Transforming Humanity: Toward the Implantable Walkstation

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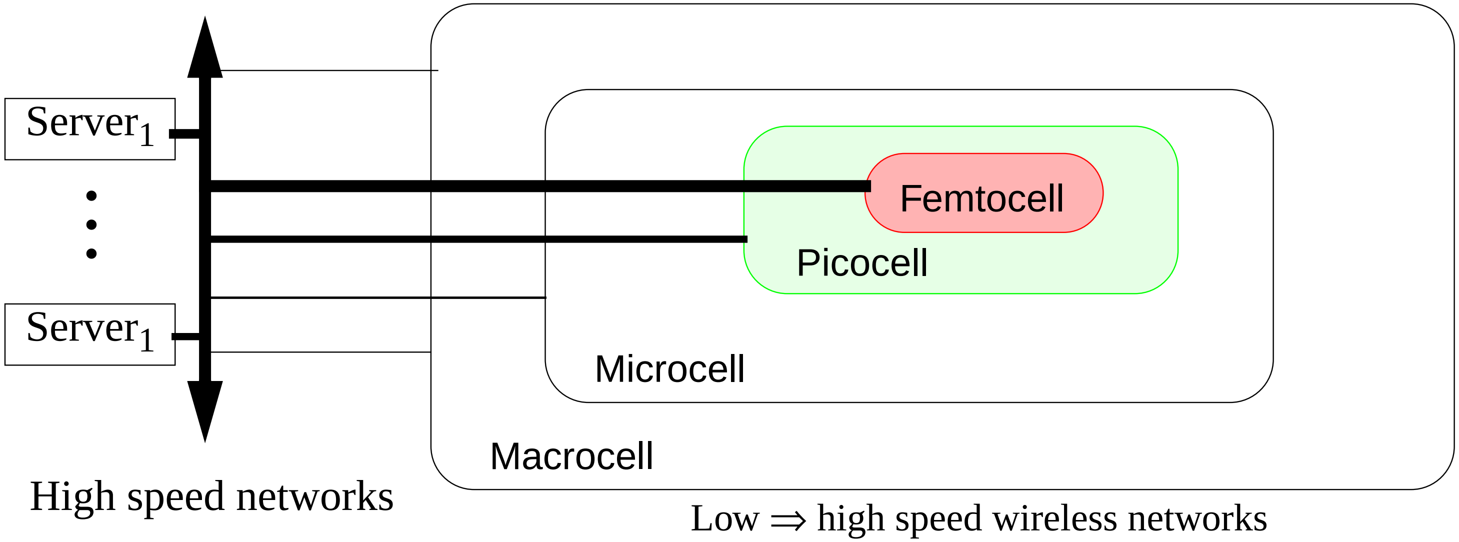
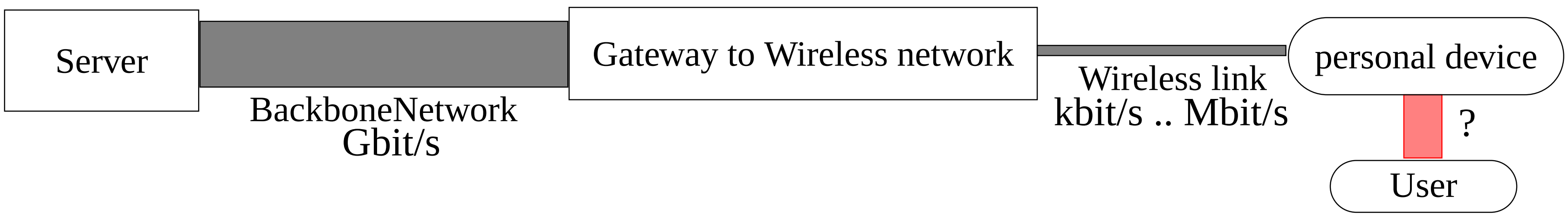
TURNING 2000: A Millennial Weekend
C.W. Post Campus, Long Island University
Brookville, NY
15-16 October 1999

Bottlenecks

- Server and Network Bandwidth and latency



- User Bandwidth and latency



- Power and Energy ⇒ need a computational theory of O(energy)
- Imagination!

Wearables

"… It will be possible to put a 100+ MIPS CPU and a 0.5 GFLOP DSP in a $200 Nintendo Game Boy within 2 years, for less than $25 bucks of Si cost. With this kind of cheap, available cycle time, how hard would it be to add a communications cartridge/dongle into a game slot? …"

-- John Novitsky
of MicroModule Systems,
and of Microprocessor Report[1]

Who are the competitors?

Ericsson, Lucent, Nokia, Siemens, … or Nintendo, Sega, Swatch, …

⇒Telecom (only) companies have no future - perhaps even the traditional datacoms have a problem!

1. From Wearables mailing list Wed, 17 Sep 1997 19:22:17 -0700.

Near Future systems

Personal Portal

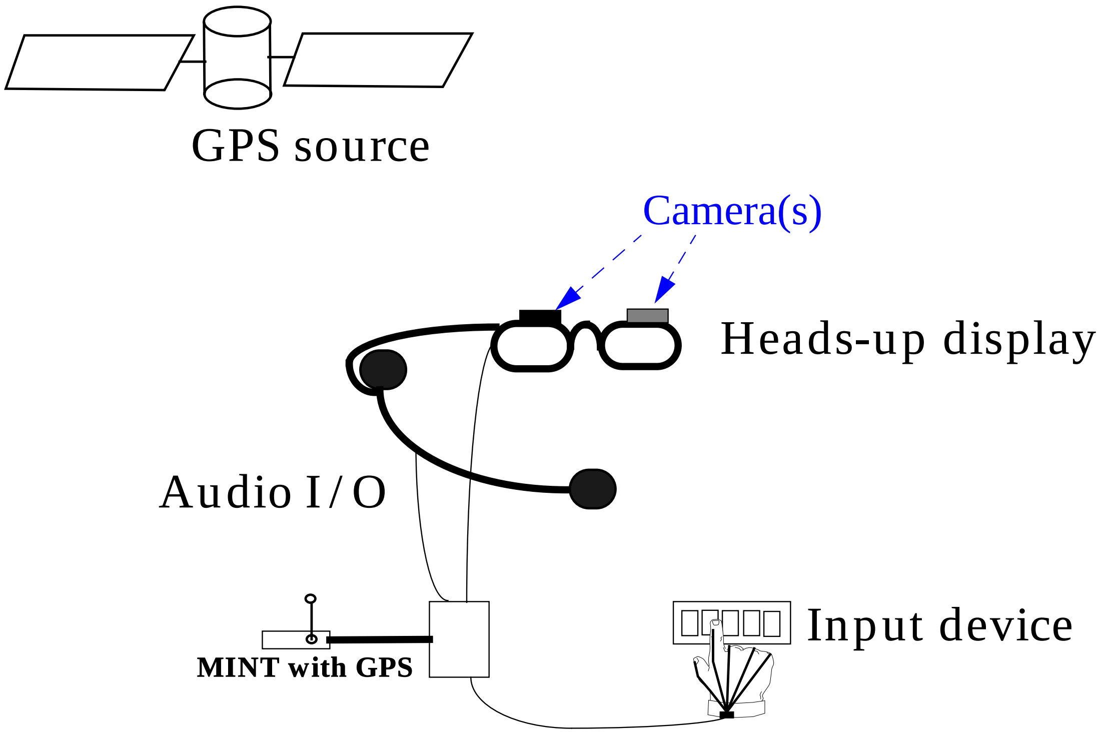


Figure 1: Vision-2, 2000 - high level of integration

Evolution of new varieties of networks

Already we have: WANs (Wide Area), MANs (Metropolitan Area), LANs (Local Area Networks)

VANs Vehicle Area Networks

Very local networks

DANs Desk Area Networks

The computer/printer/telephone/… will all be part of a very local area network on your desk.

- wireless links ⇒ No longer will you have to plug your printer into your computer (PDA/…) into your computer
- active badges⇒ No longer will you have to sign in/out of areas, write down peoples names at meetings, … the system can provide this data based on the active badges

Olivetti and Xerox are exploring “Teleporting” your windows environment to the workstation nearest you, on command, if there are multiple choices probe each one (currently a “beep” is emitted to tell the user which).

BANs Body Area Networks

Users will be carrying multiple devices which wish to communicate:

- thus there will be a need for a network between these devices which you carry around; and
- personal devices will wish to interact with fixed devices (such as Bankomat machines, vehicle control systems, diagnostic consoles (for a “mechanic” or repairman), …) and other peripherals.

