Homo Technologicus

Tampere – May 18 2017

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Homo Sapiens Technologicus

*Man creating technology as an antithesis to nature*

[Wikipedia – quoting Yves Gingras, 2005]
“The body has always been a prosthetic body. Ever since we evolved as hominids and developed bipedal locomotion, two limbs became manipulators. We have become creatures that construct tools, artifacts and machines. We’ve always been augmented by our instruments, our technologies. Technology is what constructs our humanity. …, so to consider technology as a kind of alien other that happens upon us … is rather simplistic.”

Joanna Zylinska
Australian performance artist in 2002 interview with Stelarc

Quote courtesy of Blaise Aguera Y Arcas (Google)
Living in a Smart World

Internet Of Things Market To Reach $267B By 2020

B2B spending on IoT technologies, apps and solutions will reach €250B ($267B) by 2020.

By 2020, 50% of IoT spending will be driven by discrete manufacturing, transportation and logistics, and utilities.

[Forbes, January 2017]
Living in a Smart World

It is happening!

Smart things, smart tools, smart cars, smart buildings, smart cities, smart everything ...
Living in a Smart Dynamic World

It is happening!

Smart things, smart tools, smart cars, smart buildings, smart cities, smart everything ...

How will we, humans, cope with all of this?
One viable option ... extend ourselves!

Mobiles
A limited bandwidth proposition
Extend ourselves - An old idea

Augmenting Human Intellect
A Conceptual Framework
Doug Engelbart, 1962

“Meaning: More-rapid comprehension, better comprehension..., speedier solutions, better solutions, and the possibility of finding solutions to problems that before seemed insolvable.”

“Mother of all demos”
NLS – December 1968, SF
Moving to Personal Agents

Apple Knowledge Navigator Concept – 1987
https://www.youtube.com/watch?v=mE2Z30pyw8c
Personal Agents
Extend ourselves!

Truly

Where Swarms and Humans Meet

[Time Magazine, September 2014]
Wearable Tech?

5 reasons why I’m returning my Apple Watch

[PolicyGenius, 2015]

functionality

Battery  Bored  works much  Limited lifetime
Over-expectation  Inaccurate  Stovepiped
Extend Ourselves

A Human Intranet
An open scalable platform enhancing human capabilities

[J. Rabaey, Pervasive. Comp., 2014]
Image courtesy Y. Khan, UCR
Human Intranet – Extend Ourselves

Introspection

Augmentation

Extrospection
The Early Adopters

**Arts**

[Naccarato Dance]

**Sports**

[Braingate, Brown Univ.]

**Health**
Human Enhancement

Boost human input-output performance
- hybrid sensory expansion
- higher information throughput

Sonification

A new visual prosthetic paradigm

Visually Impaired  ↔  Visual Sonification  ↔  Camera  ↔  Real World
Human Enhancement

Boost human input-output performance
- hybrid sensory expansion
- higher information throughput

Information to Tactile

Haptic radar

Echosense [T. Vega]

[Courtesy: Watanabe, U. of Tokyo, 2006]
Minesweeper

Real-Time Co-Processor
- Actuation
- Mapping
- Processing / Interpretation
- Sensing

Computed Risk Map

High Risk Actuation
Output: [Image of a mine]

Low Risk Actuation
Output: [Image of a safe area]

CV on Pixels

“Agent” to reduce cognitive load

Microflagellator

[Courtesy: Tomas Vega, UCB]
Human Enhancement

A direct connection to the brain

Brain-Machine Interfaces
BMI for Motor Control

[C. Bouton et al, Ohio State, Nature, April 2016]

NY Times, April 13 2016

Also: BMI for Neuropsychiatric diseases
It takes a Human Intranet

Closed-loop modulation at network level

In combination with various wearable sensors

The OMNI Device
[UCB, Cortera Neuro, LLNL]

Tension – Stress – ... Emotion

- Skin conductance
- 3D accelerometer
- Activity

[Jo De Boeck, IMEC, ISSCC 2011]
Realizing a Human Intranet

What it takes !?
unobtrusive

and

wearable
Unobtrusive

The **Smart Dust** Vision

[K. Pister, UCB, 1997]

Not entirely evident at first ...

UC Berkeley PicoNodes

Anno 2000

Anno 2007
Unobtrusive

The **Smart Dust** Vision
[K. Pister, UCB, 1997]

Now a reality!

Michigan Micromote [Blaauw et al, 2014]

Enabling true **BioCyber** Systems

Smart Dust Will Be The Future Of The Internet Of Things
Brain-Machine Interfaces

[Doerner, 2010]

[Brown U., 2013]

[U. Pittsburg, 2012]

[Ohio St., 2016]
Miniaturization Today

[Muller et al, 2014]

64 channel μECoG

[Maysam, Yeager, 2014]

64 channel neuromodulator

Implantable neuromodulation devices
Miniaturization Tomorrow

Neural dust: microscopic nodes free floating in tissue to record neural activity

[DJ Seo, Neuron 2016]
Beyond “neural” dust

Circuits and sensors for
- Pressure
- Temperature
- Strain
- pH
- O₂
- ...

[Slide courtesy M. Maharbiz, UCB]

Internal organs
- Pharynx
- Larynx
- Heart
- Arteries
- Muscles
- Liver
- Gallbladder
- Kidneys
- Skeleton
- Intestines
- Brain
- Lungs
- Lymph nodes
- Spleen
- Bone marrow
- Stomach
- Veins
- Pancreas
- Urinary bladder

[M. Haggström, Wikiversity, 2014]
Wearable Electronics

For sensing

Printed oxonometry system
[Courtesy: A. Arias, UCB]

Blood oxonometry, EEG, EMG, ECG, heart rate, thermistors, motion, humidity, stress, ...

