

The Computer as a Communications Device: Wiener and Licklider and the Internet

Since the 1970s, a new communications medium, the Internet, has been emerging with a growing effect on most aspects of human society. It functions as a globally distributed interconnection of people, computing machines and communications media. The Internet has made obvious that computers are communication devices.

The communications essence of computers was appreciated at least as early as the 1940s.

In the actual envisioning and launching of the Internet, a prominent role was played by the American physio-psychologist J.C.R. Licklider (1915-1990). Licklider foresaw a great leap for human society based on a tight coupling and networking of people and computers. He did much to infect others with his early enthusiasm. He also set in motion in the US a public sponsorship and funding mechanism that brought the communications network he envisioned into reality. In the 1960s, Licklider published two seminal articles, "Man Computer Symbiosis"(1) in 1960 and "The Computer as a Communications Device"(2) written with Robert Taylor in 1968. Looking for the conceptual roots of Licklider's vision and of the Internet itself, several researchers (3) have been drawn to cybernetics and the work of Norbert Wiener (1896-1964), a mathematician/philosopher at the Massachusetts Institute of Technology (MIT). A thread that runs through the connected work of Licklider and Wiener is the conception of the computer as a communications device.

Norbert Wiener: The computer as communications apparatus

In connection with World War II, a number of research teams including one centered on Wiener, undertook to analyze the problem of improving the success of anti-aircraft artillery fire. Fire control technology had been developed between the two world wars especially addressing ship to ship warfare. Elaborate semi-automatic and automatic systems were already in place which could track a target ship, calculate its motion and help aim the big guns that would fire so as to attempt a hit. It was upon this technology that anti-aircraft fire control was built.(4)

Anti-aircraft artillery must be aimed at a substantial distance ahead of where the target is at the time of firing because of the relatively great speed of aircraft. Where to aim is based on knowledge of how the plane has been traveling and where it is likely to travel in the time the shell takes to reach it even if the pilot takes evasive action. The amount and direction ahead must be estimated quickly and accurately. The speed of World War II aircraft moved the problem beyond human capability unless aided by automatic rapid calculation. Wiener felt he would be able to contribute significantly to the solution of the prediction part of the problem partly because he had previously developed the equation to be solved when knowledge in one region is used to predict, via a statistical analysis, behavior in another, the so called Hopf-Wiener integral equation(5). Wiener was also familiar with the work at MIT of Vannevar Bush with analog computers and work he had done with Yuk Wing Lee on creating electrical circuits that correlated with mathematical equations. Together with the engineer Julian Bigelow (1913-2003), Wiener was confident he could build circuitry that would solve the prediction problem, as he said, "in the metal."

Wiener and others working on the anti-aircraft fire control problem envisioned the coupling of anti-aircraft guns with human tracking fed to a computing circuit with output based on the mathematical solution of the prediction equation(6). Motors attached to the gun turrets could position and aim the gun under the control of data generated by the mathematical processing of input from the human trackers. Later, as radar became perfected humans played a diminished role in the process. But humans were still needed as spotters and gun loaders(7).

Wiener reports that his work on this problem had a profound impact on him.

Up until this work, the mechanisms for the control of gun turrets were almost always assumed to belong to power or control technology rather than communications technology even when they were automated as servomechanisms. What Wiener reports dawned on him was that the action of the motors could be conceived valuably as communicating the aiming parameters to the turret and hence that the motors and the computers controlling them could be treated as communications devices. Input into the computing circuits and the output from them could be analyzed as signals or messages conveyed to the motors. So, what appeared as control mechanisms could equally well or even better be analyzed mathematically as communication processes based on frequency analyses of messages.

Wiener wrote that this point of view made him "regard the computer as another form of communications apparatus, concerned more with messages than with power."(8)

Wiener's phrase "computer as another form of communications apparatus" appeared in print in 1956 but he was writing of the time in the early 1940s. The computers which Wiener had in mind were collections of electrical resistances, potentiometers, capacitors and vacuum tubes, connected together in various configurations to take as input voltage variations from tracking devices. The combination of circuits was constructed so as to represent a solution of the path prediction problem. It would give as output resulting voltage variations. These would be used as control inputs to the motors which mechanically set the height and angle of rotation of the artillery pieces. Together with the time of firing setting, these settings located a point in three-dimensional space at which the shell would explode calculated to be in close proximity to the aircraft at the time of explosion. The motors had self correcting features which made them servomechanisms. The purpose of this whole system was to increase the chance that the shell would explode sufficiently close to the target aircraft some 20 seconds after firing to damage or destroy it.