Situational awareness and Adaptability

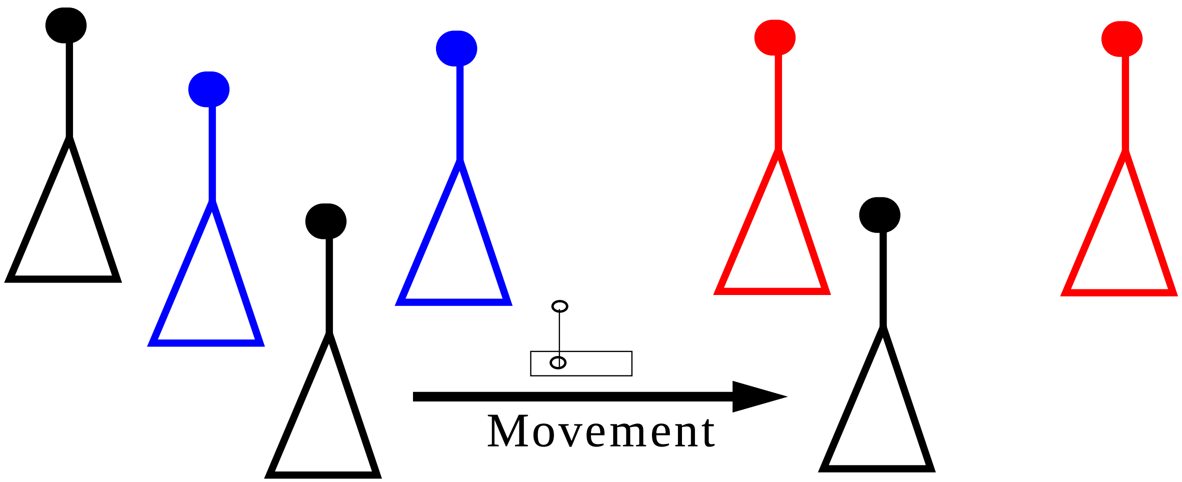


Figure 2: Where am I? What am I? Who am I?
Where am I going? When will I be there? What should I become? Who should I become?

- Location dependent services
- Predicting location to reduce latency, reduce power, hide position, …
- Adapting the radio to the available mode(s), purposely changing mode, …
- Reconfigure the electronics to adapt, for upgrades, for fault tolerance, …
- Reconfiguration vs. powering up and down fixed modules (what are the “right” modules, what is the “right” means of interconnect, what is the “right” packaging/connectors/…, needed speed of adaptation)

What are the possibilities? Using augment reality for manufacturing and repair.

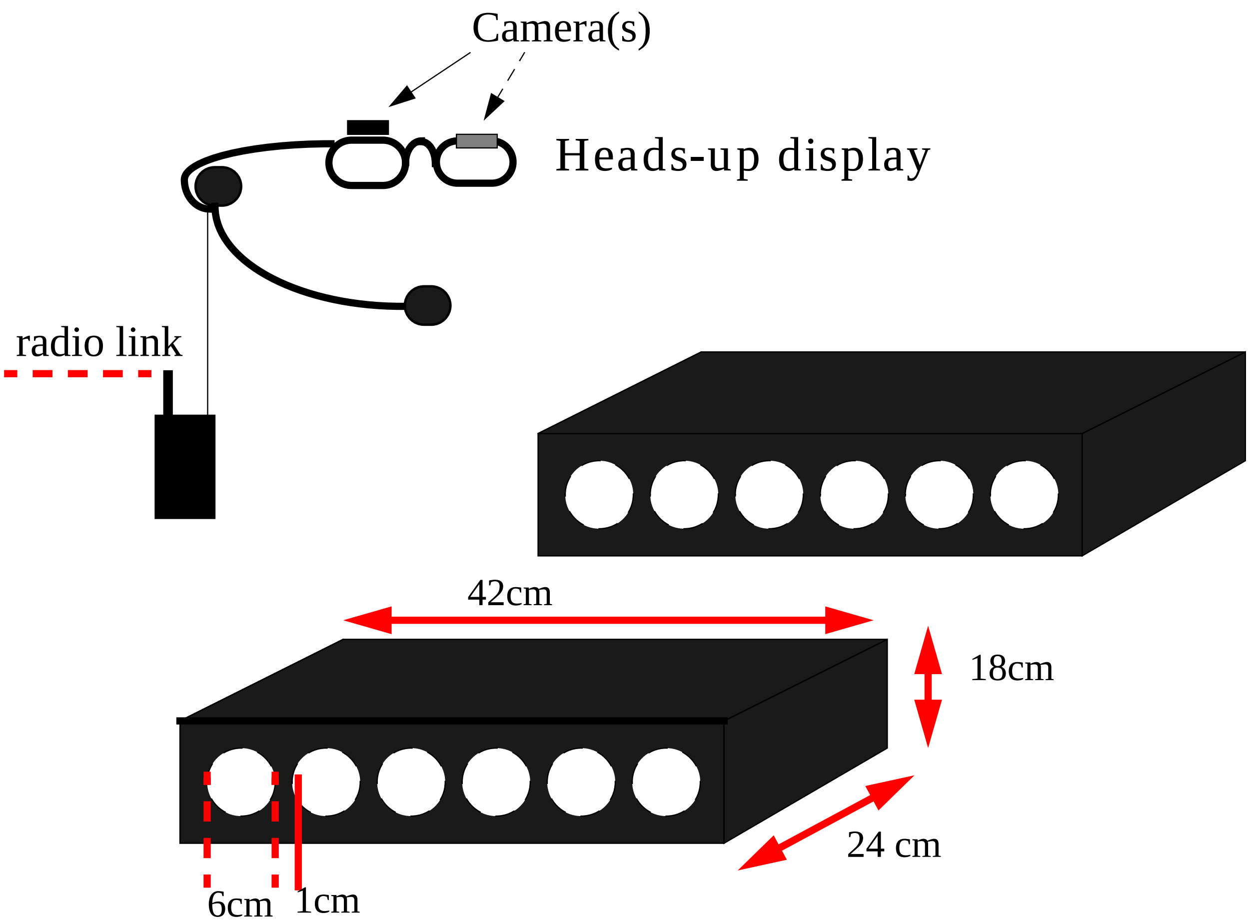


Figure 3: User carries their own interface - for use in local environment

Use camera(s) for returning image to an expert [a human and/or a machine] for assistance.

HUD as a windowing system

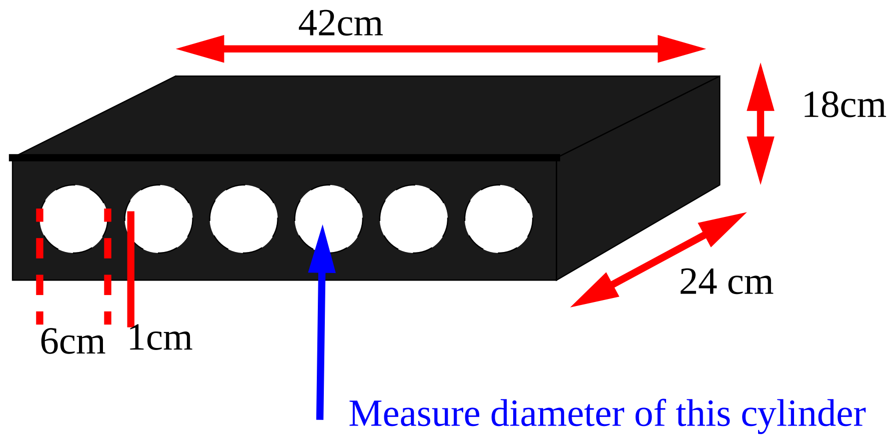


Figure 4: User receives audio/graphic/video information from remote advisor.

