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Jerome R. Cox Jr.

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Abstract

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This talk was given by Dr. Jerome R. Cox at his installation as the Harold B. and Adelaide G. Welge Professor of Computer Science, April 24, 1989.

Welge Installation Address

April 24, 1989

THE PHYSICIAN'S WORKSTATION

HEALTH CARE REVOLUTION OR THE NEAREST MIS YET?

Jerome R. Cox, Jr.

Introduction

Thank you Dean McKelvey and Chancellor Danforth. Thanks especially to Harold and Adelaide Welge, who have made this occasion possible. Thanks, too, to the faculty and staff of the Department of Computer Science. They have provided me unfailing support and, more important, they are my good friends.

Four members of my family are here, my wife Bobby, our son Jerry and his wife Margaret and our youngest son Randy, a graduate of the Washington University School of Engineering. Our daughter Nancy, her husband and our two granddaughters are on vacation in Florida this week. I am proud of them all and would like the four who are here to stand for a moment. I would also like to recognize the former Director of Research at Central Institute for the Deaf, Dr. Hallowell Davis, my first Saint Louis boss and mentor, whose splendid example as a scientist and as a warm human being has influenced me deeply.

It is a great honor to be named the first Harold B. and Adelaide G. Welge Professor of Computer Science. For me, this event signals the coming of age of our young profession, now just over two decades old. Perhaps in these two decades computer science has been guilty of the error of believing that intelligence is a substitute for experience. I hope that when mature our profession will not be guilty of believing that experience is a substitute for intelligence.

For more than twenty years I have been interested in the possibility that computers could assist a physician in the practice of medicine. In some years this interest has been forced to the side; in other years it has been a central issue for me. My colleagues and I may be able to claim some modest success in narrow areas of computer applications to medicine, but despite a half dozen years of sustained attention to medical information systems, we had no success that would lead your physician to want to use a computer directly for patient care.

My interest in this unruly, but fascinating topic has been rekindled by electronic radiology, a new field that explores the role that images, such as X-rays can play in the interactions of physician and computer. Thus, I beg your indulgence for the next half hour while I try to present my thoughts regarding computers and the practice of medicine.

The Promise of the Physician's Workstation

The practice of medicine is an information rich activity. Physicians can bring to bear on their medical decisions information obtained from the patient's complaint, the patient's record, their medical training, medical journals, libraries, consultants and colleagues. There is more information available for their decision making than they have time to use. Unfortunately, all these information sources may not be easily available or equally useful to physicians seeing patients at their offices. Portions of the patient's record may be stored in the hospital or otherwise not

readily accessible. The physician's training may be outdated or uncertain. Needed facts may be difficult to find in libraries or medical journals because of distance, indexing inefficiencies, recondite presentation or conflicting results. Recourse to consultants is time-consuming, particularly for the patient. Only the medical colleague can supply quick and relevant advice, but too often that advice may be flawed.

In general, physicians work hard to overcome impediments to gaining the best information to apply to each decision, but medical urgency and limits on their time usually require decision making even while substantial gaps in the available information remain. The acculturation that a physician endures while in training insures that such an incomplete basis for decision making is familiar, though not at all welcome. The goal of the physician's workstation is to aid the user in making more informed decisions and initiating appropriate actions. As a by-product, it can automate many burdensome non-medical tasks imposed as a result of the increasing regulation of medical practice. Through communications and computer technology the physician's workstation is expected to bring together the needed information even though it may be geographically distributed and bibliographically obscure. The ultimate goal, a revolution in the availability of information for health care, is a distant one, but many hope that important steps toward it can be taken in the next few years. The need is urgent because of the significant changes the health care system is now experiencing. But more of that later.

I would like to take a moment to try to distinguish the computer workstation from the personal computer. The computer workstation has an improved display (double the resolution both vertically and horizontally), an improved processor (up to 10 times the performance in instructions per second) and the ability to execute multiple software processes concurrently and with relative ease. These are quantitative distinctions. The important qualitative distinction, in my opinion, is the ability of the workstation to work easily and efficiently with a wideband communication system, whether local or national. Finally, we should note that the workstation shares with the personal computer the highly desirable property of predictable response time; a property sadly lacking in a time-shared computer serving many terminals.

Along another dimension the computer terminal is substantially less expensive than the personal computer which in turn is substantially less expensive that the workstation. These distinctions are blurred at the edges, but it is important for today's discussion to assume a high quality display, considerable computing power, multiprocessing and, most important, wideband communications. Within five years the marvels of microelectronics will surely bring the cost of such workstations down to levels accessible to all physicians.

What Is A Revolution In Health Care?

