

Artificial Intelligence and the Singularity

piero scaruffi

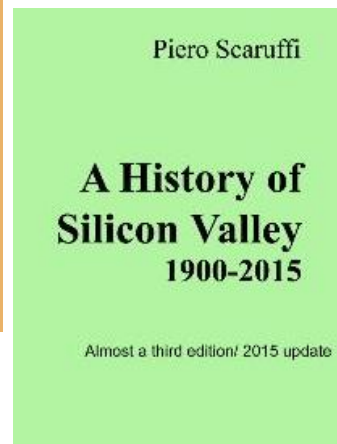
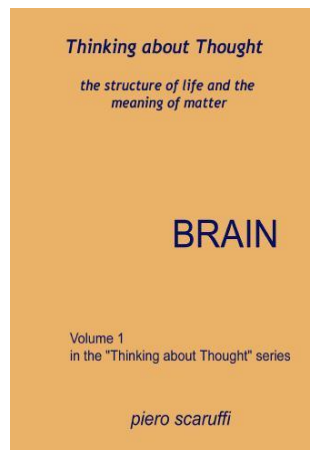
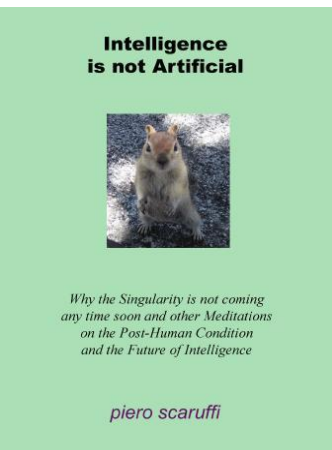
www.scaruffi.com

October 2014 - Revised 2016

*"The person who says it cannot be done should not
interrupt the person doing it" (Chinese proverb)*

Piero Scaruffi

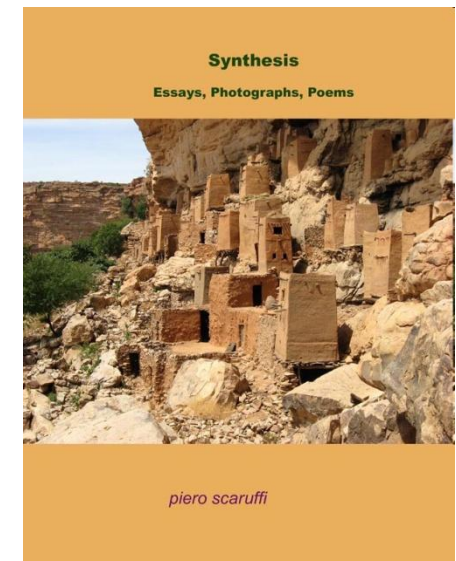
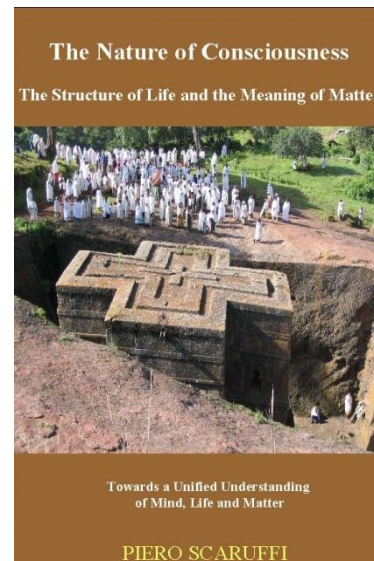
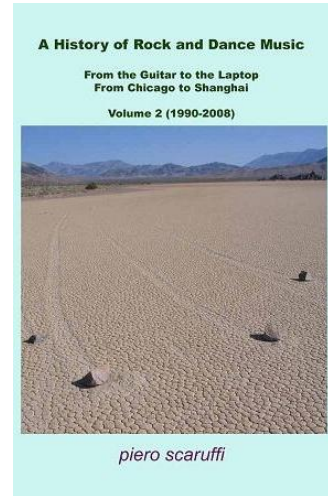
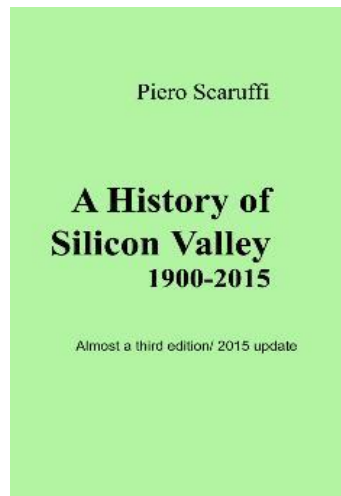
- piero scaruffi
p@scaruffi.com
scaruffi@stanford.edu



Olivetti AI Center, 1987

Piero Scaruffi

- Cultural Historian
- Cognitive Scientist
- Blogger
- Poet
- www.scaruffi.com



This is Part 5

- See <http://www.scaruffi.com/singular> for the index of this Powerpoint presentation and links to the other parts
 1. Classic A.I. - The Age of Expert Systems
 2. The A.I. Winter and the Return of Connectionism
 3. Theory: Knowledge-based Systems and Neural Networks
 4. Robots
 5. Bionics
 6. Singularity
 7. Critique
 8. The Future
 9. Applications
 10. Machine Art
 11. The Age of Deep Learning

Bionics



A Brief History of Bionics

1952: Jose Delgado publishes the first paper on implanting electrodes into human brains:
"Permanent Implantation of Multi-lead
Electrodes in the Brain"

1957: The first electrical implant in an ear (André
Djourno and Charles Eyriès)

1961: William House invents the "cochlear
implant", an electronic implant that sends
signals from the ear directly to the auditory
nerve (as opposed to hearing aids that
simply amplify the sound in the ear)



A Brief History of Bionics

1965 : Jose Delgado controls a bull via a remote device, injecting fear at will into the beast's brain

1969: Jose Delgado's book "Physical Control of the Mind - Toward a Psychocivilized Society"

1969: Jose Delgado implants devices in the brain of a monkey and then sends signals in response to the brain's activity, thus creating the first bidirectional brain-machine-brain interface.



A Brief History of Bionics

1973: Jacques Vidal, first paper on brain-machine interfaces



Copyright 1973. All rights reserved

TOWARD DIRECT BRAIN-COMPUTER COMMUNICATION

JACQUES J. VIDAL¹

*Brain Research Institute,
University of California, Los Angeles, California*

1988: Emanuel Donchin's and Larry Farwell's
“brain-fingerprinting”



PSYCHOPHYSIOLOGY
Copyright © 1991 by The Society for Psychophysiological Research, Inc.