New objects in Web space: URLs or URNs on everything

Henrik Gustafsson’Matchbox Badge
http://www.pcs.ellemtel.net/pcc/TI98/Prototype/equipment.htm

Imagine an International Article Numbering Association (EAN International) or Universal Product code (UPC)[1] subspace mapping to product web pages with safety, ingredients, recipes, etc.

as computed by:
http://www.milk.com/barcode/

http://051000029522.upc.org

or perhaps:

http://029522.051000.upc.org

in item.manufacturer form
more suitable for DNS use

For decodings see http://www.deBarcode.com/ for UPC or
http://www.upclink.com/ for mapping from ISBN to publisher’s information about a book

1. Invented by George J. Laurer of IBM, in 1973

Future Systems

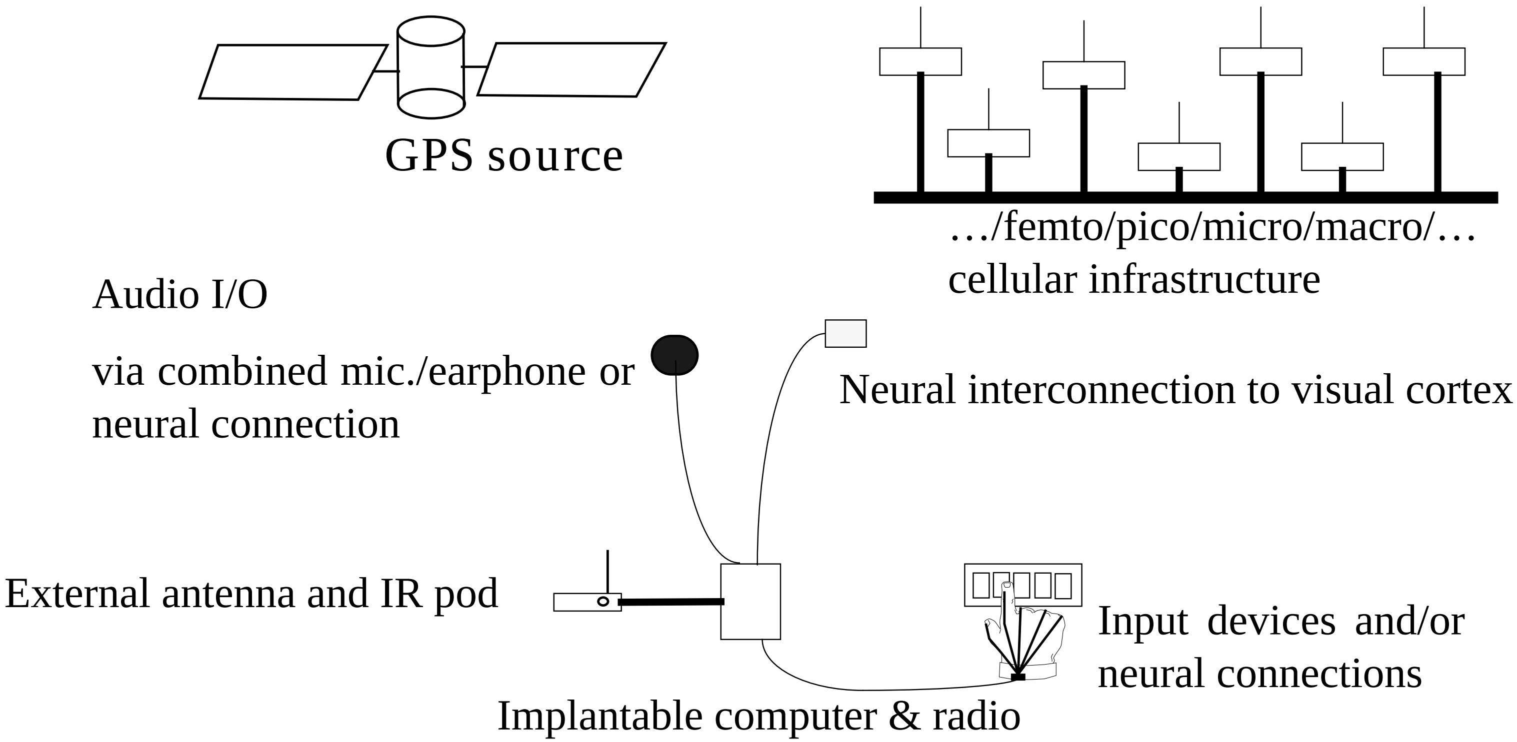


Figure 5: Vision-3, 2005-2015 - very high level of integration

Cochlear Implants

Cochlear implants directly stimulate the auditory nerve.

>10,000 have been implanted (since 1957)

Cost

- ~20,000 ECU for the implant {surgery is an additional cost}
- current cost based on the existence of a single supplier.

User evaluation

- Congenitally deaf - do not find them of much interest
- However, those who have lost their hearing find them to be wonderful (even though they provide limited auditory information).

Morbidity

- very low

Prosthetic Vision

"The use of neuro-stimulation to create artificial vision for the blind was first proposed by Benjamin Franklin in his treatise on lightning in 1751. Franklin's work is continued at the Dobelle Institute -- an effort begun by Dr. Wm. H. Dobelle in 1969 at the University of Utah.

Our goal is to create an artificial vision device to allow unaided mobility for the blind."

--- http://www.dobelle.com/research/av.html

In the 1960s, Giles S. Brindley of the Univ. of Cambridge, attached 80 electrodes to miniature radio receivers and implanted them into a sightless volunteers brain. Subject reported seeing phosphenes.

1992 a blind volunteer at the U.S. National Institute of Neurological Disorders and Stroke
$\Rightarrow$ recognized phosphene letters

Two approaches:

- Retinal implants - to avoid brain surgery; requires health optic nerve and nerves to retina
  - MIT and Harvard: 20 micron thick retinal implant - will link to camera in glasses frame via laser diode http://rleweb.mit.edu/retina

“Our work over the last nine years has included: 1) study of the response of retinal ganglion cells to retinal stimulation, 2) development of surgical techniques to implant a device into the eye, 3) methods to stimulate the retina electrically and record the induced responses from the brain, and 4) design and fabrication of prototype implantable solar batteries and stimulator chips, described above. We have developed a basic prototype of the prosthesis and have performed "proof-of-concept" experiments with animals, showing that implantable electronics can deliver a visual signal to the brain. But theseexperiments cannot tell us whether the information that has arrived at the brain is interpretable, i.e., could be useful to blind patients. Therefore our next major goal is to carry out short-term implant experiments with blind human volunteers. These will help to determine the quality of perception that can be attained over a period of two or three hours with electrical stimulation of the retina through a surgically implanted microelectrode array. This array will not remain in the eye following surgery, since we have not yet developed a biocompatible implant that will ensure long-term safety following implantation. That will be our subsequent goal, and must be attained before the prosthesis can be used as a treatment for disease. This long-term goal is ambitious, and we cannot provide an accurate timetable for its completion. But we do not anticipate having a suitable device to treat these diseases within the next five years.”

--- http://rleweb.mit.edu/retina/firstpage.html

- Two other groups connection to the front of the retina are: one lead by Eugene DeJuan, M.D. and Mark Humayun, M.D. at Johns Hopkins Medical School, and the other by Prof. Rolf Eckmiller at the University of Bonn in Germany.

- Dr. Alan Chow in Chicago and Dr. E. Zrenner in Tubingen, Germany are working on an ocular implant that connects to the back side of the retina.
- Duke University

- Cortical implants - requires brain surgery (Utah team uses a 1 cm^2 hole in the skull)
  - since it penetrates the visual cortex it produces highly localized stimulation
  - can have higher mass than retina implant (since movement is slower than eye movement)
  - Current 10x10 array is 4.2mm x 4.2mm, base of electrode is 80 μm
  - Each electrode is tipped with platinum or gold (or iridium)
  - Each electrode is insulated with polyimide [which has known adhesion when exposed long term to body temperature saline]
  - Currently wire attachments are made to the back side of the array (by ultrasonic welding) - the wires then connect to a percutaneous connector
  - the array is inserted pneumatically in the brain - to provide good electrode depth

Terry Hambrecht, M.D., of the National Institutes of Health is also persuing a visual cortical prosthesis