The last few paragraphs were intended to clarify the meaning of the word "workstation" in the title and I hope you now have an initial idea of what is meant by the phrase "Physician's Workstation." Before going on to my analysis of the chances of achieving the goal of the physician's workstation, I would like to try to explain the first half of my subtitle, "Health Care Revolution."

John Brooks in his book, *Telephone*, notes that the first rudimentary telephone exchange on record, built in 1877, connected the Capital Avenue Drugstore in Hartford, Connecticut, with various local doctors. Curiously, the first automatic telephone exchange, installed in 1891 in Kansas City, was designed and installed by an ambitious undertaker so that his potential customers could bypass the manual exchange and the questionable integrity of its operators. Thus, for about 100 years the major medical events in our lives have been intertwined with telephone service, both coming and going.

Just after the introduction of the automatic exchange, the automobile came rumbling into our lives and that of the general practitioner. Physicians found that they could decrease their time spent in travel, compensate for the mobility of their patients and even increase their practices by buying an automobile. Paul Starr in his book, *The Social Transformation of American Medicine*, reports a physician's comment that, "an auto cut the time required for house calls in half." As patients also bought automobiles, it was possible for the physician to cut travel time even more by increased dependence on the telephone and by asking patients to visit the office.

These two technological innovations, the telephone and the automobile produced a revolution in the practice of medicine. In the mid 1800s, before their introduction, Starr says, "physicians probably averaged no more than five to seven patients a day. By the early 1940s, the average load of general practitioners, both rural and urban, was about eighteen to twenty-two patients a day." This change in physician productivity was gradual, but revolutionary in its effect on the manner in which medicine was practiced. These developments reduced the isolation of medical practice and made possible more rapid intervention in emergencies. As Starr says: "Increasingly, one came to expect the doctor's intervention. Improved access ultimately brought greater dependency."

Another technological revolution in health care was Roentgen's 1895 discovery and application of X-rays to imaging the bones of his wife's hand. This discovery was reported around the world within 15 to 20 days and was followed by an immediate and universal outbreak of activity that foreshadowed a medical revolution whose consequences are still unfolding. One such consequence is computed tomography or the CT scanner. Introduced in 1972 by Nobel laureate Godfrey Hounsfield, the CT scanner took less than a decade to completely revolutionize neuroradiology and several other branches of diagnostic radiology.

These examples of health care revolutions give you an indication of what I mean by the first half of my subtitle. In fact, descendants of two of them, the telephone and x-ray images are important parts of the story of the physician's workstation that I will discuss later.

Near MISes

The second part of my subtitle is an unpardonable pun on the acronym for Medical Information System or MIS. The pun is about as melancholy as the history to date of medical information systems, a history that spans more than 25 years. Perhaps a tenth of a billion dollars have been spent by government and industry seeking the goal of a comprehensive medical information system that assists the physician in the practice of medicine. Such a system will store, organize, reconcile and communicate the information needed by the physician to make informed clinical decisions.

Pioneers of this era can be identified more easily by the arrows in their backs than by the laurels on their heads. There have been many MIS developments throughout the world, but only a small fraction have been comprehensive and only a few of those have achieved continued clinical operation. In general, even today the comprehensive MIS is still struggling for widespread acceptance. The financial and scheduling functions of a hospital have, of course, been automated and are in widespread use, but the interaction of computers and physicians in the process of medical decision making has hardly left the research laboratory. In fact, each new attempt to put such a system into widespread use seems to constitute the nearest MIS yet.

What Has Been Missing?

Many of the MIS developments to date have been hindered by limited technology: alphanumeric screens, keyboard input, slow and unpredictable response times, incomplete

availability of the medical record, primitive user amenities and availability in the hospital or in a group practice, but not both. These technical shortcomings must be overcome if future systems are to approach more closely the three MIS desiderata, completeness of medical information, ubiquity of access and ease of use.

Completeness. For over 100 years the hospital has been the physician's workshop. There a complete medical record, the chart, is maintained containing information on daily medical care, specialized diagnostic techniques and therapeutic procedures. The central role in medical care that the hospital has played is now being challenged by government, employers and public opinion. In Donald Cohodes' article, "Health Care Under Siege", he is reminded of the words of Jack Kent Cook, owner of the Washington Redskins, when he fired George Allen, "I gave him an unlimited budget and he exceeded it."

The results of this challenge to the economics of health care are already visible in decreased hospital occupancy rates and a proliferation of less expensive treatment settings. A major fraction of the former inpatient business of the hospital has been shifted to various outpatient facilities with significantly reduced costs. This shift exacerbates the problem of assembling a complete medical record for use in clinical decision making.

Even the information that is in the chart may not be accessible by computer. Handwritten notes from nurses or doctors account for two-thirds of the paper in the chart and even if coded and entered into a computer system still account for half of the stored information in the electronic patient record. The fact that these handwritten notes are not available to present MIS users has repeatedly been viewed as a serious handicap.