**Talking off the top of your head: toward a mental prosthesis utilizing
event-related brain potentials**

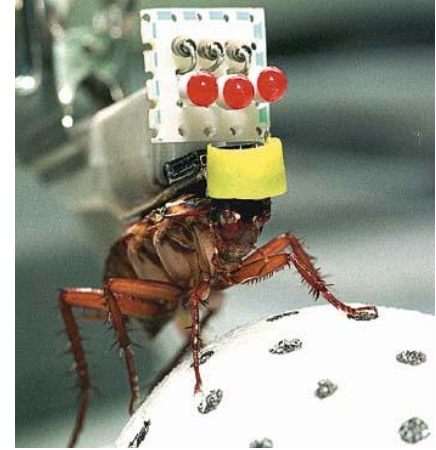
L.A. Farwell and E. Donchin

*Dept. of Psychology and Cognitive Psychophysiology Laboratory, University of Illinois at Urbana-Champaign,
Champaign, IL 61820 (U.S.A.)*

A Brief History of Bionics

1997: Remotely controlled
cockroaches at Univ of Tokyo

1998: Philip Kennedy develops a brain
implant that can capture the "will"
of a paralyzed man to move an
arm (output neuroprosthetics:
getting data out of the brain into a
machine)



A Brief History of Bionics

2000: William Doherty develops an implanted vision system that allows blind people to see outlines of the scene. His patients Jens Naumann and Cheri Robertson become "bionic" celebrities.



2001: Peter Fromherz's hybrid circuit of a electronics and neurons



2002: John Chapin debuts the "roborats", rats whose brains are fed electrical signals via a remote computer to guide their movements



A Brief History of Bionics

2002: Miguel Nicolelis makes a monkey's brain control a robot's arm via an implanted microchip



2005: Cathy Hutchinson, a paralyzed woman, receives a brain implant from John Donoghue's team that allows her to operate a robotic arm (output neuroprosthetics)



2004: Theodore Berger demonstrates a hippocampal prosthesis that can provide the long-term-memory function lost by a damaged hippocampus



A Brief History of Bionics

2004: Color-blind artist Neil Harbisson becomes the first person in the world to have an antenna implanted in his skull, a device that turns color into sound



A Brief History of Bionics

2003-8: Marcel Just and Tom Mitchell
at Carnegie Mellon University read
minds



Classifying Instantaneous Cognitive States from fMRI Data

Tom Mitchell, Rebecca Hutchinson, Marcel Just,
Stefan Niculescu, Francisco Pereira, Xuerui Wang

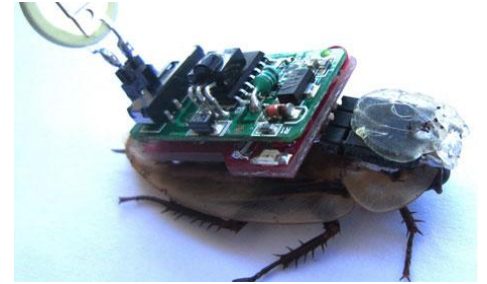
Carnegie Mellon University

November, 2003

A Brief History of Bionics

The age of two-way neural transmission...

2006: The Defense Advanced Research Projects Agency (Darpa) asks scientists to submit "innovative proposals to develop technology to create insect-cyborgs



2011: Matti Mintz replace a rat's cerebellum with a computerized cerebellum



2011: Theodore Berger develops "memory chips" that can turn memories on and off in a mouse's brain



A Brief History of Bionics

The age of two-way neural transmission...

2013: Miguel Nicolelis makes two rats communicate by capturing the "thoughts" of one rat's brain and sending them to the other rat's brain over the Internet



A Brief History of Bionics

The age of two-way neural transmission...

2013: Rajesh Rao and Andrea Stocco devise a way to send a brain signal from Rao's brain to Stocco's hand over the Internet, i.e. Rao makes Stocco's hand move, the first time that a human controls the body part of another human

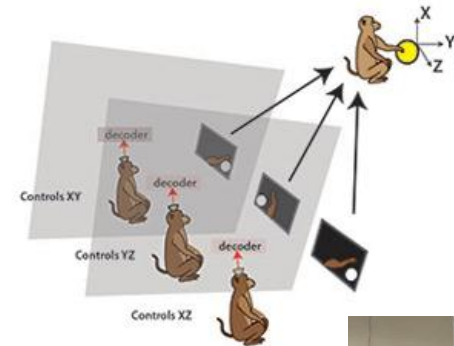


2014: An amputee, Dennis Aabo Sørensen, receives an artificial hand from Silvestro Micera's team capable of sending electrical signals to the nervous system so as to create the touch sensation

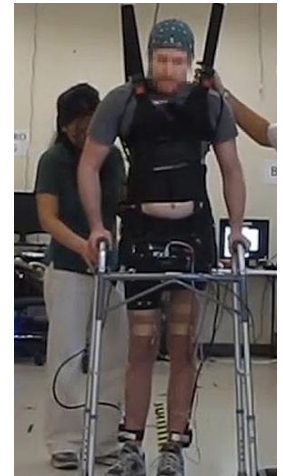


A Brief History of Bionics

2015: Nicolelis connects brains of monkeys so that they collaborate to perform a task



2015: Zoran Nenadic and An Do attach an electroencephalograph device to the head of a paraplegic man and make him walk



2015: Ted Berger and Dong Song build a brain prosthesis to help people suffering from memory loss



Brain prosthesis aims to provide breakthrough for people struggling with memory loss

SEPTEMBER 29, 2015

A Brief History of Bionics

Stimulating the vagus nerve

IEEE SPECTRUM

Follow on: [f](#) [t](#) [in](#) [+](#) [m](#)

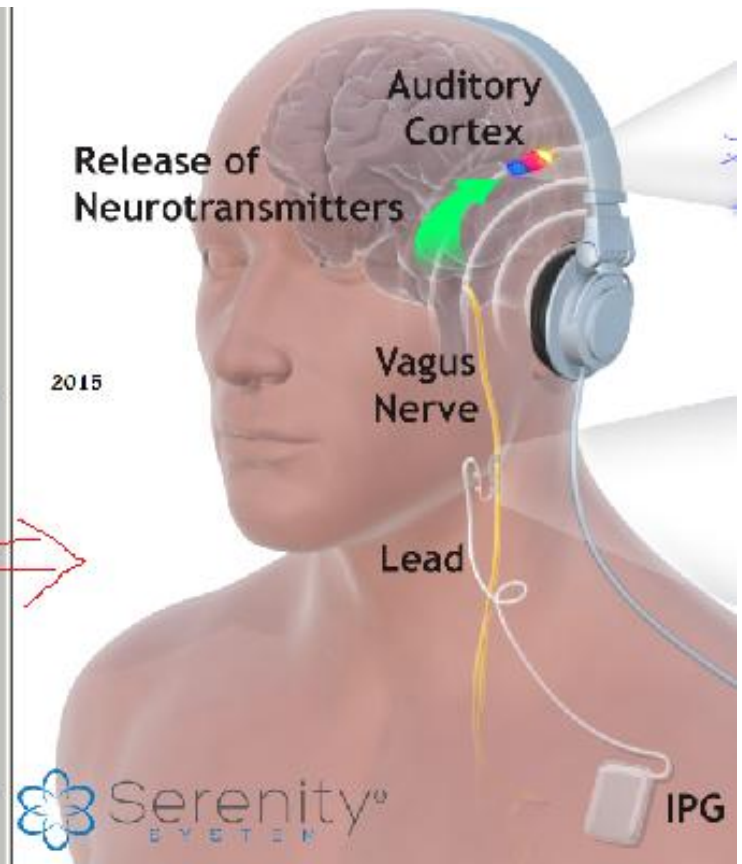
Topics ▾ Reports ▾ Blogs ▾ Multimedia ▾ Magazine ▾