Bionic Technologies, Inc.'s Intracortical Electrode Array

Acute microelectrode assembly (10x10 array, 100 active electrodes) $1,250.00

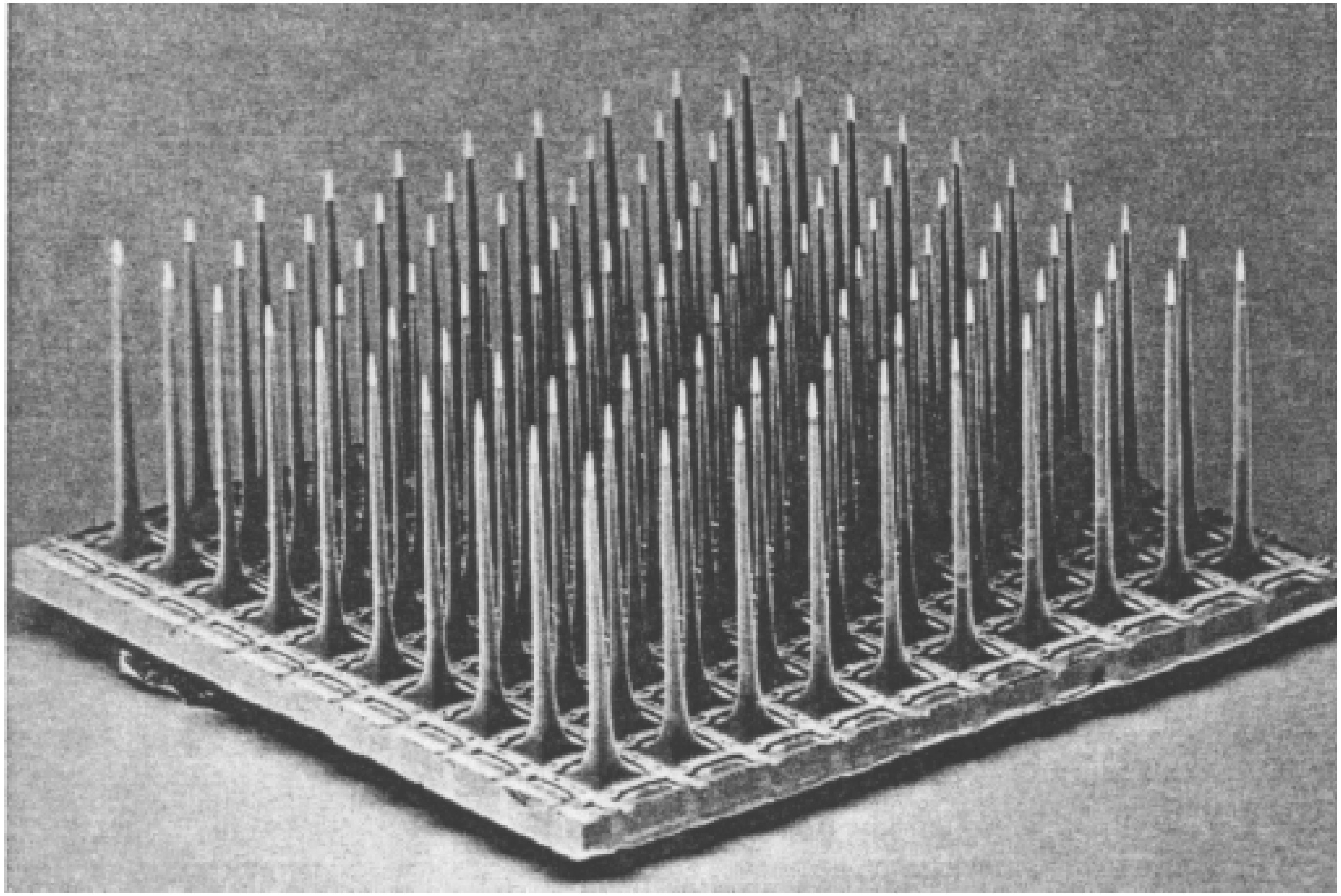


Figure 6: 10 x 10 silicon electrode array (each electrode: 1.5mm long, 0.08mm wide at base, 0.001mm tip), Built at the Univ. of Utah, by Richard A. Normann, et al.; from Scientific American, March 1994, pg. 108.

Neural Recording

The Utah array has also been used to record neural signals:

- evoked response to visual stimulation

Nordhausen, Rousche, and Normann have proposed that it might be implanted in the motor cortex area of the brain to allow control of external devices (such as wheelchairs, etc.)

Other multiple probe designs have been proposed:

- thin film multiple electrode probes: Prohaska, Olcaytug, Pfunder, and Dragaun
- planar multisite probes: Drake, Wise, Farraye, Anderson, and Be-Ment
- multisite microprobes: Blum, Carkhuff, Charles, Edwards, and Meyer
- …

Non-metalic bi-directional neural interfaces

Neurochip: Neuron silicon circuits http://mnphys.biochem.mpg.de/ :

(a) Silicon-Neuron Junction (input to the nerve) (b) Neuron transistor (output from the nerve)

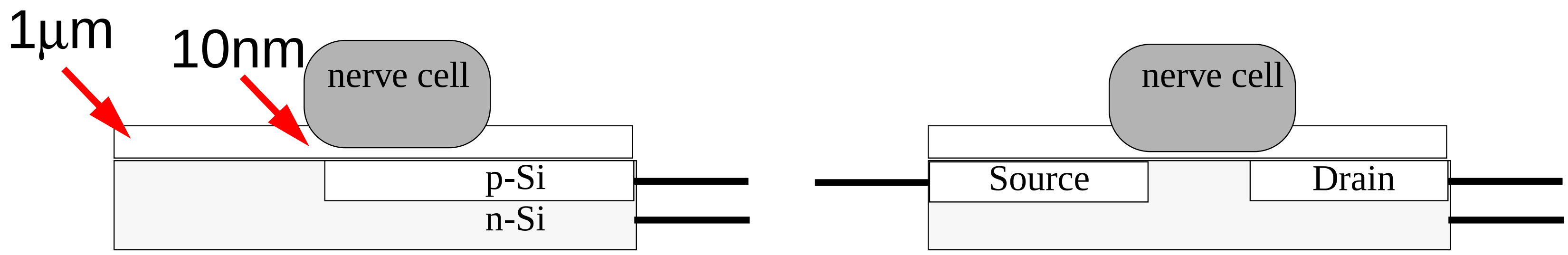


Figure 7: (a) Capacitive coupling of data into nerve and
(b) using the charge in the nerve to control a transistor's gate for getting data out of the nerve

(a) Peter Fromherz and Alfred Stett, "Silicon-Neuron Junction: Capacitive Stimulation of an Individual Neuron on a Silicon Chip" Phys.Rev.Lett. 75 (1995) 1670-1673

(b) P.Fromherz, A.Offenhäusser, T.Vetter, J.Weis, "A Neuron-Silicon Junction: A Retzius-Cell of the Leech on an Insulated-Gate Field-Effect Transistor" Science 252 (1991) 1290-1293.

“The apparent problems posed by this junction on the physical and informational levels are so enormous that it is impossible today to predict whether such a form of communication will ever become a reality. For this reason, an ethical consideration of issues such as "chip in the brain" or "brain in the computer" would be unfounded and superfluous.”

-- P. Fromherz, “Neuron-Silicon Junction or Brain-Computer Junction?’ Ars Electronica Festival. Eds. G. Stocker, C. Schöpf. Springer, Wien 1997, pp.158-161. http://mnphys.biochem.mpg.de/general/pub/ars/ars_e.html

Why not use an external system?

Numerous researchers (such as Masahiro Kahhata) has proposed using non-implanted interfaces (such as EEG[1] {Masahiro Kahhata's Interactive Brainwave Visual Analyzer[2]}, EMG, …) to control external devices. Other researchers have used tactile, auditory, … means to provide input to the human.

Positive attributes:

1. no surgery needed
2. much simpler to get approval for marketing such system
3.

Negative attributes:

1. These systems are not as energy efficient as a direct neural interface.
2. They are something additional the user needs to carry with them.
3. So far they seem to have much more limited bandwidth than the potential bandwidth of direct interfaces
   Since an action potential (i.e., nerve impulse) lasts about 1 ms (millisecond) but takes about 5 ms to cross the synapse to influence the next cell we ought to be able to signal at ~200Hz on each signal path.

