slowing and that the size of transistors on chips is approaching the physical limit. Logic implies that there is some minimum, physical size that will be reached someday. Does this mean the computing progress will halt? Quantum Computing is one possible solution to this emerging problem. As we approach the atomic level, the rules that apply to behavior of matter change from physical rules to quantum mechanical rules. Our existing technology will no longer work at this level, but quantum mechanical principles imply that new efficiencies and higher speed computing are possible.

Conclusion

Computing is changing rapidly and will continue to do so. If it is true that we are moving to an information based economy, Computing will be the key enabler because its major function is to process and store information. Since information can be worth a lot of money, businesses need to keep an eye on the legal and regulatory actors to monitor how they and commercial interests are influencing developments. There are many potential obstacles due to issues like hacking and loss of privacy. Although many of the technologies are working in development labs, the path to market is muddy and rutted. On the web you will find opinions on Computing from viewpoints varying from Techo-Optimist to Neo-Luddite. Keep a close eye on developments in this domain and have fun!