Feature | Biomedical | Devices

Hacking the Human OS > Changing the Code > Bioelectronics

The Vagus Nerve: A Back Door for Brain Hacking

Doctors stimulate a nerve in the neck to treat epilepsy, heart failure, stroke, arthritis, and a half dozen other ailments

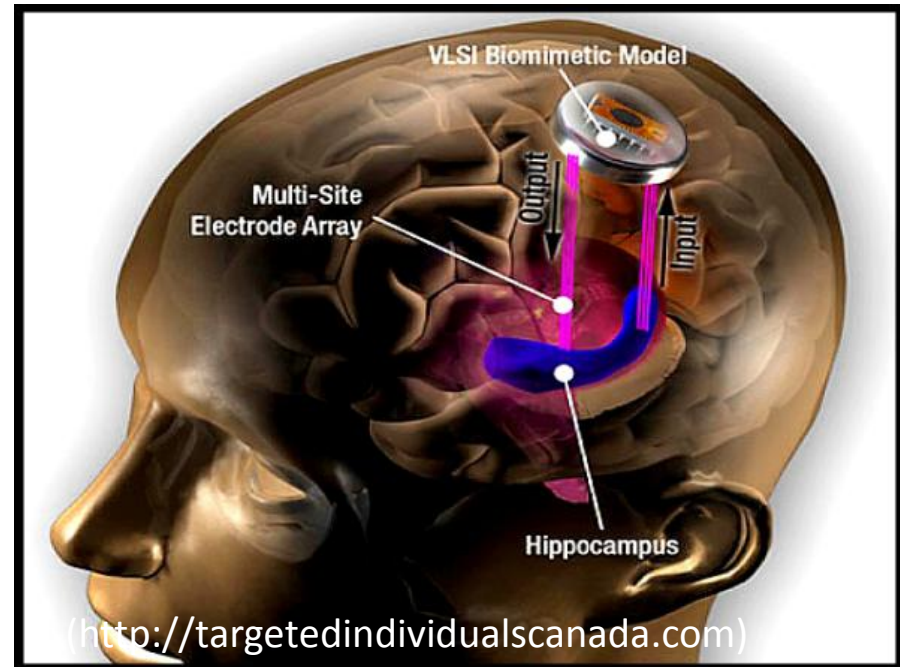


A Brief History of Bionics

Neuro-engineering?



(<http://its-interesting.com>)



*The future of the human brain?
neural implants that offer you
pleasant experiences for free in
exchange for sending neural
impulses to your brain that will
make you desire their products*

A Brief History of Bionics

Microchip implants

1998: Kevin Warwick at the University of Reading implants an RFID tag above his left elbow



2003: Neil Harbisson implants an antenna to his skull



Neil Harbisson, 34, lives with an antenna fixed to his skull. The preeminent "cyborg" uses the device to interpret sounds from colours. (SYSTEM / LARS NORGAARD)

A Brief History of Bionics

Microchip implants

2004: VeriChip starts selling an RFID chip implant for humans

2006: Amal Graafstra has a microchip in each hand, one for storing data (that can be uploaded and downloaded from/to a smartphone) and one for a code that unlocks his front door and logs into his computer



A Brief History of Bionics

Microchip implants

2010: Epoc (Australia) develops an EEG neuroheadset for videogames (Emotiv)

2012: Amal Graafstra implants chips on attendees of the Toorcamp for \$50 each

2013: Rich Lee implants headphones into his ears

2014: Ada Poon at Stanford invents a safe way to transfer energy to chip implants ("electroceutical devices")



A Brief History of Bionics

Brown Univ (Arto Nurmikko) & Cyberkinetics' BrainGate (2008): wireless transmitter for paralyzed patients with a neural implant that bypasses the spinal cord



Brown Univ (Leigh Hochberg) uses BrainGate to make a tetraplegics operate a robotic arm simply by thinking about the movement (2011)



Leigh Hochberg



A Brief History of Bionics

Federal Institute of Technology/ EPFL
(Switzerland, 2015): robotic wheelchair
that combines brain control with artificial
intelligence

Grégoire Courtine at EPFL restores
movement to a primate's paralyzed leg
using Brown's BrainGate (2016)



**Researchers Restore Leg
Movement in Primates
Using Wireless Neural
Interface**



EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

NEUROSCIENCE NEWS × NOVEMBER 9, 2016

A Brief History of Bionics

2016 Nick Ramsey inserts wireless electrodes into the skull of a paralyzed patient (unable to speak or move) so that she can control a computer mouse simply by thinking of moving her fingers



UMC Utrecht
Brain Center Rudolf Magnus



Nick Ramsey

2016 Niels Birbaumer: victims of complete motor paralysis answer yes/no questions with their thoughts



UNIVERSITÄT
TÜBINGEN



A Brief History of Bionics

2016 No brain implant! Bin He demonstrates an EEG cap fitted with 64 electrodes that can convert the “thoughts” a person into the movement of a robotic arm



A Brief History of Bionics

2017 Bill Kochevar, a man with complete paralysis, feeds himself using Bolu Ajiboye's brain-controlled arm



Bionics

Eric Leuthardt (Washington Univ)

Newton Howard (Oxford Univ)

Dong Song (USC)