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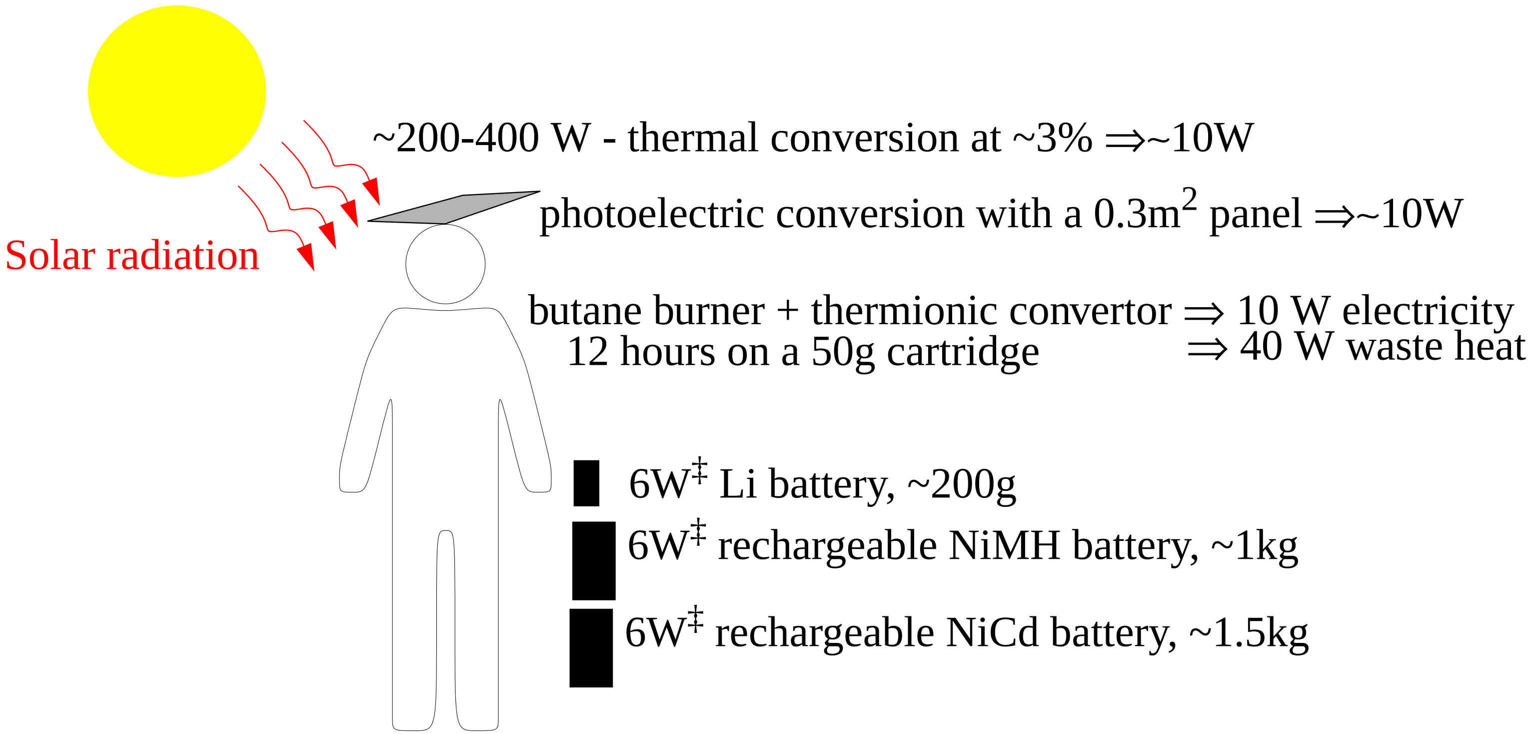
1. http://www.ee.ic.ac.uk/research/neural/bci/review.html
2. http://www.IBVA.com

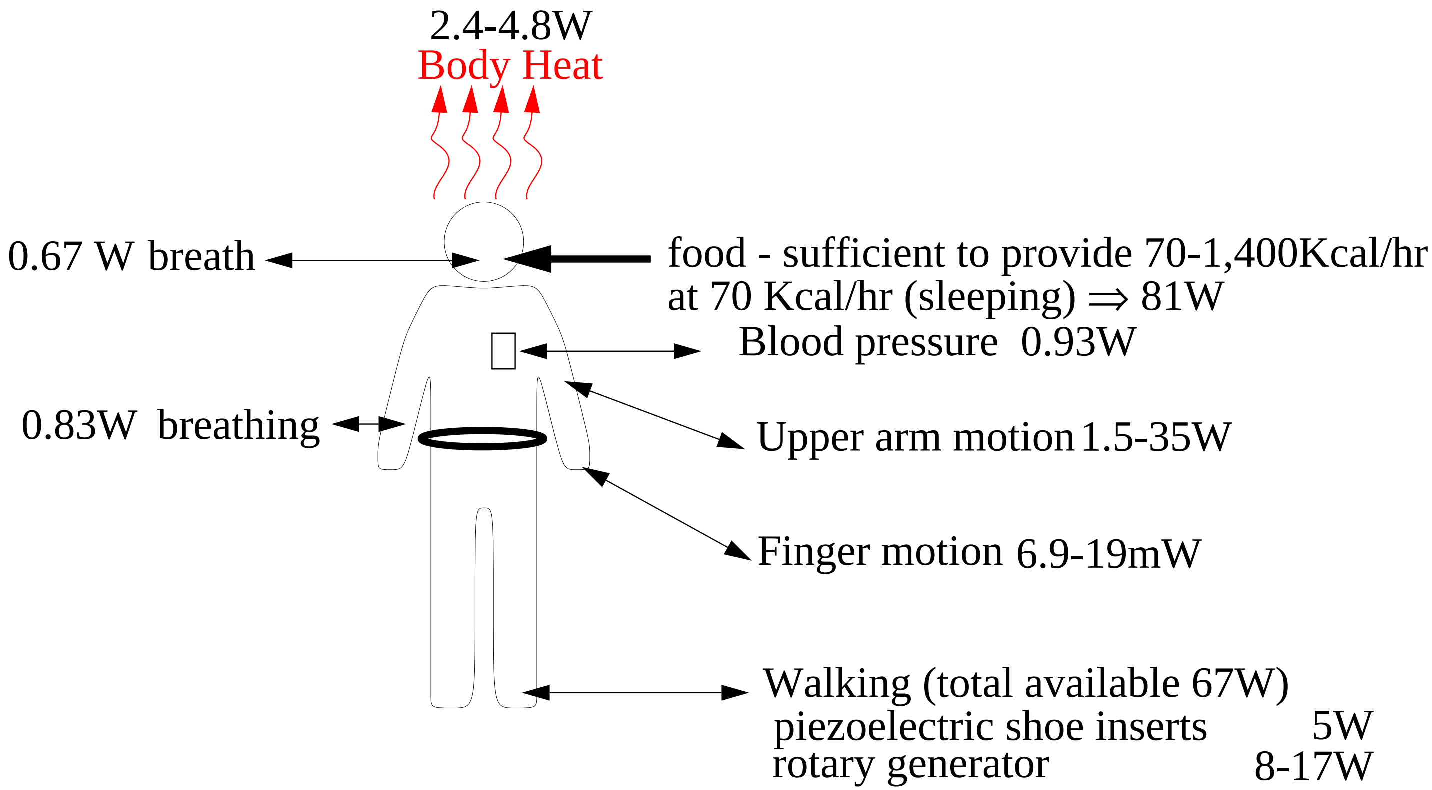
External Power



Numbers are approximations for a 50 kg adult, with light color skin, 1.6m in height, with an area of $1.5m^2$

Figure 8: based on Wearables e-mail discussion by G.Q.Maguire Jr., Vaughn Pratt, Paul Picot

Power by the people



Numbers are approximations for a 60-70 kg adult, eating ~2,000kcal/day ⇒ 2325 Wh

Figure 9: based on “Human Powered Wearable Computing”, by Thad Starner, MIT Media Laboratory, TR-328, May 1995.

