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EMPOWERING THE INFORMATION AGE

OVERVIEW

It is widely accepted that the technology of today's Information Age has had a major impact on global communications and commerce, and that it will continue to support major improvements in human productivity. However, while the World Wide Web is making significant contributions to this progress, there remain many challenges to its further development into a resource with intelligent features.

For the Information Age to achieve its full potential in improving human productivity, at least two key new advances must still be achieved: (*1*) ubiquitous access to transaction applications of all types; and (*2*) intelligent software applications enabling automated transactions.

For example, Web Services require human processing to be implemented. In addition, Web Services rely on the interoperation of two competing proprietary server frameworks to successfully communicate complex business logic. The solution of the W3C to both of these problems is to deliver automatic machine processing globally through a Web architecture utilizing layers of open markup languages.

This chapter begins by highlighting what is meant by the concepts of "thinking" and "intelligent applications" on the Web. Then, the development of the Information Age and the emergence of the Web as an empowering force for global change is presented. We discuss the forces behind the Information Revolution that are transforming the world's economic and social systems, and producing

Thinking on the Web: Berners-Lee, Gödel, and Turing, by H. Peter Alesso and Craig F. Smith

the demand for intelligent features on the Web. Next are presented the limitations of today's Web and the need for intelligent automatic capabilities through the development of the Semantic Web.

In addition, some of the philosophical issues that underpin the information revolution are highlighted, by providing the first of a threaded series of vignettes in Interlude #1 entitled "Thinking about Thinking," following this chapter.

THINKING AND INTELLIGENT WEB APPLICATIONS

When the philosopher René Descartes proclaimed his famous observation "Cogito, ergo sum," he demonstrated the power of thought at the most basic level by deriving an important fact (i.e., the reality of his own existence) from the act of thinking and self-awareness.

Today, the term "thinking" is frequently loosely defined and ambiguously applied. For that reason, it is important to provide a brief preview of what we mean by the term in the context of intelligent applications on the World Wide Web.

In general, thinking can be a complex process that uses concepts, their interrelationships, and inference or deduction, to produce new knowledge. However, thinking is often used to describe such disparate acts as memory recall, arithmetic calculations, creating stories, decision making, puzzle solving, and so on.

Some aspects of the concept of thinking can be inferred by recognizing that an individual can be identified as intelligent if they have accurate memory recall, the ability to apply valid and correct logic, and the capability to expand their knowledge through learning and deduction. Ultimately, self-awareness and consciousness are important if not central aspects of human intelligence, but these characteristics prove much more difficult to analyze or emulate than other, more direct indicators of intelligence.

The term "intelligence" can be applied to nonhuman entities as we do in the field of Artificial Intelligence (AI). But frequently we mean something somewhat different than in the case of human intelligence. For example, while one might be quite impressed with the intelligence of a child prodigy who can perform difficult arithmetic calculations quickly and accurately, a computer that could perform the same calculations faster and with greater accuracy would not be considered to be particularly intelligent. An individual who has rapid memory recall and who has accumulated sufficient amounts of information to consistently win games such as Scrabble, or Trivial Pursuit, might also be considered to be very intelligent; while a computer storing much greater quantities of accessible factual information would not.

It is recognized that human thinking involves complicated interactions within the biological components of the brain, and that the process of learning is also an important element of human intelligence. Increasingly, software applications perform tasks that are sufficiently complex and human-like that the term intelligent may be appropriate. Whereas AI can be seen as the science of machines that behave intelligently (or simulate intelligent behavior), the concept of intelligent applications entails the efforts to take advantage of AI technologies to enhance applications and make them act in more intelligent ways.

This brings us to the question of Web intelligence or intelligent software applications on the Web. The World Wide Web can be described as an interconnected network of networks, but that does not go quite far enough. The present day Web consists not only of the interconnected networks, servers, and clients, but also the multimedia hypertext representation of vast quantities of information distributed over an immense global collection of electronic devices. With software services being provided over the Web, one can readily see an analogy to the human (or machine) thinking process where information is stored, accessed, transferred, and processed by electronic patterns in electrical devices and their interconnections.

However, the current Web consists primarily of static data representations that are designed for direct human access and use. Search engines are one Web technology designed to automatically process information from large numbers of Web sites to deliver useful processed information, but the search methods used today have rudimentary capabilities. The key to moving to the next level is the improvement of the ability of software applications to communicate directly with one another, and the representation of information in ways that are far more usable by software applications.

An important framework for creating such meaningful abilities can be provided by the proposed next generation of Web architecture: the Semantic Web.