The nature of such a computing machine, Wiener continued, "was that of a series of switching devices, so enchained together that the information coming out of a number of stages of these was introduced into a subsequent stage as ingoing and regulating information."(9) That is, the internal functioning of the computing device was conceived by Wiener to be communication among its various internal circuits. Also, the resulting output variable voltage was conceived as a signal or message conveyed to the servomechanism of the aiming motors which controlled the angle of rotation and elevation of the anti-aircraft gun. Since this was an ongoing process, the changing motion of the plane was matched by changing orientations of the guns appearing as if the gun was following where the plane would be.

With this point of view, Wiener saw a striking analogy between the workings of an automatic anti-aircraft system and that of a living organism. There was input, processing of that input, and resulting action, which was corrected by further input so the action brought closer the achievement of the goal. He began to regard a computing machine in much the same light as the brain and nervous system, both as communications with self correcting feedback mechanisms. Out of such considerations a new synthesis emerged which Wiener eventually termed cybernetics (from the Greek word for "steersman").

Wiener worked out his new synthesis in, *Cybernetics or Control and Communication in the Animal and the Machine* (10) and later popularized it in *The Human Use of Human Beings*(11).

Communication, - for Wiener the receipt, processing, transfer and correction of messages- was the unifying thread in this synthesis. He even concluded that "communication is the cement of society. Society does not consist merely in a multiplicity of individuals meeting only in personal strife and for the sake of procreation, but in an intimate interplay of these individuals in a larger organism."(12)

Wiener included that society had a memory of its own facilitated by the invention of writing, now further facilitated by online archives.

Also, Wiener's work raised a question. What will be the relations between humans and machines in the age of computers and automation?(13)

After WWII, cybernetic ideas from many sources in the United States, the United Kingdom, Germany and elsewhere, began to be known and discussed in scientific circles. Licklider attended such discussions in Cambridge, Massachusetts. He brought to them his relevant experience gained from research in psycho-acoustics. His papers, mentioned above, carried on the work. In them he formulated his answers to the question of the relation between humans and computers and the importance of communication.

JCR Licklider: Man-Computer Symbiosis

In 1960, in the article "Man-Computer Symbiosis"(14), Licklider envisioned a tight coupling of people and computing machines in which each would contribute what it did best. Both the thinking of the people and the information processing of the computers would thereby improve with time. The main aims of the partnership would be to let computers facilitate formulative thinking and to enable human-computer cooperation in decision-making and in the control of complex situations with greater flexibility. Licklider opposed his vision to that of creating computers that would be able to do thinking and problem solving without human assistance. Licklider saw the possibility that the time-sharing computer centers could all communicate with each other so that in some way all users and all computers would become one vast human-computer communications system. He began to use the name "Intergalactic Network."

For Wiener the communication was within the device or organism. Licklider, a psychologist and acoustic scientist, centered his career around communication, in the brain, in aircraft and in society

as well as between people and machines as separate species. In 1968 he expanded his vision in an article which he co-authored with Robert Taylor, "The Computer as a Communication Device"(15).

JCR Licklider and Robert Taylor: The Computer as a Communications Device

Now in 1968, Licklider and Taylor saw the communication device as the whole human to human communications system. They wrote that their "emphasis on people is deliberate," that human to human communication is more than the engineering task of sending and receiving information. Their starting point was that humans communicate meaningfully when they can share and compare mental models. So in some ways human minds are part of the communications systems. With graphical input and output devices and rapid computer information processing, mental models will be more accurately externalized and shared. They will be easier to interact with and to combine. The result will be a greater chance to achieve common understandings and purposes.

Such communication, Licklider and Taylor argued could be more effective even than face-to-face communication. A well-programmed networked computer will provide direct access both to informational resources and to the processes for making use of and sharing the resources. Each communicator can better work out his or her model and present it to others with text and graphics and whatever else the computer was developed to do. The full value would come from the media allowing interaction, people with computers, computers with computers and people with people via the net yielding a joint construction beyond what would be possible without the computer communications system.

For Licklider and Taylor, this modeling function of the computer as communication device was primary.