C&C Work Package 3
MOBILE INFRASTRUCTURE

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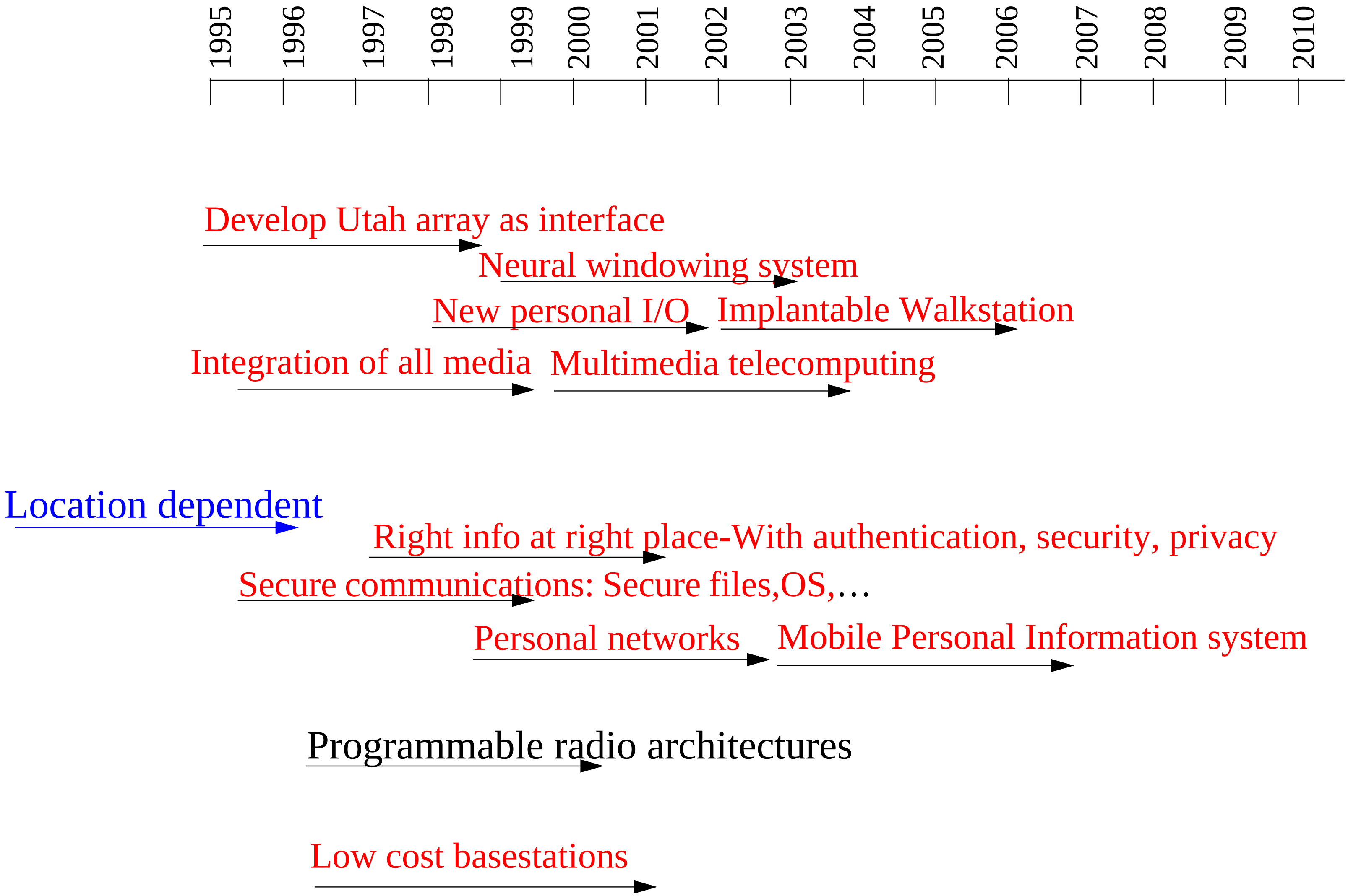
5 April 1995


1995
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2010
Develop Utah array as interface
Neural windowing system
New personal I/O
Implantable Walkstation
Integration of all media
Multimedia telecomputing
Location dependent
Right info at right place-With authentication, security, privacy
Secure communications: Secure files,OS,…
Personal networks
Mobile Personal Information system
Programmable radio architectures
Low cost basestations

Interview Q&A[1]

Q. (Peter.Thomas): What are the primary motivations for the idea of connecting up digital and neural systems - the notion of 'cyborgs' has of course been a mainstay of much SF for a long time - but what new motivations are there? (I'm thinking particularly of your remarks about BANS at the MoMuc paper).

A. (G.Q.Maguire Jr.): I think that the only way to really have personal systems which have both low power consumption and a "large" user interface - is to build them in. SF and some scientists have been exploring the idea of cyborgs for sometime (so it is now widespread within society), while bioengineering and medicine have been producing the basic science to enable the creation of biocompatible interfaces and prosthetic, computing and microelectronics have enable the construction of both computation devices and now micromechanical devices, telecommunication R&D has enabled mobile communication supported by a high speed infrastructure, … . Thus the stage is set and the time has come to address the concrete construction of cyborgs as well as to discuss the moral, ethical, and social issues involved.

Q: What are the actual means by which it will be achieved?

A: As we have discussed previously, the key idea which I am trying to build upon is that of new "personal" interfaces which a user can LEARN to use - and which exploit existing and emerging technology being developed for OTHER uses (such as prosthetic, PDAs {Personal Digital Appliances}, PCS {Personal Communication Systems}, …). Thus this is an effort in synthesis and system design as well as an attempt to influence the development of these OTHER devices so that they can be readily incorporated into implantable and wearable computing and communication devices.

Prof. Richard Normann (at the Univ. of Utah) and others is developing arrays of microelectrodes which when places in the visual cortex could be used to electronically stimulated the brain to "see" either scenes from a CCD camera or a completely synthetic scene - such as a windowing system which today we display on CRTs {Cathode Ray tubes}. They have stated that putting these arrays in the motor cortex could allow the control of external devices (such as wheelchairs, etc.). Thus these devices can clearly be see to be both input and output devices.

The use of such arrays means that we don't need to use exotic technology (such as SQUIDs {Superconducting QUantum Interference Devices}).

Q: Is this qualitatively different from work on restoration of vision, hearing, sensation and on developing user interfaces using (for example) EEG outputs?

A: Yes, this work is different than the traditional approach of trying to generate a "replacement" for a sense. Note that above, I said "LEARN" to use - a major difference between the ideas I have proposed and the traditional view - is that I have no interest in how the brain and eye CURRENTLY function, i.e., there is no reason to require new interfaces to work in the same way as old interfaces. As an illustration, suppose that I were to loose one hand in an accident, this would make a serious impact on my current work which involves using a keyboard and mouse combination designed for an individual with two hands. However, I have used a number of other systems for inputting text which do not require two hands: a heads up display for typing with your eyes (designed for those without use of any hands) and a combination mouse+cord key (which you can operate with one hand). Neither of these systems involves movement of A finger to a specific key, pressing this key, and then releasing the key. Similarly, I know how to code a given letter using just two states of a signal into ASCII or Morse code. Neither of these has anything to do with the number of strokes in the letter, or its position on a keyboard. Thus the "visual" interface need not

1. My response (on Thu, 8 Jun 1995 20:50:27 +0200) to Peter.Thomas@csm.uwe.ac.uk, Re: "New Scientist" questions

generate something shaped like the letter “A” in order for me to “see” the letter “A”. Therefore, constructing a new “visual” interface device we do NOT need to understand how the shape recognizers of the human visual system respond.

Q: Is understanding of the ways in which neural processing works sufficiently advanced to enable progress in getting bits of information flowing both ways down a neural interconnection? What major parts of the picture remain to be understood?

A: I don’t think we understand enough about how we can learn to use such new interfaces, but I don’t think it will come from increased understanding of how we use existing senses. This is not to say that this other work should be abandoned, just that we need to take a look at new ways of using these “new” senses, rather than just looking at how the existing senses work.

Q: You make the analogy to other bits of ‘prosthetics’ we accept without question (spectacles, hearing aids, internal synthetic devices). Is a chip blown into the brain of the same type as these?

A: I have NEVER said that we accept these ‘prosthetics’ without question. I personally have reservation against ANY internal medical care. But this is a matter of personal choice as I do not see any benefits that accrue to me. However, I do wear glasses and would consider a pair of visual+motor cortex implants - as I believe the benefit does out way the risks. In fact, it is because of the resistance to accepting these changes from a moral, ethical, social, … point of view that we have to carefully explore the benefits, risks, and effects which these devices will cause.

For example, cochlear implants have been done on more than 10,000 people over a period of time beginning in 1957. These are now FDA approved for use with deaf adults and prelingually deafened children above the age of two [according to “Issues in the use of cochlear implants with prelingually deaf children” by M. Vernon and C.C.Alles, in American Annals of the Deaf, 139(5):485-92, Dec. 1994]. In a review on “Cochlear implants in children” by C.R. Souliere, Jr., S.M. Quigley, and A. W. Langman [in Otolaryngologic Clinices of North America, 27(3):533-56, June 1994.], the authors state “Cochlear implants are no longer considered new or experimental technology. In a study by N.L. Cohen, R. A. Hoffman, and M. Stroschein [in Annals of Otology, Rhinology, and Laryngology - Supplement. 135:8-13, Sept.-Oct. 1988], a questionnaire was sent to 152 surgeon to survey complications associate with a particular commercial multichannel cochlear implant, of 459 reported operations there were no deaths, 55 complications (11.8%), with 23 (4.8%) being major and 32 (7%) being minor. Implantation of these cochlear implants is quite invasive while the procedure used by Normann et al. of blowing an array into the brain via a small hole is much less invasive. Both the electrodes and the tissue surrounding explanted (i.e., extracted) cochlear implants have been studies and there appear to be no adverse effects even after 10 years of us.