**The Surgeon Who Wants to
Connect You to the Internet
with a Brain Implant**



Eric Leuthardt

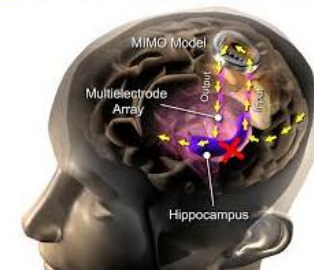
November 30, 2017



Science
alert 14 NOV 2017

**For The First Time Ever
Scientists Have Boosted Human
Memory With a Brain Implant**

USC



Bionics



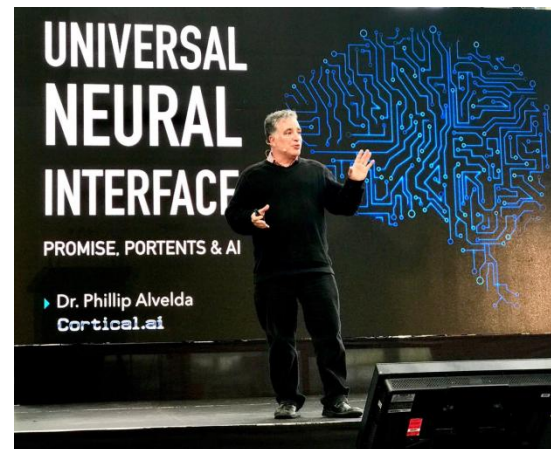
DEFENSE ADVANCED
RESEARCH PROJECTS AGENCY

Neural Engineering System Design

DARPA's Neural Engineering Systems Design (Phillip Alvelda, 2017)

Towards a High-
Resolution,
Implantable Neural
Interface

Edward Chang (UCSF)



 **frontiers**
in Computational Neuroscience

26 March 2018

Closed-Loop Deep Brain Stimulation for Refractory Chronic Pain

Prasad Shirvalkar^{1,2*}, Tess L. Veuthey^{3†}, Heather E. Dawes² and Edward F. Chang²



nature

International weekly journal of science

22 November 2017

AI-controlled brain implants for mood disorders tested in people

Researchers funded by the US military are developing appliances to record neural activity and automatically stimulate the brain to treat mental illness.

Bionics

Stefan Harrer (IBM Australia, 2018):
GraspNet = brainwave sensor +
Deep Learning + Nvidia Jetson
TX1+ robotic arm



IJCAI

International Joint Conferences on Artificial Intelligence Organization

Stockholm, 13-19 July 2018

GraspNet: An Efficient
Convolutional Neural Network for
Real-time Grasp Detection for
Low-powered Devices

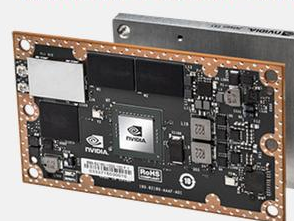
Umar Asif, Jianbin Tang, Stefan Harrer



IBM



NVIDIA Jetson TX1



Bionics



Andrea Stocco (2018): BrainNet

BrainNet: A Multi-Person Brain-to-Brain Interface for Direct Collaboration Between Brains

Linxing Jiang^{1,*}, Andrea Stocco^{2,3,4,5}, Darby M. Losey^{6,7,8}, Justin A. Abernethy^{2,3}, Chantel S. Prat^{2,3,4,5}, and Rajesh P. N. Rao^{1,4,5,+}

¹University of Washington, Paul G. Allen School of Computer Science & Engineering, Seattle, WA 98195, USA

²University of Washington, Department of Psychology, Seattle, WA 98195, USA

³University of Washington, Institute for Learning and Brain Sciences, Seattle, WA 98195, USA

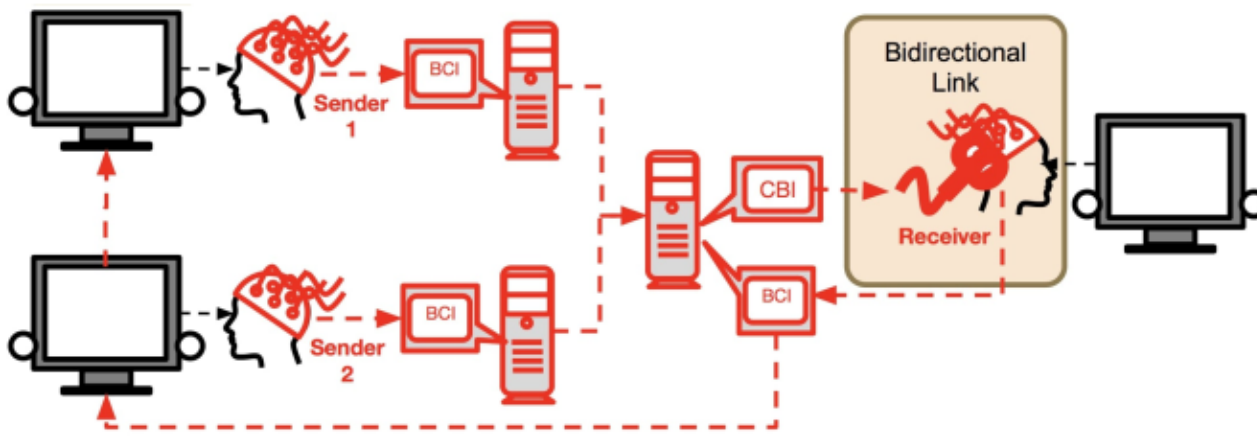
⁴University of Washington, Center for Neurotechnology, Seattle, WA 98195, USA

⁵University of Washington, Institute for Neuroengineering, Seattle, WA 98195, USA

⁶Carnegie Mellon University, Program in Neural Computation, Pittsburgh, PA 15213, USA

⁷Carnegie Mellon University, Center for the Neural Basis of Cognition, Pittsburgh, PA 15213, USA

⁸Carnegie Mellon University, Machine Learning Department, Pittsburgh, PA 15213, USA



Bionics

2017: David Blodgett (Johns Hopkins APL) decodes thoughts from neural signals using electrodes placed on the surface of the brain in patients undergoing treatment for epilepsy

JUNE 24, 2019



JOHNS HOPKINS
APPLIED PHYSICS LABORATORY



David Blodgett

APL DEVELOPING NONINVASIVE BRAIN-COMPUTER
INTERFACES TO CONTROL COMPLEX SYSTEMS

Proc. SPIE 10194 May 2017

**Portable non-invasive brain-computer
interface: challenges and opportunities of
optical modalities**

Author(s): Clara A. Scholl; Scott M. Hendrickson; Bruce A. Swett; Michael J. Fitch; Erich C. Walter;
Michael P. McLoughlin; Mark A. Chevillet; David W. Blodgett; Grace M. Hwang

Bionics

Gregoire Courtine's spinal implant (2018)