Leading the Way

The Greek philosopher Aristotle considered intelligence to be the main distinguishing feature of humans when he described humans as “rational animals.” He also established many precedents in the study of logic and began the process of codifying syllogisms, a process later extended by other mathematicians. Logicians then developed logic with mechanical rules to carry out deductions.

The nature of human intelligence is still controversial, but it is possible to recognize certain attributes that most would agree reflect the concept. These attributes include: the ability to learn, the ability to assimilate information, the ability to organize and process data, and the ability to apply knowledge to solve complex problems. Many of these real intelligence attributes can be traced into the field of artificial intelligence. Artificial intelligence addresses the basic questions of what it means for a machine to have intelligence.

There have been many contributors to the concepts of thinking, logic, and intelligence, but in this book the focus will be on three pioneers who had a profound affect in shaping the Information Revolution: Gödel, Turing, and Berners-Lee.

In the 1930s, the logician, Kurt Gödel, established that, in certain important mathematical domains, there are problems that cannot be solved or propositions that cannot be proved, or disproved, and are therefore undecidable. This is relevant to the field of artificial intelligence because of the limits and boundaries that can be inferred from Gödel’s insights. We will revisit Gödel and his contributions to the Information Revolution in Chapter 2.

In 1947, mathematician Alan Turing first started to seriously explore the concept of intelligent machines. He determined that a computing machine can be called intelligent if it could deceive a human into believing that it was human. His test—called the Turing Test—consists of a person asking a series of questions to both a human subject and a machine. The questioning is done via a keyboard so that the questioner has no direct interaction with the subjects; human or machine. A machine with true intelligence will pass the Turing Test by providing responses that are sufficiently human-like that the questioner cannot determine which responder is human and which is not. We will investigate Turing and his contributions to the Information Revolution in Chapter 3.

The inventor of the World Wide Web, Tim Berners-Lee, is also the originator of the proposed next generation Web architecture, the Semantic Web. The objective of the Semantic Web architecture is to provide a knowledge representation of linked data in order to allow machine processing on a global scale. Chapter 4 presents Berners-Lee and his contributions to the Information Revolution. But before the detailed discoveries of these pioneers are examined, let us find out how the Information Age began and progressed until it became evident that an intelligent Web was a necessary requirement for the fulfillment of the Information Revolution.

THE INFORMATION AGE

We are accustomed to living in a world that is rapidly changing. This is true in all aspects of our society and culture, but is especially true in the field of information technology. Most are aware of the rapid advances in computer and information technology as exemplified in "Moore's law," the observation made in 1965 by Gordon Moore, co-founder of Intel, that the number of components on integrated circuits had doubled every 18 months.

As a result, it is common to observe such rapid change and comment simply that "things change." But, even accepting the reality of rapid change, when can we assess that the change has actually improved human productivity? And what types of change can produce transformation on a global scale?

To gain an historical perspective of global change, take a brief look back. Over the millennia, mankind has experienced two global revolutionary changes: the Agricultural Revolution and the Industrial Revolution. Each produced over a 100-fold factor of improvement in the access to basic human resources and subsequently freed individuals to pursue higher level cultural and social goals. In addition, over the past half century, many have been pondering the possibility that the technological inventions of the Information Age may in fact be of such scope as to represent a third revolutionary change: the Information Revolution.

Should the rapidly changing world of the Information Age be considered a global revolutionary change on the scale of these earlier revolutions? In order to address this issue we must compare it with the changes associated with the Agricultural Revolution, which began around 8000 B.C. and continued through around 1700 A.D., and the Industrial Revolution, which began around 1700 and is still continuing to spread across the underdeveloped world even today.

Ten thousand years ago, humans lived in migratory groups and with the aid of flexible, rapidly evolving cultures, these loosely organized groups of "hunter–gatherers" were able to adapt to virtually all the climate zones and environmental niches on the planet, from the Arctic to temperate zones to the tropics. They fed themselves by hunting, herding, fishing, and foraging. The essence of hunting and gathering economies was to exploit many resources lightly rather than to depend heavily on only a few. Small, mobile human populations subsisted on whatever resources were available within their territory. In such small, continuously moving communities, there was little opportunity for economic or other kinds of specialization to develop. What one person knew and believed, the entire group tended to know and believe. Life was communal; cultural and technical knowledge and skills were widely diffused.

However, a major and dramatic turning point in human social development occurred when humans discovered the utility of agriculture. Agriculture resulted in living permanently in one place. Living in one spot permanently means exploiting a relatively small amount of land very intensively and over a long period of time.