Note that despite the apparent success of cochlear implants there remain good reasons why one might or might not use them in a given individual. [See the article by Vernon and Alles cited above.]

Q: Could you give a timescale for seeing the techniques and technologies advance to a point of commercial exploitability and a market with applications?

A: Just like any other prosthetic there will be different preferences for those wanting them. In addition, one can expect the same S curve adoption pattern as for other technology. The earliest adopters will be those with a disability, who will use this as a more powerful prosthetic device. I have suggested that one of the first groups of “non-disabled” volunteers will be the professional military, where the use of an implanted computing and communication device with new interfaces to weapons, information, and communication systems could be lifesaving. [For example to create truly fly by wire aircraft.] The next group will probably be those involved in very information intensive business, who will used these devices to develop an expanded information transfer capability [truly having “eyes in the back of their head”]. As to time scales, I expect that the first prototype devices as prototypes will be available in 5 years, with the military prototypes starting within 10 years, and information workers using prototypes within 15, general adoption will take roughly 20-30 years.

Q: Is the effort in all this primarily with technology (the development of new devices such as that of Normann’s group, or soft/firmware to control them) of with biological sciences in understanding the operation of systems into which they interconnect?

A: I think others are going to develope the basic technology, what I am personally interested in is the software and system use of this technology. How can we used these devices as personal interfaces and what are the missing new personal interface devices [I think this will take the next several years to explore.] What will a future “windowing” system look like if the user has direct neural interface? [This is something I hope to understand by 2003.] How do we provide the right information to the right place and in a secure fashion [this will take until ~2000]. What type of computing and communications infrastructure will this require? … .

Q: Do you have a scenario for how a user would experience accessing digital services via such a connection?

A: I envision it as a new kind “windowing system” combined with agent technology to allow activities to migrate to and from the fixed infrastructure. I also expect it will change the idea of where the boundary is between me “the physical self” and me the “perceptory/intellectual self”, by expanding the ability to perceive and interact far beyond what can be done with video conferencing!

Q: Will the opening up of this area to competitive pressure bring problems? (Will Microsoft charge for hardware upgrades and will they diversify into techo-healthcare? What will happen if quality control of hard/soft/firmware is not as it should be?)

A: As we all know there are lots of concerns already for quality - both of software and hardware; adding to this are the complications (legal, ethical, …) associated with medical device technology. At IFIP 1994, I tried (but was unsuccessful) to gather a panel of people from industry and government to discuss some of the issues such as: 1. Upgrade policy? 2. Warranties? 3. Mandated implants? [For example for criminals] 4. What kind of architectures should be used to facilitate upgrades?

There are also some very positive aspects of these developments. One major benefit is that prosthetic devices based on this new market base could be commodities and thus priced as commodities. In addition, I think that carrying a personal interface will mean that my computer can interact with the computers around me to accomplish things - thus eliminating the different interfaces (bank AMT machines, airline check-in counters, hospital admissions, etc.) and lead to a more PERSONAL interaction. For example, I can interact with my computer in English, or Swedish, or German - while the system which I am interacting with does not have to have an English, Swedish and German interface. Thus, the bank’s AMT machine only needs to do its function - such as dispense money. My computer and the bank’s computer will converse in an EDI {Electronic Data Interchange} dialect.

Disappearing objects

list of what are the products which will disappear (in the sense of having a separate identity)

Wired phones	garage door openers
Cordless phones	wireless car door/vehicle security transmitters
Mobile (cellular) phones	GPS units (as a separate single purpose device)
(pocket) radios [Also applies to vehicles]	calculators
stereo receivers	credit cards/checks/cash {the later will soon be outlawed in any case}
tape decks	clocks and watches
TVs	pagers
CD players	computers as PCs/Workstations/... {which we already can not always recognize!}
modems	File Cabinets (JMS)
answering machines	ATM machines (JMS)
cable decoders	Maps (JMS)
FAX machines	Thermometers (JMS)
newspapers and other periodicals (in print form)	Business Cards (JMS)
film based cameras (except for pure hobbyists)	Security Badges (JMS)
VCRs	Toll Booths (JMS)
camcorders	

Some may remain as antiques/art works/... . But as separate devices they will disappear to such an extent that a child born in just a few years, will not recognize any of these devices when they enter college - except from visits to museums or “classic” literature or history lessons.

Personal Computing and Communication (PCC)

Upper limit of bandwidth: saturate the senses: sight, sound, touch, smell, taste

$\Rightarrow$ ~1 Gbit/sec/user

Current workstations shipping with 1 Gbit/sec interfaces for LAN!

> Telepresense for work is the long-term “killer” application
>
> -- Gordon Bell and James N. Gray[1]

1. “The Revolution Yet to Happen” in Beyond Calculation: The Next Fifty Years of Computing, Eds. Denning and Metcalfe, Copernicus, 1997.

Looking forward

Turning a transistor on/off - number of electrons:

1997: 10^3 2010: 8-9 2020: < 1

We already have DNA based computing, the beginning of Quantum Computing, …

50 years: Auxiliary brain

- a single chip storing 2×10^{16} bits of data, ~storage capacity of 10^5 human brains.
- volume of 1 cubic centimeter, about the size of a sugar cube.
- with power of 500 million Pentium Pros
- able to record life's experiences and replay them

"We should not be shy about our predictions."

-- Joel Birnbaum, Senior VP R&D and Director of HP Labs[1]

1. from ACM'97:The Next 50 Years of Computing (http://www.acm.org/acm97/home.html) and http://www.research.microsoft.com/acm97/

Uploading ourselves to the net

In Bob Metcalf’s speech at MIT: http://web.mit.edu/alum/president/speech.html

One of great insights of this talk is that the internet is the way to immortality[1]:

> Now, for the next 50 years, the web will drive electronic commerce into the information age, ubiquitous computers will disappear into the woodwork, and we’ll start uploading ourselves into the Internet to become at last immortal.
>
> -- Robert M. Metcalfe
> June 26, 1997

For further reading see “Mind Uploading Home Page”
http://metalab.unc.edu/jstrout/uploading/MUHomePage.html

1. Robert M. Metcalfe, “Internet Futures”, MIT Enterprise Forum, June 26, 1997.

Questions?

- Cockpits will not have any instruments displays/knobs/buttons/… in them
- Maintenance and test equipment will not have any displays/controls/… on them
- Security of communication links will be **very** important
- Numbers of and types of links will increase (especially for very local areas, for example: within the cockpit, when near the plane/space craft/missile, when near a situation status “board” [what ever will it be?], when doing a briefing or debriefing, when on the flight deck, when in a Command and Control facility, when standing beside another officer/crew/agent)
- Who has the ability/authority to reconfigure/reprogram/enable/disable/destroy/… these personal systems? What are the safety interlocks? Who hold the keys to them?
- Cost of implants and training vs. cost of external microdisplays/HUDs/… and their training
- How will these systems be powered? (now and in the long term)
- Who will be first to be equipped? Who will be the last to be equipped?

Conclusions

- Low cost access points which exploit existing or easily installed infrastructure are key to creating a ubiquitous mobile infrastructure with effectively infinite bandwidth.
- Personal Communication and Computation in the early 21st century: “Just Wear IT!”
- Coming in 20-30 years: “Just implant IT!”

Desired changes

Ron Hale-Evans, "Functional Mods and Antique Rockers " http://www.apocalypse.org/pub/u/rwhe/modnrock.etx.txt (10/97).

Table 1: POSSIBLE HACKS TO THE BODY ELECTRIC

- CHASSIS HACKS
  - [elided]
- BRAIN HACKS
  - faster brain with better memory and higher intelligence
  - in-brain Net link
  - better self-metaprogramming capability
  - ability to instantly alter consciousness in any way
- SENSORY HACKS
  - wider-spectrum vision and hearing
  - extra senses of all sorts (e.g. sonar, polarised light, electromagnetic senses, internal organ monitoring)
  - ability to adjust intensity ("volume") of senses, and to turn them off ("close one's ears")

References

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Maynard, E. M., Nordhausen, C. T., and Normann, R. A. “The Utah Intracortical Electrode Array: A Recording Structure for Potential Brain-Computer Interfaces”. Electroenceph. and Clinical Neurophys. 102(3):228-239; 1997.