But they also saw the importance of the communication switching function of the computer. They had seen time-sharing technology make a central computer accessible to many simultaneous users. It had done that by parceling out quanta of processor time to all users in a round robin fashion with such speed that each user had the perception of being the sole user. And by so doing, it had helped communities of users form around each such time sharing computer. The shared computer gave rise to the sharing of programs and know-how and data and even personal message files users could leave in each other's directories. Such sharing glued the users together.

As Licklider and Taylor wrote their article, the ARPANET, an experimental packet switching network that would connect the separate time shared computers was being planned. By breaking up all messages into parcels of data called packets and interspersing the packets from many users, packet switching technology would use communications lines with a great efficiency. Each packet would contain address and sequence data as well as a string of data from the message. Each packet would be passed on by computers as switches along the network until it arrived at its destination. Error detection and correction or retransmission would insure the accuracy of the data. The messages would be reassembled at their destination computers and delivered to the addressee. As opposed to voice messages using circuit switching technology, the packets would not have captured or dedicated circuits for their exclusive use. During a communications session each packet shared the lines with all other packets

Licklider and Taylor saw that all of these communications functions would be played by the computer as a communications switching device. Perhaps the most important aspect of this use of computer technology was the great decrease in cost interspersing packets would achieve. Packet switching made possible for the first time full time utilization of the full capacity of communications lines. The prevailing circuit switching technology originally designed for voice data required payment for the line during an entire communications session whether there was traffic on the line or not. Also, with packet switching, with more users, the degree of sharing and efficiency increases yielding an economy of scale. The resulting decrease in cost makes possible long distance even international communication on a par in cost with local communication.

Such a packet switching network of time shared computers allows the central computers to communicate with each other and through them all the members of the separate local communities to communicate and share files, programs, opinions, news etc. without regard to geography. Connecting all such packet switching networks, which is the technological feat of the internet, produces perhaps the largest human-machine interconnection history has ever seen. Considerations like this led Licklider and Taylor to emphasize that the new system would foster the creation of online interactive communities, communities not of common location, but of common interest.

Licklider and Taylor, like Wiener, saw that the technological system would have a social component. By eliminating distance and technological and geographic barriers as obstacles to communication, users will be able to find other people with similar or a common interest. When the system has spread far enough, for each interest, a “critical mass” of people may find each other so that they are empowered to act on that interest or to offer each other support. (For example, today there are online rare-disease-suffers support groups, graduate students uncovering and exposing scientific fraud, mailing list and web sites by means of which masses of people are organized to protest an injustice and social networking systems that help users keep track of and in touch ‘friends’.).

Licklider and Taylor projected in 1968 that life with an online component would be a life improved via computer enhanced communication. And that the benefit to society from people acting in communities of common interest and communicating across the world could be significant.

But they had a warning:

“For the society, the impact will be good or bad, depending mainly on the question: Will ‘to be on line’ be a privilege or a right? If only a favored segment of the population gets a chance to enjoy the advantage of ‘intelligence amplification,’ the network may exaggerate the discontinuity in the spectrum of intellectual opportunity.”(15)

The Internet: Global Communications

That was in 1968. In 2008, almost 40 years later, the Intergalactic Network of people and computers and communications media that Licklider and others foresaw has spread to almost every country, even if not yet by a long way to most people. There are positive signs that access to the Internet is still increasing. There are reported to be an increasing 163,000,000 people in China with Internet access. It is reported that North Korea has sought to have its country code domain acknowledged by the International Corporation for Assigned Names and Numbers (ICANN).(16).

Over 800,000 blogs have been started on the Internet by Iranians, Bloggers in Egypt are helping the mainstream Egyptian media report on strikes and demonstrations. Still the question of access both to the Internet and to all content and full use of the Internet is a struggle everywhere. An advanced example is South Korea.

A reported 80 to 90% of South Korean households have computers and affordable broadband connectivity, thanks in part to governmental investment and encouragement. It is not uncommon for Koreans of all levels of society to spend many hours a day online. In a sense everything anyone does online is a form of communication. There is massive online sharing, online experimentation and online communities of common interest. The full political spectrum has online presences including progressive and conservative and radical. The Internet has been described by one researcher as an important social infrastructure. Even in politics, mass sports cheering, exposure of scientific fraud and journalism, netizens of South Korea are a major force. By and large South Koreans are comfortable and excited about their intimate relation with their computers as communication devices. Yet, before the 2007 presidential election, the Korean government enforced a harsh Internet censorship law which inhibited online discussion and participation in the evaluation of potential candidates.(17)

Despite the contradictions and efforts at control and censorship, there is evidence that a human-computer symbiosis, an intimate global relation among humans and between humans and computers is emerging. The insights in the 1940s and 1960s seem supported by the continuing growth of the Internet as a global communications system based on the computer as a communications device.