To survive, agriculturalists had to collect all their food for the year at one or two harvest times, rather than gathering year round. Nothing, therefore, could be allowed to interrupt the harvest. This is due to a very narrow window of opportunity for planting and cultivating. Under this kind of pressure, agricultural communities became more time-conscious. Agriculturalists also had to store the produce of their fields for the rest of the year, protect it from moisture, vermin, and thieves, and learn to distribute supplies so the community could survive and still have seed for next year's planting. These conditions created a new kind of life style.

While a hunter–gather acquired resources from 100 acres to produce an adequate food supply, a single farmer needed only 1 acre of land to produce the equivalent amount of food. It was this 100-fold improvement in land management that fueled the agricultural revolution. It not only enabled far more efficient food production, but also provided food resources well above the needs of subsistence, resulting in a new era built on trade.

The Agricultural Revolution crept slowly across villages and regions, introducing land cultivation and a new way of life. During the long millennia that this revolution progressed, the world population was divided into two competitive categories: primitive and civilized. The primitive tribes continued in the mode of hunting–gathering while the civilized communities worked the land. The civilized communities produced foodstuffs for their own use with a surplus to allow for trade.

Because farmers consumed what they produced directly and traded their surplus locally, there was a close relationship between production and consumption. However, as trade developed the Agricultural Revolution encouraged the construction of the roads that facilitated the exchange of specialized produce on an expanding scale until it eventually become global.

This evolutionary transition to an agricultural basis for society was still incomplete when, by the end of the seventeenth century, the Industrial Revolution unleashed a new global revolutionary force. Societies, up until this period, had used human and animal muscle to provide the energy necessary to run the economy. As late as the French revolution, millions of horses and oxen provided the physical force that supported the European economy.

Where a single farmer and his horse had worked a farm, during the Industrial Revolution, workers were able to use a single steam engine that produced 100 times the horsepower. Consequently, the Industrial Revolution placed a 100-fold increase of mechanical power into the hands of the laborer. It resulted in the falling cost of labor and this fueled the economic growth of the period. The new industrialization process moved rapidly over Europe and across the other continents. It utilized flowing water, wood, coal, oil, and gas to generate energy that in turn produced an abundance of food and material goods.

In contrast to the agricultural cycle of planting and harvesting, the industrial society followed the continuous linear timing of machines to build inventory and maintain stored goods. This enabled consumers to be far removed from the producer. The industrialization process, therefore, broke down the close relationship between local production and consumption. The result was a stockpiling of resources at strategic locations along the distribution path. Again this revolutionary change also stimulated the intellectual growth of the society in order to meet the skill requirements for the workers.

The Industrial Revolution was defined by the application of power-driven machinery to manufacturing. It was not until 1873 that a dynamo capable of prolonged operation was developed. Through the nineteenth century the use of electric power was limited by small productive capacity, short transmission lines, and high cost. The coming of the railroads greatly facilitated the industrialization process and the building of transcontinental railroads mimicked the early growth of roads during the beginning of the Agricultural Revolution.

The Industrial Revolution became characterized by six basic characteristics: Standardization: mass production of identical parts. Concentration: work and energy maintained locally. Centralization: authoritative leadership. Specialization: division of labor. Synchronization: work at the pace of machines. Maximization: strategic planning.

One important development was the construction of the railroads that facilitated the exchange of raw materials into finished products on a global scale.

The 1950s—the decade that introduced the computer—began the latest historic turning point, the Information Age. However, it did not approach its full potential toward reducing information transaction costs until the computer was networked for global communications beginning in the 1990s with the growth of the Internet.

Today, the Information Age is establishing a new set of rules to replace those of the Industrial Revolution. For example, "standardization of parts" is being replaced by parts "designed and manufactured to custom specifications." And "concentration of workers" is being replaced by flexible work forces including "telecommuters." And most importantly, "concentration of stockpiles" is being replaced by "just-in-time" inventory and reductions in planning uncertainty.

As a result, production and consumption are continuing to move further apart. For many years, the falling cost of information has shifted power from the hands of the producers into the hands of the consumer. Even so, the cost of information has generally changed very slowly. The evolution of information distribution from writing to the printing press took thousands of years. However, once moveable type was developed, the transition rapidly accelerated. When significant drops in the cost of information occurred, as a result of the printing press, only certain types of organizations survived. From the ancient empires to the world's industrial giants, leaders have recognized that information is power. Controlling information means keeping power.

In fact, it was the high cost of information that made early civilizations most vulnerable. If a temple was sacked, it meant the loss of all available knowledge: from when to plant crops to how to construct buildings. Information was expensive to collect and maintain, and as empires rose and fell, the cost of information remained high. Empires in China, India, and Europe all used large, expensive bureaucracies to control information collection and dissemination.