Spinal implant helps three paralysed men walk again

31 October 2018



Targeted neurotechnology restores walking in humans with spinal cord injury

Fabien B. Wagner^{1,2,3,5}, Jean-Baptiste Mignardot^{1,2,3,5}, Camille G. Le Goff-Mignardot^{1,2,3,5}, Robin Dernesmaeker^{1,2}, Salif Komi^{1,2}, Marco Capogrosso¹, Andreas Rowald^{1,2}, Ismael Sedfner^{1,2}, Miroslav Caban^{4,5}, Elvira Pirondini^{1,2,4}, Molywan Vat¹, Laura A. McCracken^{1,2}, Roman Heimgartner^{1,2}, Isabelle Fodor¹, Anne Watrin⁴, Perrine Seguin^{1,2}, Edoardo Paoles⁴, Katrien Van Den Keybus¹, Grégoire Eberle¹, Brigitte Schurch¹, Etienne Pralong¹, Fabio Vecce⁴, John Prior⁴, Nicholas Buse¹⁰, Rik Buschman¹⁰, Esra Neufeld¹¹, Niels Kuster^{1,12}, Stefano Carda¹, Joachim von Zitzewitz¹, Vincent Delattre⁴, Tim Denison^{10,13}, Hendrik Lambert⁴, Karen Minassian^{1,2,16}, Jocelyne Bloch^{1,2,14,16} & Grégoire Courtine^{1,2,7,14,16}



Bionics

Kristin Zhao & Kendall Lee (Mayo Clinic):
Jered Chinnock walks (2018)



Bionics

Peter Mitchell (Royal Melbourne Hospital) develops the StentrodeT (2020) that allows paralyzed patients to type sentences on a computer (14-20 characters per minute)

THE ENGINEER

**Stentrode implant
lets paralysed
patients text and
email**

29th October 2020 9:47 am



 **synchron**



Professor Peter Mitchell



Bionics

Michel Maharbiz & Jose Carmena (UC Berkeley): “Neural Dust”

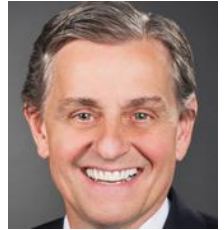
A dust-sized, wireless, battery-less sensor that can be implanted in the nervous system, in muscles and in organs (commercialized by Iota Biosciences, Berkeley, 2017)



Bionics

Electroceuticals

- Implantable devices that deliver electrical impulses to the neural circuits of organs in order to treat ailments.
- 1958: The first implantable pacemaker (Rune Elmqvist, Sweden)
- 1998: Kevin Tracey discovers that the nervous system and the immune system communicate via the vagal nerve.



Bionics

Electroceuticals

- Vagal nerve stimulation (VNS) is a tool to “hack” the immune system.
- SetPoint Medical (Los Angeles, 2007, cofounded y Tracey)
- Galvani Bioelectronics (Britain and South San Francisco, 2016) = GlaxoSmithKline + Google's Verily to accelerate development of bioelectronics

The New York Times Magazine

**Can the Nervous
System Be Hacked?**



Bionics

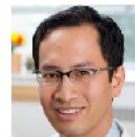
Mind Reading

- Edward Chang's team at UC San Francisco (2019):
 - A recurrent neural network decodes cortical recordings into vocal tract movement representations, and then transforms those representations into speech



Article | Published: 24 April 2019

Speech synthesis from neural decoding of spoken sentences



Gopala K. Anumanchipalli, Josh Chartier & Edward F. Chang

Bionics

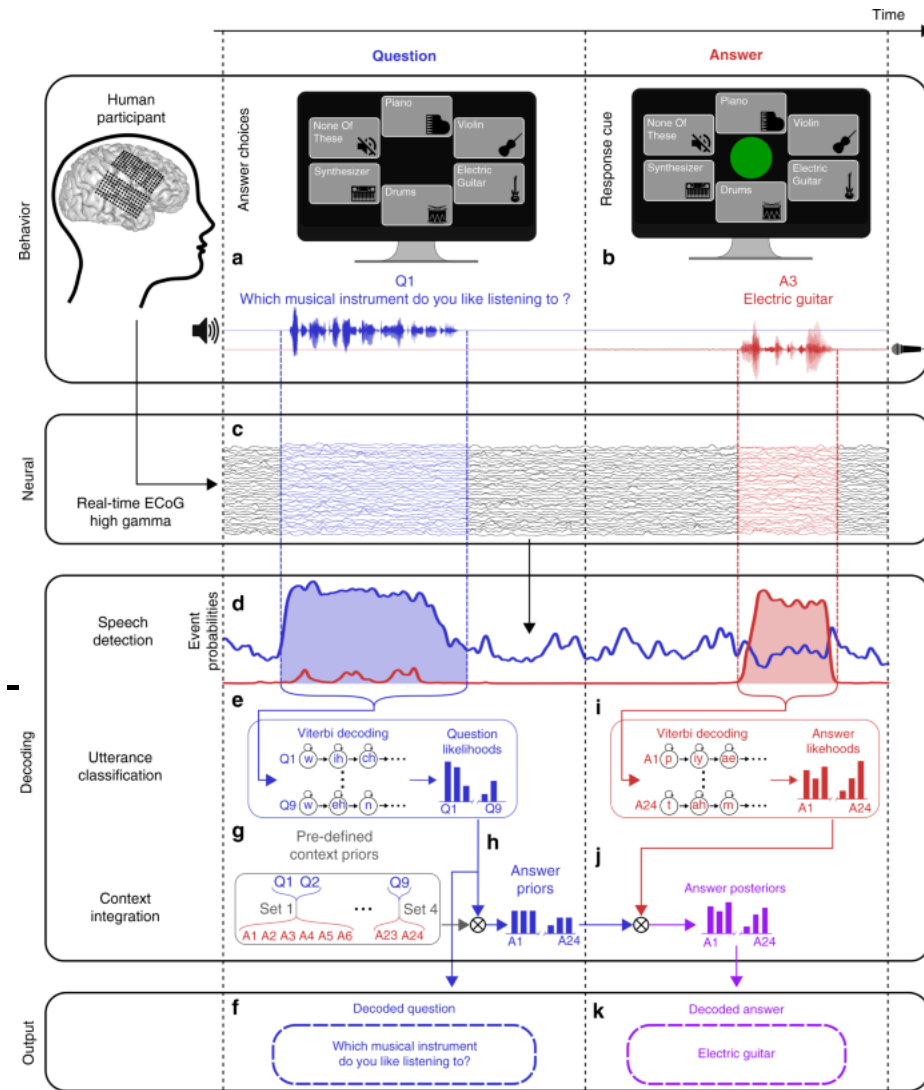
Mind Reading

- Edward Chang's team at UC San Francisco (2019):
 - Speech decoder: real-time decoding of perceived and produced speech from high-density ECoG activity in humans during a task that mimics natural question-and-answer dialogue

Article | [Open Access](#) | Published: 30 July 2019

Real-time decoding of question-and-answer speech dialogue using human cortical activity

David A. Moses, Matthew K. Leonard, Joseph G. Makin & Edward F. Chang 



Bionics

Mind Reading: can an A.I. visualize your thoughts?