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Notes:

1) Licklider, J.C.R.: "Man-Computer Symbiosis", In: *IRE Transactions on Human Factors in Electronics*, Vol HFE-1, March, 1960, pp. 4-11. Also reprinted in: *In Memoriam: J.C.R. Licklider: 1915-1990*, Report 61, Systems Research Center, Digital Equipment Corporation, Palo Alto, California, August 7, 1990, pp. 1-19. (<http://memex.org/licklider.pdf>)

2) Licklider J.C.R., and Robert Taylor: "The Computer as a Communication Device," In: *Science and Technology: For the Technical Men in Management*, No 76, April, 1968, pp. 21-31. Also reprinted in: *In Memoriam: J.C.R. Licklider: 1915-1990*, Report 61, Systems

Research Center, Digital Equipment Corporation, Palo Alto, California, August 7, 1990, pp. 21-41. (<http://memex.org/licklider.pdf>)

3) See for example, Chapter 6 in Hauben, M. and R. Hauben, *Netizens: On the History and Impact of Usenet and the Internet*, IEEE Computer Society Press, Los Alamitos, 1997, (<http://www.columbia.edu/~hauben/netbook/>); Chapter 8 in SEGAL, Jérôme: *Théorie de l'information: sciences, techniques et société de la seconde guerre mondiale à l'aube du XXIe siècle* Faculté d'Histoire de l'Université Lyon, Lyon, 1998, (<http://www.mpiwg-berlin.mpg.de/staff/segal/thesis/>) and Chapter 1 in Mindell (2002). For the earlier period and for other sources of cybernetic insights see e.g., Bennet, S.: *A History of Control Engineering 1930-1955*, Peter Peregrinus, London, 1993; and Dittmann, F.: "Aspects of the Early History of Cybernetics in Germany", in: *Trans. Newcomen Soc.*, 71, 1999-2000, pp. 143-154.

4) See for example Chapters 1 and 2 in Mindell (2002)

5) See Masini (1990), page 185, Wiener and Bigelow's Hopf-Wiener Integral Equation as a solution of the anti-aircraft fire control problem:

$$g_h(t) = \int_0^{\infty} f(t - \tau) dW_h(\tau) \quad t \geq 0$$

where

$f(t-\tau)$ is the input data from the tracking mechanism

$W_h(\tau)$ is the weighting function that took into account the averaging over the possible paths and included the filtering of the tracking errors

$g_h(t)$ is the predicted future position of the plane an interval h later.

6) See illustration, page 204, Mindell (2002). See also illustration, between pages 214 and 215, Baxter, J.: *Scientists Against Time*, Little Brown and Co., Boston, 1946.

7) See illustration, page 133, Buderer, R.: *The Invention that Changed the World*, Simon & Schuster, New York, 1996.

8) Wiener (1956), page 265.

9) Ibid.

10) Wiener, N: *Cybernetics or Control and Communication in the Animal and the Machine*, The MIT Press, Cambridge, Massachusetts, 1948, (Second Edition, 1961)

11) Wiener, N: *The Human Use of Human Beings: Cybernetics and Society*, Discus Books, New York, 1950.

12) Wiener (1956), page 326.

13) See Wiener (1964) Chapter VI which begins on page 71: “Thus one of the great future problems which we must face is that of the relation between man [sic, humanity] and the machine, of the functions which should properly be assigned to these two agencies.”

14) Ibid., note 1

15) Ibid., note 2.

16) Ibid., page 31 in the original, page 40 in the reprint.

!7) See ICANN website at: <http://www.icann.org/announcements/announcement-2-17aug07.htm> (last accessed on 12/31/07)

18) See “Netizens Censored in South Korean Presidential Election: Harsh new election rule prevented online discussion and debate” by Ronda Hauben in OhmyNews International, 12/25/2007

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Jay Hauben 1/1/2008