The Roman Empire set the pace of communications by constructing 53,000 miles of roads, thereby eliminating the traditional dependence on water transportation. The Empire lasted for centuries and spread its administration across Europe, West Asia, and North Africa. Couriers traveled over Roman roads to the furthest reaches of the Empire. Rome also moved the management of knowledge from the temples to libraries for civil administration and learning. But for access to information resources, one still had to go to the libraries, which meant that information had limited distribution.

The invention of the printing press enabled common people to gain access to scientific knowledge and political ideas. By the sixteenth century, information moved into the hands of the people and out of the strict control of the state. In a similar dramatic change, the invention of the telegraph produced the possibility for instant widespread dissemination of information, thereby liberating economic markets. So while there has been continuous improvement in information flow for centuries, it is also clear that only within recent years has the pace accelerated as a result of the computer and the Internet.

Today, there is a competitive collision of industrial-based organizations and information-based systems. Information-based technology systems are the catalysts for the rapid change that has led to the dissemination of information throughout the workplace and home. The world's leading nations are experiencing a shift to knowledge-based economies requiring knowledge workers. These knowledge workers must be highly educated and possess significant technology skills. As a result, technology is facilitating globalization of the world economy and requiring a more highly educated society.

While it is still to be determined if the Information Age will actually become a revolution comparable in scope to the Agricultural and Industrial Revolutions, it remains a strong candidate. Indeed, service workers today complete knowledge transactions many times faster through intelligent software using photons over IP switching, in comparison to clerks using electrons over circuit switching technology just a few decades ago.

By the mid-twentieth century, the explosion of available information required greater information management and can be said to have initiated the Information Age. As computer technology offered reduced information costs, it did more than allow people to receive information. Individuals could buy, sell, and even create their own information. Cheap, plentiful, easily accessible information became as powerful an economic dynamic as land and energy.

The falling cost of information followed Moore's law, which said that the price performance of microprocessors doubled every 18 months. Starting in the 1950s, mainframe computers cost $10 million/MIPS (Million Instructions Processed per Second). By 1996, the comparable cost for the readily available PC was at $1/MIPS.

While the computer has been contributing to information productivity since the 1950s and has experienced the cost reduction due to Moore's law, the resulting global economic productivity gains were slow to be realized. Until the late 1990s, networks were rigid and closed, and time to implement changes in the telecommunication industry was measured in decades. Since then, the Web has become the "grim reaper" of information inefficiency. For the first time, ordinary people had real power over information production and dissemination. As the cost of information dropped, the microprocessor in effect gave ordinary people control over information about consumer products.

What makes the Web such a catalyst for change is its ability to take advantage of the marginal cost of information both for business-to-consumer (B2C) and business-to-business (B2B). While traditional company clerks once used electrons over the phone system circuit switching technology, today's service workers can now process multiple orders acquired through automatic services through intelligent software using photons over IP packet switching. Thus, the Web is the least expensive of all communication media and is a natural marketplace.

Today, the service worker is beginning to see the productivity gains in rapidly communicating knowledge transactions. A service worker can now complete knowledge transactions 100 times faster using intelligent software and ubiquitous computing in comparison to a clerk using written records. As a result, the Information Revolution places a 100-fold increase in transaction speed into the hands of the service worker. Therefore, the Information Revolution may be based on the falling cost of information-based transactions, which in turn fuels economic growth.

A defining feature of each revolution has been the requirement for more knowledgeable and more highly skilled workers. The Information Age clearly signals that this will be a major priority for its continued growth. We can expect the Web to play a central role in the development of the Information Revolution because it offers a powerful communication media that is itself becoming ever more useful through intelligent applications.

Over the past 50 years, the Internet/Web has grown into the global Information Superhighway. Just as roads connected the traders of the Agricultural Revolution and railroads connected the producers and consumers of the Industrial Revolution, the Web is now connecting everybody to everybody in the Information Revolution.

THE WORLD WIDE WEB

How is the World Wide Web managing knowledge and empowering the Information Revolution? Does rapid change and improved information productivity require more intelligent Web capabilities? What technologies offer the best opportunities for sustained powerful change? Let us explore these questions by briefly evaluating the development and limitations of today's Web technology.

The history of the Web extends back more than 40 years. Looking back, we can find early signs of network architecture in the 1960s. The RAND Corporation began research sponsored by the U.S. Air Force to determine how to develop robust, distributed communication networks for military command and control that could survive and function in the event of a nuclear attack.