- Yukiyasu Kamitani (Kyoto Univ, Japan)



Japanese scientists just used A.I. to read minds and it's amazing

Published Mon, Jan 8 2018



'Yuki' Kamitani
@ykamit

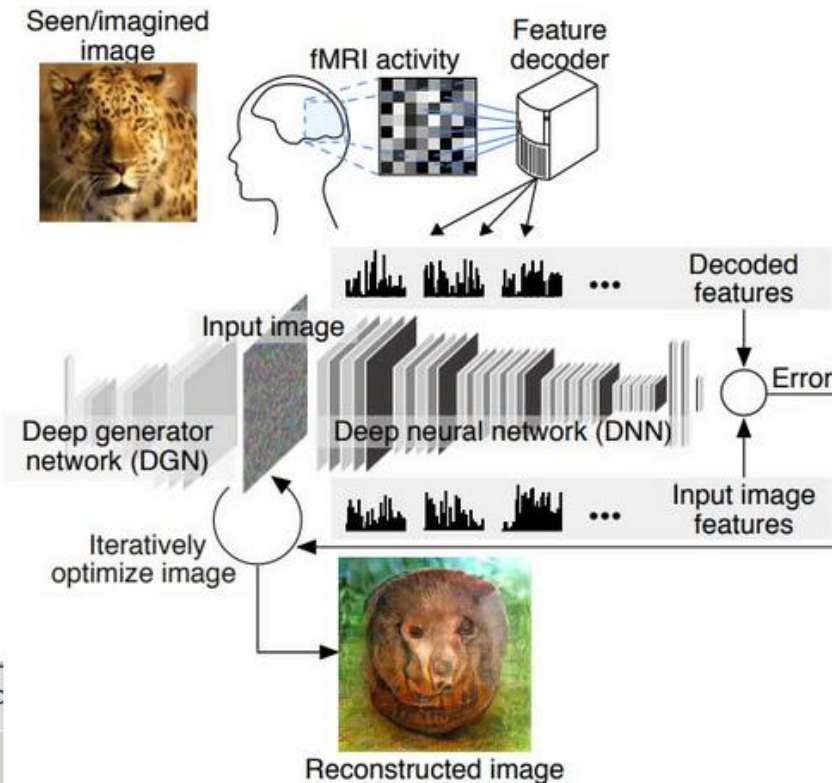
Deep image reconstruction: Natural images (seen images), GIF version

Left: Seen images

Right: Images reconstructed from brain activity (being optimized)

pic.twitter.com/YY0ZDxi7T5

♡ 946 11:43 PM - Jan 3, 2018



Bionics

Mind Reading: can an A.I. visualize your dreams?

- Yukiyasu Kamitani (Japan)



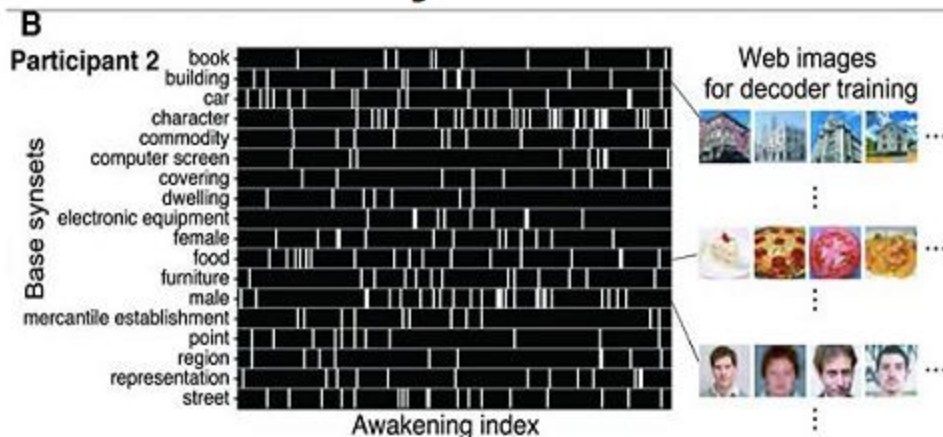
Science 03 May 2013:
Vol. 340, Issue 6132, pp. 639-642

Neural Decoding of Visual Imagery During Sleep

T. Horikawa^{1,2}, M. Tamaki^{1,*}, Y. Miyawaki^{3,1,†}, Y. Kamitani^{1,2,‡}

¹ATR Computational Neuroscience Laboratories, Kyoto 619-0288, Japan.

Visual content labeling



Bionics

Mind Reading: can an A.I. visualize your dreams?

- Jack Gallant (UC Berkeley)

 **frontiers**
in Systems Neuroscience

07 October 2016

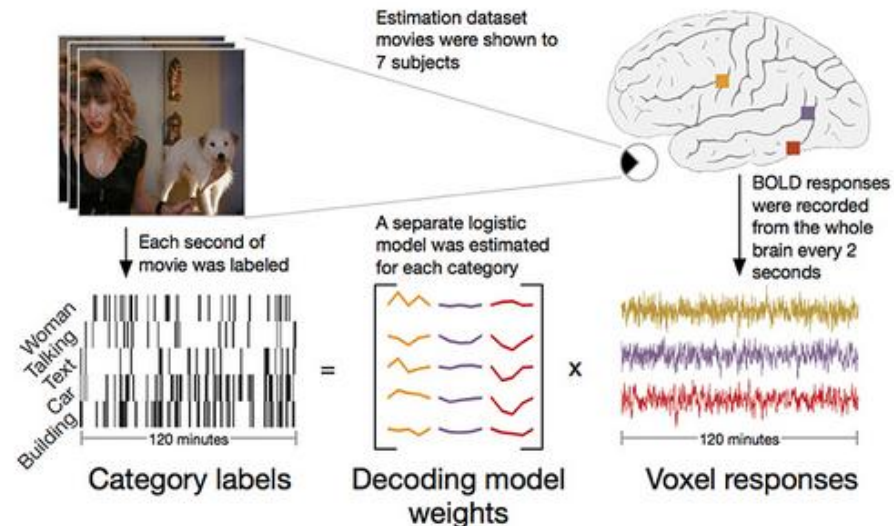
Decoding the Semantic Content of Natural Movies from Human Brain Activity

 Alexander G. Huth¹,  Tyler Lee¹,  Shinji Nishimoto^{1†},  Natalia Y. Bilenko¹,  An T. Vu² and  Jack L. Gallant^{1,2,3*}

¹Helen Wills Neuroscience Institute, University of California, Berkeley, Berkeley, CA, USA



Decoding model estimation



Bionics

Memory transfer between individuals

- David Glanzman (UCLA)