Thin Film μECoG
[Courtesy: M. Maharbiz, UCB]

Sweat Sensors
Courtesy: A. Javey, UCB]

Cheap, compliant, flexible, ...

Thin Film EEG
[Courtesy: J. Rogers, UIUC]
Wearable Electronics

RFID-like energy harvester [J. Rogers, UIUC]

For energy delivery, storage, and data communication

Flexible batteries [Arias, UCB]
Flexible MRI coils

Wound monitoring bandages

[Courtesv: Arias Lab]
The ultimate wearable technology

Skintillates
Conformal, flexible, wearable electronics

[See also: OCTattoos, Peter Hamilton, Pandora’s Star]

[Courtesy JoAnne Loh and Eric Paulos, UCB]
Symbiotic with the biological networks

integrated information and energy distribution
H1 as a Hybrid Data/Energy Network

- Local networks optimized for data/energy delivery
- Mesh networks provides robustness and redundancy
- Hubs as communication/computation/energy centers
- Body-Area network skeleton/skin as a mesh of hubs
Energy at the fringes

What is 1 mm$^3$ good for?

- Storage (Lithium Polymer): 1 J/mm$^3$
- Storage (Printed Lithium Ion): 0.6 J/mm$^3$
- Harvesting (Printed Photodiodes): 3-300 µW/mm$^2$
- Harvesting (Micro Fuel Cell): < 1 µW/mm$^3$
- Harvesting (EM – 1mm$^2$): 10 µW/mm$^3$

Printed PV/battery module

[Courtesy: A. Arias, UCB, 2016]

EM Harvester

Abiotic fuel cell

[M. Mark, UCB, 2011]
Communication at the Fringes

Energy per transmitted bit
- $B_{t,LE} @ 1$ Mbps: 10 nJ/bit
- Narrowband Radio @ 10 Mbps: 200 pJ/bit
- Directional mmWave @ 1 Gbps: 3 pJ/bit
- Backscattering @ 1 Mbps: 10-100 fJ/bit

Directional mmWave (24/60 GHz) RFID
[Tabesh, VLSI14]

300 MHz Active RFID
[Muller, ISSCC 2014]

Other human-body link options:
- Inductive/Capacitive/Resistive
- Acoustic/ultrasound/vibration
- Optical
Optimization at all layers of the stack

Mesh network with Hub Concentrators

[A. Moin, 17]

Ultrasound beamforming
[B. Boser, UCB]

ECoG implant
Electromagnetic

Cochlear implant
Inductive
intelligence
Closing the loop
Adaptive and evolutionary systems
at ultra-low latencies (msec) and energy levels (mWs)

Typical BMI System
GOPs at mWs?

[Courtesy: M. Shanechi, USC]

Not easily provided by todays embedded processors

<table>
<thead>
<tr>
<th>Step</th>
<th>Computation</th>
<th>Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output dimensionality reduction</td>
<td>$O(T(K^0)^2)$ floating point multiplications</td>
<td>$O(10^9)$</td>
</tr>
<tr>
<td>System identification (&quot;offline&quot;)</td>
<td>$O(4N(K + N)(K + M)M^2(K + N)^2)$ floating point multiplications</td>
<td>$O(10^{12})$</td>
</tr>
<tr>
<td>State estimator</td>
<td>$O(KM)$ multiplications</td>
<td>$O(10^3)$</td>
</tr>
<tr>
<td>Feedback controller (MPC)</td>
<td>$O(hM^3N^2)$ multiplications</td>
<td>$O(10^9)$</td>
</tr>
</tbody>
</table>
A Symbiotic Relationship

Adopt innovative neuro-inspired computational techniques
Learning based {machine, deep, hyper, ...}
High-Dimensional Computing
Computing with (random) patterns

One-shot learning
Extremely robust
Energy-efficient

EMG-based gesture recognition

Superb match to 3D nanoscale technologies
Secure, safe and private
Human firewall

- Encryption
- Biomarkers
- Obfuscation
The cost of encryption

Energy per bit for AES standard

- Software (on Pentium III): 67 nJ/bit
- Hardwired ASIC (45 nm): 2.3 pJ/bit

[Singelee, KU Leuven, 2011]
Unique Biomarkers

Brainwaves as Unique ID (100% Accuracy)
[IEEE Spectrum, April 16]

Biometric Security Poses Huge Privacy Risks
Without explicit safeguards, your personal biometric data are destined for a government database

ECG
Others: voice, gait, emg, eeg, retina ...

[Photo: Binghamton University]
Virtual Cloaks: Obfuscation and Subterfuge

Hiding data in a heartbeat ...
[IEEE Spectrum, 2013]

Jamming Signal
Antidote Signal

Figure 2 — The jammer-cum-receiver design uses two antennas that transmit the jamming signal and receive the antidote signal. The receive antenna is connected to the jamming chain. The antidote signal is transmitted to the jammer to cancel out the jamming signal requiring alignment.

Jam hostile communications and prevent overhearing
[Gollakota 2011]
High-order bits

- The new age of information processing: ubiquitous, distributed and VERY personal

- Humanity and technology becoming extremely intertwined and blended

- Challenges society and humanity in many unforeseeable ways – the conversation starts NOW!
Thank You!