Other graphical and pictorial information such as electrocardiograms and radiographic images are not included in the electronic chart of a typical MIS. Thus, the missing information leads the MIS user to extra work and frustration when, for example, outpatient surgery records, radiographic images or notes on a specialist's consultation are required for decision making.

Ubiquity. If the MIS is installed in a hospital, it may provide information to physicians at their offices about inpatients, but either no system or a different system must be used for outpatients. For the few physicians using an MIS and on the staffs of several hospitals, only information on a small fraction of their patients is accessible electronically. The general availability of today's MIS is far, far from that of the telephone.

Ease of Use. The technology available to MIS developers has not been up to the job. Most physicians do not like to use a keyboard; it slows them down. Even the color of the paper forms and the organization of handwritten notes provide some clues about a page's contents that are not available in the tedious sameness of the typical alphanumeric computer display. User interface technology has been primitive and frustrating to users who are always under time pressure and find little advantage to using computers in medical decision making.

Will Emerging Technology Help?

The goal of the physician's workstation is to aid its user in making more informed medical decisions and in initiating appropriate actions. Unfortunately, efforts to reach this goal have fallen short in one or more of the categories: completeness, ubiquity or ease of use. For most physicians, use of such systems has just not been worth the effort.

Were it possible to overcome the technological shortcomings that have hindered contemporary efforts, would the predicted information revolution in health care sweep the nation? Before I give you my answer to that question, let's review the near-term technology that might be

helpful.

Completeness. Exciting work is underway here at Washington University and at several other medical centers in the acquisition, storage, transmission and display of radiographic images in digital form, a technology known as electronic radiology. The resolution of the images as they are displayed on a computer screen is now so high that diagnostic decisions can be made as easily as can be done with light box and film.

Scanners that can quickly capture arbitrary black-and-white images, such as handwritten notes, are being integrated into computer systems. With this technique, a facsimile of a scanned page can be presented on the computer screen as a bitonal image even if the content of the page cannot be coded in alphanumeric form. Speech in acoustic form can now also be captured, stored and reproduced, but not, in general, understood by a computer. Thus, a dictated report can become part of the electronic chart pending its transcription to alphanumeric form by a typist.

Optical disk systems are being installed that can manage a trillion bytes of data, enough for the on-line storage of all of the images produced in our radiology department for a period of several months. Off-line storage of all images produced for a decade or more could be placed in space that is less than 2% of that presently occupied by film storage. Even if handwritten notes were stored in facsimile form, the electronic storage of a day's information from the conventional patient chart would occupy less than 1% of the electronic storage required for a single day's images.

Ubiquity. A revolution in telecommunications is underway throughout the western world. The Integrated Systems Digital Network known as ISDN is being introduced in hundreds of communities in the U.S. this year. ISDN will provide channels for the digital transmission of information that are an order of magnitude higher in speed than present voice lines and will soon cost about the same as today's business lines. Over such channels it will be possible to send digitally compressed radiographic images to any ISDN location within the nation in a few seconds. Future developments will even reduce this time to a fraction of a second. Similarly, the electronic chart can be brought up to date in under a second even at remote locations. Lap top computers are now commonplace in business so that, from a technical point of view, true ubiquity can soon be achieved with an approach that might be called a cellular computer by analogy to the cellular telephone. In short, POTS, an acronym for Plain Old Telephone Service is being replaced by PANS or Pretty Amazing New Services.

Ease of Use. New powerful workstations have recently been announced by several vendors, each of which is scrambling in the latest competition to make, break or merge with your favorite computer company. These new workstations have high-resolution screens with the ability to simulate the top of the user's desk covered with many overlapping pieces of paper. One contender includes in their workstation an optical disk that can store the 75 most popular medical textbooks, and have room to spare. Screens that will display radiographic as well as bitonal images with clarity and precision will soon be added. But unstructured speech input from dictation of progress notes coded directly into alphanumeric form is still a decade or more in the future.

Forty years ago computers dedicated a trivial portion of their processing resources to user amenities. The portion so dedicated has grown steadily over the intervening four decades until the large majority of the resources used by software processes running on the new workstations are devoted to a dialogue with the user. An emerging "human-computer interaction" technology is developing whose present vocabulary is peppered with terms such as buttons, menus, widgets, windows, hypercards and artificial intelligence. This is a technology that recognizes the possibilities of computers are not limited by their power to compute, but rather by their power to

communicate with human users.

Will the Physician's Workstation Become a Reality?

Well then, what's the problem? With all this slick technology we should be on the threshold of the information revolution in health care. Unfortunately, there are several fundamental difficulties ahead.