UCLA

UCLA biologists 'transfer' a memory



eNeuro

RNA from Trained *Aplysia* Can Induce an Epigenetic Engram for Long-Term Sensitization in Untrained *Aplysia*

Alexis Bédécarrats, Shanping Chen, Kaycey Pearce, Diancai Cai, and David L. Glanzman

eNeuro 14 May 2018, 5 (3) ENEURO.0038-18.2018; DOI: <https://doi.org/10.1523/ENEURO.0038-18.2018>

Bionics

Elon Musk's Neuralink (2017)



Bryan Johnson's Kernel (2017)



Thomas Oxley's Synchron

Matt Angle's Paradromics

Robert McIntyre and Michael

McCanna's Nectome (2015)



Synchron
Neural interface
technology



Paradromics
Neural Interfaces



Bionics

Nectome

Billionaire signs up to be killed, have brain digitally preserved

March 14, 2018 | 4:03pm



Sam Altman

MIT
Technology
Review

Mar 13, 2018

Cyborgs

A startup is pitching
a mind-uploading
service that is “100
percent fatal”

NECTOME

32-YEAR-OLD BILLIONAIRE JUST PAID
\$10K TO HAVE HIS BRAIN UPLOADED
AND BE KILLED IN THE PROCESS

MARCH 16, 2018

Bionics

Foc.us (London, 2012): “brain stimulators” to improve reaction speeds of gamers



Neuropace (San Francisco, 1997): predict, detect and stop the signals sent among neurons that cause seizures



Neurable (Boston, 2015): control toys and games with thoughts



Brainco (Boston, 2015): monitor the level of focus of students in the classroom



A Brief History of Bionics

Facebook Launches "Moon Shot" Effort to Decode Speech Direct from the Brain

April 27, 2017

Mark Chevillet



Apr 19, 2017

Technology could allow Facebook users to type 100 words per minute—using only their thoughts

ARM Wants to Put Its Chips Inside Your Brain

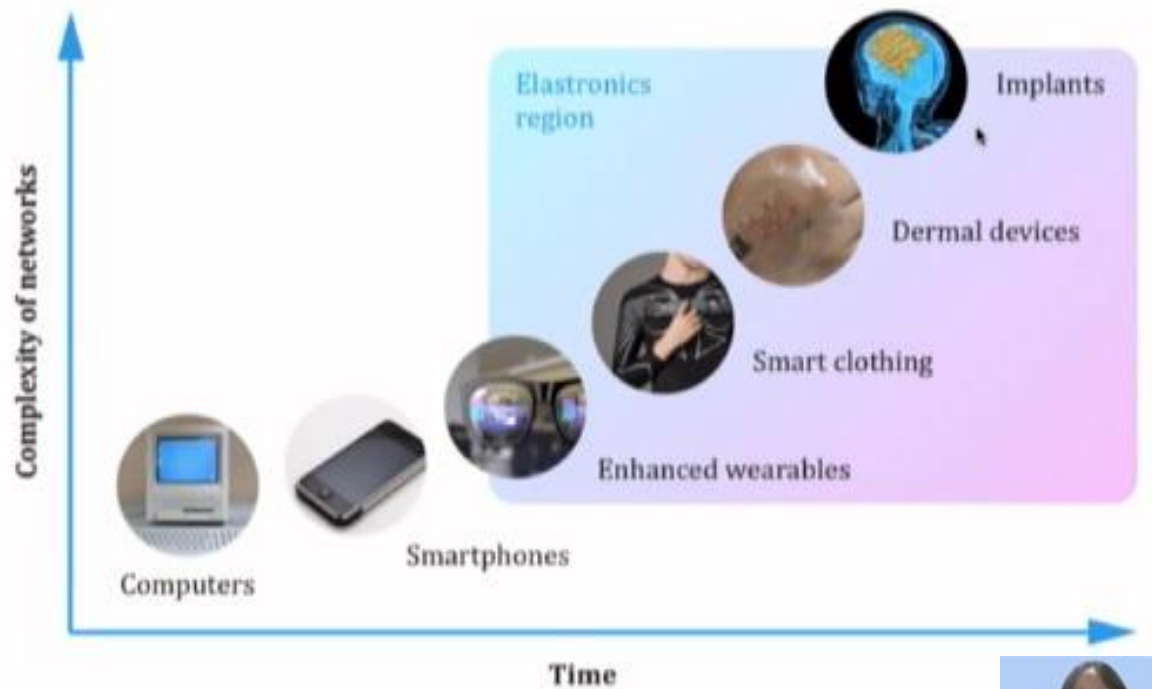
May 17, 2017

Neural implants are all the rage in Silicon Valley. Now the well-known chip designer thinks its low-power processors could help make them a reality.

The Future of Body

- Implantable electronics

A world beyond smartphones



Chu, Chang, Burnette, Bao, **Nature**, September 21, 2017



The Future of Body

- Implantable electronics

Bio-electronics interface



Low-V stimulation of nerve

Liu, Liu, Bao, et al. *Nature Biomedical Engineering*, 2019



Electrophysiological mapping on porcine heart for arrhythmia

Liu, Liu, Lee, Bao, et al. *PNAS*, 2020



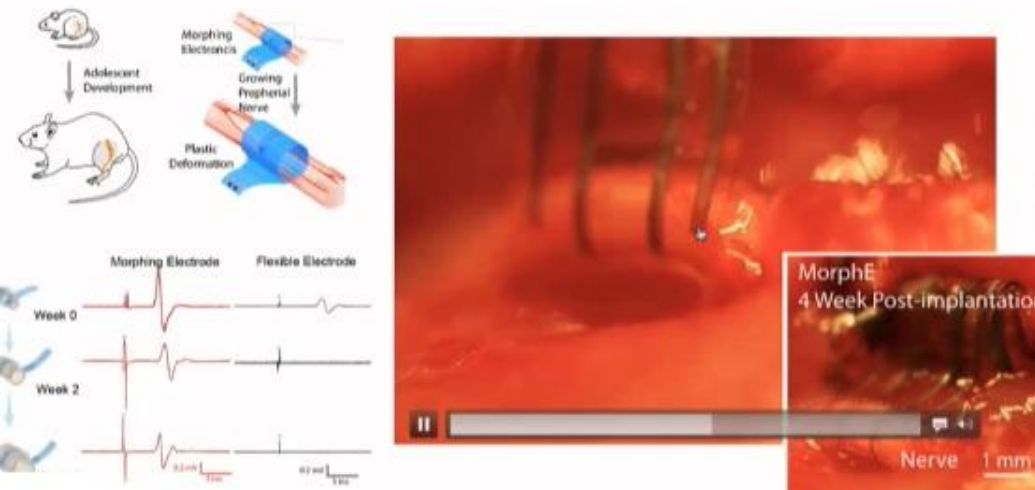
Implanted neurostimulator and dopamine sensor