This initial study led to the development of the Advanced Research Programs Agency Network (ARPANET) an agency of the U. S. Department of Defense. In addition to robustness, it promoted the sharing of supercomputers among scientific researchers in the United States. ARPANET originally consisted of four nodes in the western U.S. (the University of California at Los Angeles, SRI of Stanford, California, the University of California at Santa Barbara, and the University of Utah) connected in a system that was to become the precursor to the Internet.

The ARPANET was a success right from the very beginning. Over those first few years, the network developed and expanded as new sites (nodes) were added, and as new capabilities and features were introduced, such as software and protocols to facilitate email and file transfers. Although the ARPANET was originally designed to allow scientists to share data and access remote computers, email quickly became the most popular application. The ARPANET became a high-speed digital postoffice as people used it to collaborate on research projects. It was a distributed system of "many-to-many" connections.

Transmission Control Protocol/Internet Protocol (TCP/IP), a suite of network communications protocols used to connect hosts on the Internet was developed to connect separate networks into a "network of networks" (e.g., the Internet). These protocols specified the framework for a few basic services that everyone would need (file transfer, electronic mail, and remote logon) across a very large number of client and server systems. Several computers linked in a local network can use TCP/IP (along with other protocols) within the local network just as they can use the protocols to provide services throughout the Internet. The IP component provides routing from the local to the enterprise network, then to regional networks, and finally to the global Internet. Socket is the name for the package of subroutines that provide access to TCP/IP.

The mid-1980s marked a boom in the personal computer and superminicomputer industries. The combination of inexpensive desktop machines and powerful, network-ready servers allowed many companies to join the Internet for the first time.

Corporations began to use the Internet to communicate with each other and with their customers. By 1990, the ARPANET was decommissioned, leaving only the vast network-of-networks called the Internet with over 300,000 hosts.

The stage was set for the final step to move beyond the Internet, as three major events and forces converged, accelerating the development of information technology. These three events were the introduction of the World Wide Web, the widespread availability of the graphical browser, and the unleashing of commercialization.

In startling contrast, AOL, CompuServe, and Microsoft were investing fortunes in proprietary networks that offered mostly duplicated and limited amounts of information to the public, but for a fee. Tim Berners-Lee on the other hand was designing a cheap, efficient, and simple way for universal access to great stores of information for free.

In 1991, Berners-Lee, working at European Particle Physics Laboratory of the European Organization for Nuclear Research, Conseil Européen pour la Recherche Nucléaire, (CERN) in Switzerland, introduced the concept of the World Wide Web.

The Web combined words, pictures, and sounds on Internet pages and programmers saw the potential for publishing information in a way that could be as easy as using a word processor, but with the richness of multimedia.

Berners-Lee and his collaborators laid the groundwork for the open standards of the Web. Their efforts included the Hypertext Transfer Protocol (HTTP) linking Web documents, the Hypertext Markup Language (HTML) for formatting Web documents, and the Universal Resource Locator (URL) system for addressing Web documents.

Today, we reach the Web through commercial browsers, such as, Internet Explorer or Netscape Navigator. These browsers are powerful applications that read the markup languages of the Web, display their contents and collect data.

The primary language for formatting Web pages is HTML. With HTML the author describes what a page should look like, what types of fonts to use, what color the text should be, where paragraph marks come, and many more aspects of the document. All HTML documents are created by using tags. Tags have beginning and ending identifiers to communicate to the browser the beginning and ending text formatted by the tag in question.

In 1993, Marc Andreesen and a group of student programmers at NCSA (the National Center for Supercomputing Applications located on the campus of University of Illinois at Urbana Champaign) developed a graphical browser for the World Wide Web called Mosaic, which he later reinvented commercially as Netscape Navigator. The graphical browser greatly stimulated Web development.

Soon studies of Web traffic began to show signs that all Web sites were not "equidistant." That is, some sites were acting as hubs and garnishing a dominant share of the "through" traffic. In addition, some Web sites acted as prominent sources of primary content, and became authorities on the topic, while other sites, resembled high-quality guides acted as focused hub, directing users to recommended sites. By 1994, the W3C was founded under the leadership of Tim Berners-Lee to develop standards for the Web.

LIMITATIONS OF TODAY'S WEB

Over the past several decades, the Web has changed from a distributed, high-reliability, open system, to a Web dominated by portals, such as Yahoo, Google, AOL, and MSN, which control much of the traffic. While the W3C developed open Web standards, vendors have been customizing their applications for efficient business logic processing through their proprietary servers and applications.