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“Ocular Implants for the Blind”, Wyatt, J.L. and Rizzo, J.F., IEEE Spectrum, Vol.33, pp.47-53, May 1996 -- http://rleweb.mit.edu/retina/a1.page1.html

“Prospects for a Visual Prosthesis”, Rizzo, J.F. and Wyatt, J.L., Neuroscientist, Vol.3, pp.251-262, July 1997 -- http://rleweb.mit.edu/retina/a2.page1.html

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Vaughan, T.M. Wolpaw, J.R. and Donchin, E. "EEG-Based Communication: Prospects and Problems". IEEE transactions on Rehabilitation Engineering, Vol 4, No. 4, December 1996.

Brain Computer Interface Project http://www.ee.ic.ac.uk/research/neural/bci/bci.html they have explored techniques which use pattern matching and achive ~1bit/sec.

In 1988, Emanuel Donchin, a professor of psychology with the University of Illinois at Champaign, and a student of his, Barry Farwell, developed and demonstrated a scheme that allowed the brain to control a computer using event-related brain potentials (ERP). They use the ERP known as P-300 to demonstrate a mental prosthesis for typing - however the I/O rate was **1.5 to 15s per letter** (depending on the level of confidence you want to achieve).

BioControl Systems, Inc. is selling BioMuse™ -- which uses 8 signals which can be from: muscles (EMG signals), eye movements (EOG signals), the heart (EKG signals), and brain waves (EEG signals) via standard non-invasive transdermal electrodes; based on signal processing of these input they generate serial output on an RS-232 link. The founders Hugh S. Lusted and R. Benjamin Knapp wrote: "Controlling Computers With Neural Signals: Electrical impulses from nerves and muscles can command computers directly, a method that aids people with physical disabilities", Scientific American, October, 1996, http://www.sciam.com/1096issue/1096lusted.html

Neurally Interfacing Humans To Mechanical and Computational Devices
http://dcwi.com/~lx/neural.html

A excellent summary of visual prosthesis work can be found at
http://www.mediacom.it/~v.colaciuri/visual.htm

University of Bonn, Department of Computer Science VI (Neuroinformatics)
http://www.nero.uni-bonn.de/index-en.html

USC Center for Neural Engineering (CNE) http://www.usc.edu/dept/engineering/CNE/

Roy Bakay of Emory University - interface to motor cortex - use regeneration of nerve into a glass cone containing electrical contacts

ESPRIT project INTER (Intelligent Neural InTERface) - use regeneration through a plate
http://www.ibmt.fhg.de/Produktblaetter/pages/inter_d.htm

Caltech’s Neuroprobe, part of the Neural Prosthesis Program of the National Institute of Neurological Disorders and Stroke (National Institutes of Health)
http://www.caltech.edu/~pinelab/pinelab.html

> “Most important, what function-restoring neural prostheses are being researched that show promise for the disabled, and may eventually lead to function-amplifying implants?”

-- Gareth Branwyn, “The Desire to Be Wired: Will we live to see our brains wired to gadgets? How about today?”, Wired Magazine, 1.04 - Sep/Oct 1993, http://www.wired.com/wired/archive/1.04/desire.to.be.wired.html

Patents

US3699970: STRIATE CORTEX STIMULATOR

Giles Skey Brindley, London, United Kingdom
Peter Eden Kirwan Donaldson, Oxford, United Kingdom

Applicants: National Research Development Corporation, London, United Kingdom

Issued/Filed Dates: Oct. 24,1972 / June 23, 1970

An implantable neurological prosthetic device comprises a plurality of electrodes for stimulating the striate cortex, a matrix of normally closed gates connected in one-to-one relationship with said electrodes, and a plurality of radio receivers tuned to predetermined frequencies and constituting at least two distinctive sets, each gate being connected for switching to an open state to energize the respective one of said electrodes by a unique group of at least two of said receivers from respectively different sets thereof. The receivers are themselves energizable by externally located respective transmitters conveniently positioned by a technique in which the transmitter tuned circuit is included as one arm in a bridge circuit balanced for maximum absorption by the respective receiver tuned circuit. This technique is more generally applicable to any implant provided with a tuned circuit.

US4979508: Apparatus for generating phosphenes

Stephen C. Beck, Berkeley, CA 94708

Issued/Filed Dates: Dec. 25, 1990 / April 11, 1987

The apparatus and method produce visual sensations by applying low voltages through conductive electrodes to the outside of a person's head, for transmission by natural mechanisms to the nervous system--to entertain or inform a sighted person, or to help a blind person to locate nearby objects.

As to entertainment, the apparatus generates various waveshapes, and an operator directs one or more to the electrodes. The operator also manually varies waveshape parameters such as frequency, amplitude, duty cycle and dc bias--or controls them with automatic sweep devices at selected sweep rates. Various wavetrains are combined at the electrodes or in the person's head for more-elaborate effects. The electrode wavetrains or necessary control signals are also received for playback.

As to information, the apparatus produces coded patterns or even rough analogs of normal visual scenes. As to aiding the blind, the apparatus responds to a sonar signal by placing phosphenes in the perceived visual field roughly where a normal person would see nearby objects.

US4664117: Apparatus and method for generating phosphenes

Stephen C. Beck, Berkeley, CA 94708

Issued/Filed Dates: May 12, 1987 / Oct. 9, 1984

The invention produces visual sensations by applying low voltages through conductive electrodes to the outside of a person’s head, for transmission by natural mechanisms to the nervous system--to entertain or inform a sighted person, or to help a blind person to locate nearby objects.

As to entertainment, the apparatus generates various waveshapes, and an operator directs one or more to the electrodes. The operator also manually varies waveshape parameters such as frequency, amplitude, duty cycle and dc bias--or controls them with automatic sweep devices at selected sweep rates. Various wavetrains are combined at the electrodes or in the person’s head for more-elaborate effects. The electrode wavetrains or necessary control signals are also recorded for playback.

As to information, the apparatus produces coded patterns or even rough analogs of normal visual scenes. As to aiding the blind, the apparatus responds to a sonar signal by placing phosphenes in the perceived visual field roughly where a normal person would see nearby objects.

D.Edell, J.L. Wyatt, Jr. and J. Rizzo, "Method and Apparatus for Preferential Neuron Stimulaton," Patent No. 5,411,540, May 2, 1995.

D. Edell, J. Rizzo and J.L. Wyatt, Jr., "Low Pressure Neural Contact Structure," Patent No. 5,476,494, Dec. 19, 1995

J. Rizzo, "Medication Dispensing Intra-Ocular Lens System," Patent No. 5,554,187, Sep. 10, 1996.

J. Rizzo, "Methods for Epi-Retinal Implantation," Patent No. 5,597,381, Jan. 28, 1997.

Michael J. Sciarra, US4551149: Prosthetic vision system

David J. Edell, John L. Wyatt, Jr., Joseph Rizzo, III, “Method and apparatus for preferential neuron stimulation”, US5411540, 05/02/1995.

US5159927, 11/03/1992, Visual prosthesis apparatus and method

US5108427, 04/28/1992, Active pupillary prosthesis

US4664117, 05/12/1987, Apparatus and method for generating phosphenes

US4551149, 11/05/1985, Prosthetic vision system

US3918461, 11/11/1975, Method for electrically stimulating the human brain

US3699970, 10/24/1972, STRIATE CORTEX STIMULATOR

US3628193, 12/21/1971, TACTILE IMAGE PROJECTION SYSTEM

US2721316, 10 /1955, Shaw

Vincent Chow and Alan Y. Chow, US5895415: Multi-phasic microphotodiode retinal implant and

adaptive imaging retinal stimulation system, Optobionics Corporation, Wheaton, IL, April 20, 1999 -- from photons in to electrical stimulation out as an artificial retina

Vincent Chow and Alan Y. Chow,US5556423: Independent photoelectric artificial retina device and method of using same, Sept. 17, 1996.

There are lots of patents regarding interfacing to nerves, see for example:

Carlo J. DeLuca and L. Donald Gilmore, US4026300: Method and apparatus for interfacing to nerves, May 31, 1977

US3918461: Method for electrically stimulating the human brain

Irving S. Cooper, Bronx, NY 10457

Issued/Filed Dates: Nov. 11, 1975 / Jan. 31, 1974

A method and apparatus for electrically stimulating the human brain which includes applying electrodes directly to the cerebellum and feeding electrical impulses to such electrodes with a view to aiding individuals suffering from intractable hypertonia, epilepsy and other ailments, said electrical impulses having a duration of from 0.5 to 2.5 milliseconds, an ampliude of from 0.5 to 14.0 volts, and a frequency of from 1 to 300 pulses per second.

…

Avery et al., US3738368, Implantable electrodes for the stimulation of the sciatic nerve, 1973