Let's go back a few eras in medicine. Mystical medicine relied on protecting spirits, evil spirits, supernatural monsters and magical monsters. The patient belonged to a society that believed all these things and thus had no basis to doubt them. An amalgam of mystical medicine and empirical medicine was commonplace throughout the ages only yielding to a purer form of empiricism with the rise of the protestant church.

A sidelight on this empiricism in primitive societies that is too good to pass up concerns a cure for bed-wetting in young boys in Nigeria. A toad was tied to the appropriate part of the boy's anatomy. When the boy wets, the toad croaks and wakes the child. As with most empirical medicine although effective this procedure has it limits and problems. It does not work on young girls and it asks a lot of the toad.

Biological understanding in medicine, called biomedicine by some, began to replace empiricism in medicine in Europe in the nineteenth century and made its way to the U.S. in the latter half of that century. It is based on objective scientific understanding of the human body and is heavily dependent on the process of abstraction. But to abstract means to select a certain set of characteristics which are common to every known member of the class under study and ignore everything else. Thus the natural sciences including human biology, examine a reality from which all human attributes have been removed by the process of abstraction.

Biomedicine has had unprecedented success over the last century. We have come to expect it to triumph over all medical problems, but with its abstract view of the body, it cannot. As G. Gayle Stevens says in his article, "Reflections of a Post-Flexnerian Physician", "medicine must go beyond the geometry of tissue to the psychic and social spaces where much of modern disease, illness and malaise reside."

Many careful analysts of the medical profession agree that we are on the threshold of a significant change in health care. With each success of abstract science, the tension between biomedicine and humanism has increased, specialization has proliferated and attention to the qualities of integrity, respect and compassion, all so essential to the humane practice of medicine, has suffered. But we the patients have asked for our present predicament. We want to believe that every disease has a pill and that there is a causal explanation for every twinge. Our raised expectations for biomedicine have put us on a course toward bankruptcy and disillusionment.

Both the patient and the physician need to have a better understanding of how to increase the long-term satisfaction resulting from their mutual encounters. I believe that the needed understanding will come from examining the evidence, evidence about outcomes and their relevant biological, environmental, behavioral and social antecedents. What I think this means is that information and the computers used to store, organize, reconcile, communicate, coordinate and manage that information will have increased importance to medicine in the future. But we may have to wait.

Care through the eras of mystical and empirical medicine and through most of the era of biomedicine has been focused on acute episodes of disease. Biomedicine, so successful in finding

treatment for most acute ills, has exposed in the population a previously less noticed mass of chronic disease and psychosocial disorders. In fact, most current hospital admissions are related to the sequelae of these more complex illnesses.

The established system of compensation in health care was created for acute disease. In this system action is valued and the information and coordination necessary to manage chronic illness and psychosocial disorders are not. Perhaps it is not too much to hope that in the future the system of payment will also provide remuneration for health care information and coordination. When that occurs the physician's workstation will not only be a reality, but a necessity for all. The information revolution for medicine will have begun and tools will be in place for greater understanding and an increase in our long-term satisfaction with health care.

However, at the moment, the physician's workstation provides insufficient payoff for the physician to want to use it on a regular basis. Even with the exciting benefits of emerging computer technology, most physicians are unlikely to buy a workstation. It is similar to the situation in the early years of this century when the transportation infrastructure, paved roads, mechanics and gas stations, were rare. A physician might buy a car for pleasure or status, but its regular use in his practice required an unusual dedication.

The infrastructure required for the comprehensive use of the physician's workstation is substantial. Like our highway system it will be developed only over a period of many years. Unlike our highway system it may be true that anything short of everything may not be enough. This fact along with the present lack of value that those who pay place on information and coordination in health care can postpone the workstation's acceptance for a decade or more.

Those of us in computer technology and medicine need to know more about the value of the physician's workstation in routine practice. This need goes beyond experiments and demonstrations; it should investigate whether the anticipated benefits in informed medical decisions and health care coordination really exist. This need is confounded by the delays in general acceptance described earlier and goes well beyond the creation of the workstation's hardware and software to the challenging task of the development of an informational infrastructure.

I believe the path to meet this need will focus on a narrow group of physicians who really need the physician's workstation now, a group for whom the benefits far outweigh the familiarization and financial investments. That such a group exists today is not certain, but good candidates are those who especially need the workstation's ability to communicate at high speed. For example, consider the physician who practices from multiple offices and the advantages of having medical records that are centralized, complete and instantly available from any one of his or her several offices. Consider, too, the cardiologist and neurosurgeon whose clinical decisions depend upon images that are often frustratingly difficult to bring to the right place at the right time.

It is an exciting time in computer science and in medicine. The problems hold our interest because they are challenging, important and we wonder how they will turn out. Although we start by seeking more information, our goal should always be more wisdom. *That* is the hard part. In fact, as T. S. Eliot cautions us, "Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost in information?"