By the year 2000, the introduction of Web Services led to a dichotomy of Microsoft's Windows (.NET) and Sun's Java (J2EE) frameworks within the server community infrastructure. As a result, the Web moved strongly toward becoming a decentralized network with highly critical hubs. The eXensible Markup Language (XML) was developed as a markup language based on the principles and rules of Standard Generalized Markup Language (SGML) and uses tags that are not predefined. This gives XML great flexibility, and extensibility. The XML remains the interoperable bridge for exchanging data between J2EE and .NET, and as a result XML is an essential support for both Web Services' frameworks.

Nevertheless, the problem with performing intelligent tasks, such as automated Web Services, is that they first require human assistance, and second that they must rely on the interoperation and inefficient exchange of the two competing proprietary server frameworks to successfully communicate complex business logic.

The Web is still based on HTML, which describes how information is to be displayed and laid out on a Web page for humans to read. In effect, the Web has developed as a medium for display of information directly to humans; there has been no real emphasis on establishing the capability for machine understanding and processing of web-based information. HTML is not capable of being directly exploited by information retrieval techniques; hence processing of Web information is largely restricted to manual keywords searches.

Because the World Wide Web has its origin in the idea of hypertext, the Web is focused on textual data enriched by illustrative insertions of audiovisual materials. The status quo paradigm of the Web is centered on the client–server interaction, which is a fundamentally asymmetric relationship between providers inserting content onto the Web hypertext (the server) and users who essentially read texts or provide answers to questions by filling out forms (the clients).

Today, the development complex networks of meaningful content remains difficult. Web browsers are restricted to accessing existing information in a standard form. In addition, some of today's basic Web limitations include search, database support, interoperable applications, intelligent business logic, automation, security, and trust. As a result, the Information Revolution awaits the next break-through to fully open the information flow.

THE NEXT GENERATION WEB

A new Web architecture called the Semantic Web offers users the ability to work on shared knowledge by constructing new meaningful representations on the Web. Semantic Web research has developed from the traditions of AI and ontology languages and offers automated processing through machine-understandable metadata.

Semantic Web agents could utilize metadata, ontologies, and logic to carry out its tasks. Agents are pieces of software that work autonomously and proactively on the Web to perform certain tasks. In most cases, agents will simply collect and organize information. Agents on the Semantic Web will receive some tasks to perform and seek information from Web resources, while communicating with other Web agents, in order to fulfill its task. The roadmap for building the Semantic Web is discussed in detail in Chapter 4.

WHY INTELLIGENT UBIQUITOUS DEVICES IMPROVE PRODUCTIVITY

For the Information Revolution to succeed, two key elements are necessary: (*1*) ubiquitous access to transaction applications of all types and (*2*) intelligent software applications producing automated transactions. The results could be orders of magnitude improvement in all decision and financial transactions creating significant improvements in human productivity.

Ubiquitous access can be achieved through the World Wide Web just as soon as small wireless devices become globally distributed: thereby extending the reach of the desktop personal computer to the persons themselves. Intelligent software applications can become available just as soon as the Semantic Web offers intelligent automatic applications.

By applying the power of Moore's law, wireless chip technology will allow cellular carriers to build networks for less and promote all of the four basic attributes of the Information Revolution: decentralization, reduced middle management, automatic knowledgeable customer service, and vertical and horizontal organization.

As computers have evolved over the past several decades, they have become smaller (main frames to handheld devices) and mobile (wired to wireless). The numbers of computing machines ranges from consumer items (in the trillions), home appliances (10s of billion), handheld devices (100 million), computers (10s of million), and the Web (1).

Within the next decade, the most prevalent computers may actually be small mobile wireless devices that combine the capabilities of cell phones, personal digital assistants (PDAs), pocket-sized PCs, and tablets. Their small size, relatively low cost, and wide availability from many manufacturers will ensure that many people will have one, or more. The computing environment of small mobile wireless devices will be very different from today's predominant desktop computing environment.

How much faster will intelligent applications over wireless Web devices improve productivity? No one knows. But accessible intelligent Web features offer a significantly enhanced contribution to an Information Revolution.

Roughly one-half of today's world economy involves some related office work. This includes buying and selling transactions, banking applications, insurance, government, and education forms, and business-to-business transactions. The required information processing is currently being done mostly by specialized humans and secondarily by machines. For the most part, information technology has been a tool to improve the productivity of the human work force. Even in that role, the Web is only beginning to scratch the surface of office work and commercial transactions.

Banking, which typically involves straightforward, standardized transactions, could be one of the first major areas for widespread small device wireless access. The ubiquitous mobile phone is the new contender in financial services and it carries with it the potential for much broader access. Unlike earlier experiments with smart cards and PC banking services, mobile devices look like a natural channel for consumer financial services. Mobile operators have built networks and technology capable of cheap, reliable, and secure, person-to-merchant and person-to-person payments. Wireless telecommunication can augment the payment system.

Small mobile devices using the Web will offer consumers as well as businesses access to products and services anytime, anywhere, and by shifting even more power from producers to consumers, the falling cost of information provides a powerful feedback loop for the economic production cycle. The introduction of millions of small devices at the fingertips of consumers no matter where they are will require more Web Services. Web Services will enable information transactions of every kind and automation of these activities will certainly mean a fundamental empowerment of the Information Age to meet its true potential.

It is this need for ubiquitous connection to global computational resources that is signaling the arrival of the Information Revolution connecting everybody to everybody. All we are waiting for now is the intelligent, automatic applications to make transactions occur at the speed of light.

CONCLUSION

This chapter presented the development of the Information Age and the emergence of the Web as an empowering force for global change. From this chapter, we may conclude that: The Web empowers individuals on a global scale, but that the evolution of the Web requires the development of more intelligent features. The Semantic Web could play a vital role in transforming the Information Age into the Information Revolution as intelligent automatic applications speed up transactions. But, important limitations present challenges to developing Semantic Web architecture. These limitations touch some of the most difficult problems in mathematics and logic, such as machine intelligence, paradox, recursion, undecidability, and computational complexity.

In the next chapters, we will continue to consider the contributions of Kurt Gödel (what is decidable?), Alan Turing (what is machine intelligence?), and Tim Berners-Lee (what is solvable on the Web?) and attempt to weave them into a coherent portrait of AI on the Web. The result will provide insight into the progress of the World Wide Web to empower the Information Revolution by introducing "thinking" on the Web.

EXERCISES

1-1. Plot the trend of Moore's law from 1970 to today. Then project processor performance for the year 2020 based on Moore's law.

1-2. Estimate the growth of small devices and desktop computers in the next 5 years. Plot the ratio of small devises to desktop computers.

1-3. List the possible uses for small devices that may develop within the next 5 years.

1-4. Explain how HTML limits the manipulation of information.

1-5. Consider how logic paradoxes could prevent finding solutions on the Semantic Web.

Some of the interesting philosophical issues involved with Web intelligence will be highlighted through the use of a threaded series of vignettes or interludes presented between chapters. The following is the first interlude entitled "Thinking about Thinking."

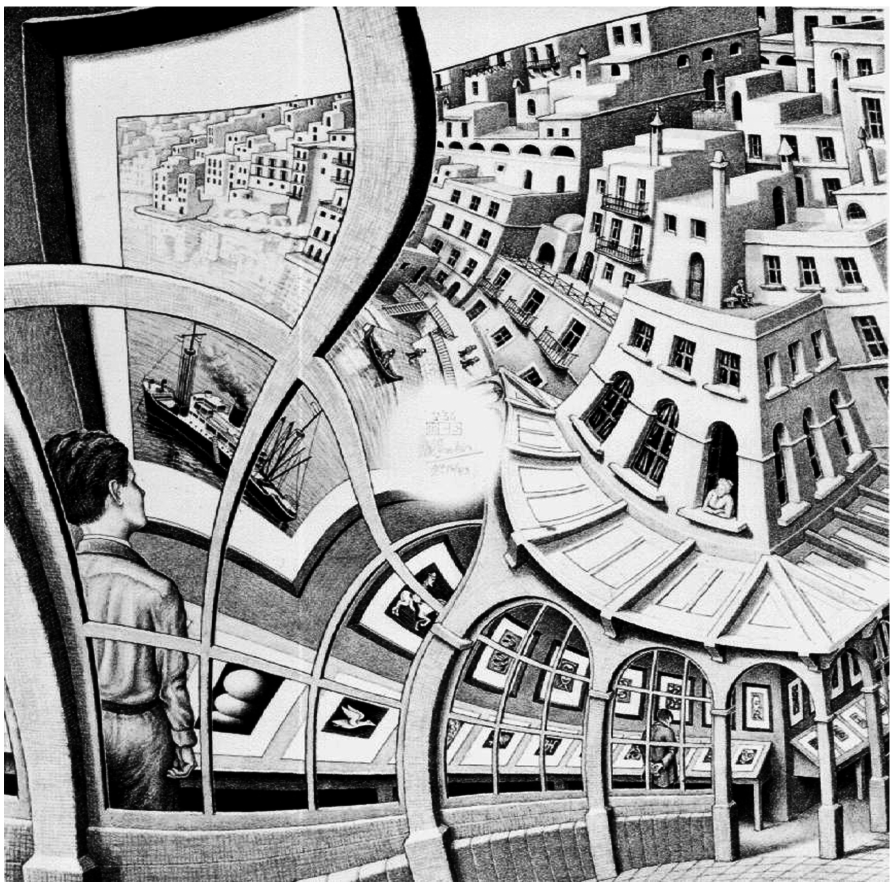

Figure 1-1. Print Gallery. Used with permission from M. C. Escher's "Print Gallery" © 2005, The M. C. Escher Company-Holland, All rights reserved www.mcescher.com.

INTERLUDE #1: THINKING ABOUT THINKING

John picked up the two double Latte Grandes and walked over to the corner table near the fireplace where Mary was setting up the chess game. She took a pawn of each color and concealed them in her hands before offering two fists to John.

Putting the cups down, he tapped Mary's left hand and was pleased to see the white piece as he took his chair.

John said "Playing chess always reminds me of the game between IBMs Deep Blue Supercomputer and the reigning World Chess Champion at the time, Garry Kasparov." He glanced at the board, "d4, I think," as he moved his pawn.

Mary said, "Me too." Mary smiled to herself as she moved her own queen's pawn forward to d5. She knew that John had strong feelings about the limits of true Artificial Intelligence and she hoped to gain an advantage by baiting him. "That was the first time a computer won a complete match against the world's best human player. It took almost 50 years of research in the field, but a computer finally was thinking like a human."

John bristled slightly, but then realized that Mary was just poking a little fun. Taking his next move, c4, he said "You can guess my position on that subject. The basic approach of Deep Blue was to decide on a chess move by assessing all possible moves and responses. It could identify up to a depth of about 14 moves and value-rank the resulting game positions using an algorithm developed in advance by a team of grand masters. Deep Blue did not think in any real sense. It was merely computational brute force."

Mary reached over and took John's pawn, accepting the gambit. "You must admit," she replied, "although Kasparov's 'thought' processes were without a doubt something very different than Deep Blue's, their performances were very similar. After all, it was a team of grand masters that designed Deep Blue's decision-making ability to think like them."

John played his usual Nc3, continuing the main line of the Queen's Pawn Gambit. "You've made my point," he exclaimed, "Deep Blue did not make its own decisions before it moved. All it did was accurately execute, the very sophisticated judgments that had been preprogrammed by the human experts."

"Let's look at it from another angle," Mary said as she moved Nf6. "Much like a computer, Kasparov's brain used its billions of neurons to carry out hundreds of tiny operations per second, none of which, in isolation, demonstrates intelligence. In totality, though, we call his play 'brilliant'. Kasparov was processing information very much like a computer does. Over the years, he had memorized and pre-analyzed thousands of positions and strategies."

"I disagree," said John quickly moving e3. "Deep Blue's behavior was merely logic algebra—expertly and quickly calculated, I admit. However, logic established the rules between positional relationships and sets of value-data. A fundamental set of instructions allowed operations including sequencing, branching, and recursion within an accepted hierarchy."

Mary grimaced and held up her hands, "No lectures please." Moving to e6 she added, "A perfectly reasonable alternative explanation to logic methods is to use heuristics methods, which observe and mimic the human brain. In particular, pattern recognition seems intimately related to a sequence of unique images connected by special relationships. Heuristic methods seem as effective in producing AI as logic methods. The success of Deep Blue in chess programming is important because it employed both logic and heuristic AI methods."

"Now who's lecturing," responded John, taking Mary's pawn with his bishop. "In my opinion, human grandmasters do not examine 200,000,000 move sequences per second."

Without hesitation Mary moved c5 and said, "How do we know? Just because human grandmasters are not aware of searching such a number of positions doesn't prove it. Individuals are generally unaware of what actually does go on in their minds. Patterns in the position suggest what lines of play to look at, and the pattern recognition processes in the human mind seem to be invisible to the mind."

John said, "You mean like your playing the same Queen's Gambit Accepted line over and over again?" as he castled.

Ignoring him, Mary moved a6 and said, "Suppose most of the chess player's skill actually comes from an ability to compare the current position against images of thousands of positions already studied. We would call selecting the best position (or image) insightful. Still, if the unconscious human version yields intelligent results, and the explicit algorithmic Deep Blue version yields essentially the same results, then why can't I call Deep Blue intelligent too?"

John said, "I'm sorry, but for me you've overstated your case by calling Deep Blue intelligent," moving Qe2. He continued, "Would you like to reconsider your position?"

Mary moved Nc3 and said, "Of course not, I still have plenty of options to think about alone this line."