Li, Liu, Chen, Bao, et al. submitted

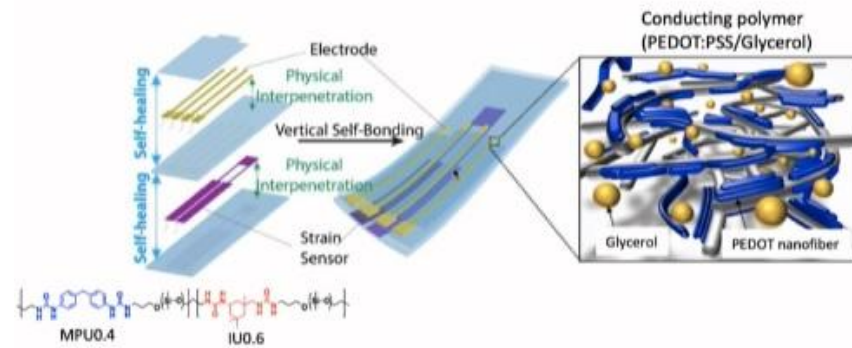
The Future of Body

- Implantable electronics
 - Yuxin Liu, Zhenan Bao, Jinxing Li: plastically deformable morphing electronics (MorphE) that grows as the body grows (as tissues grow)

Morphing Electronics “Grow” with Tissue



Morphing electronics: neuro stimulator



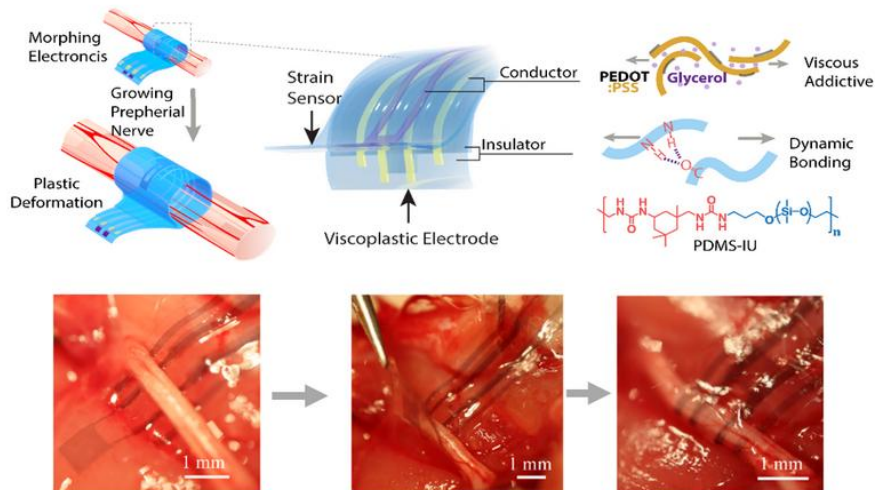
Y. Liu* J. Li*, S.Song* P. George, Z. Bao et al *Nature Biotechnology*, 2020

The Future of Body

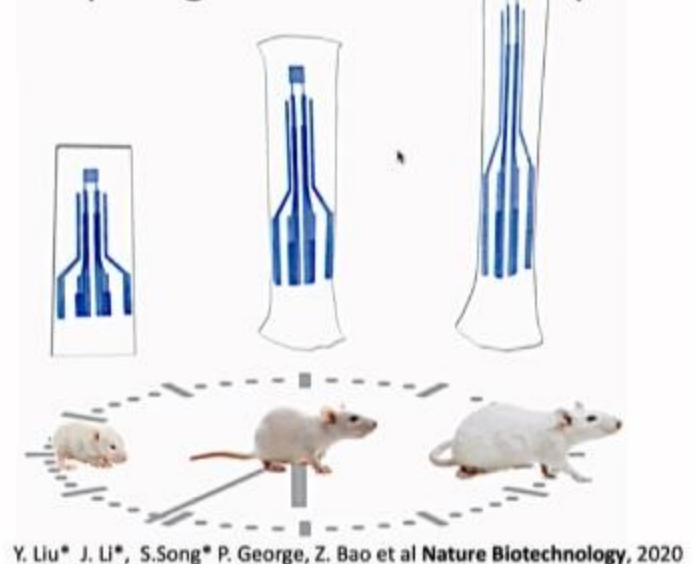
- Implantable electronics
 - Yuxin Liu, Zhenan Bao, Jinxing Li: plastically deformable morphing electronics (MorphE)



Yuxin Liu
Stanford University



Morphing Electronics: MorphE



Art & Bionics

- Richard Ramchurn (2018): “The Moment”, a brain-controlled film

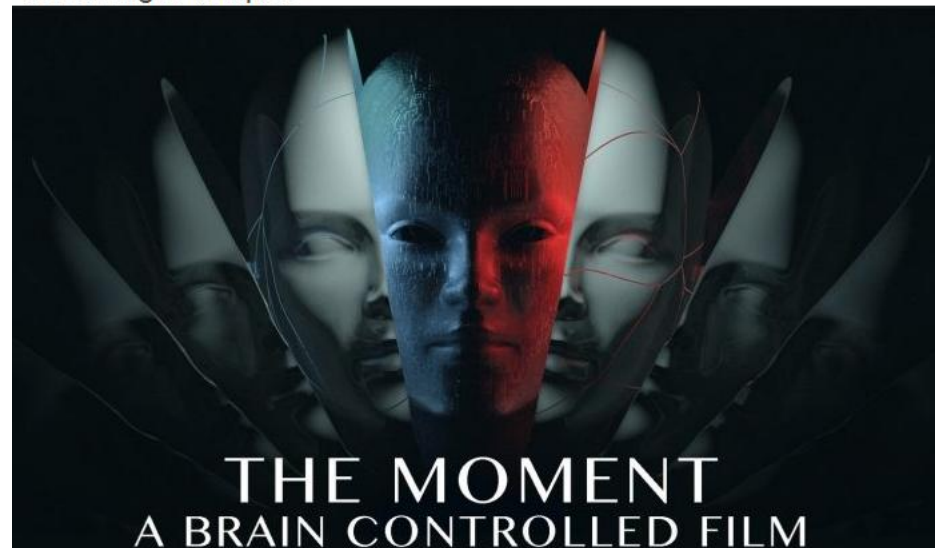


University of
Nottingham
UK | CHINA | MALAYSIA



The MOMENT is a brain controlled dystopian sci-fi film following three interlinking stories. Directed by artist and researcher Richard Ramchurn, it uses a Neurosky headset to detect EEG brain waves which will effect the edit, sound mix and narrative of a specially created movie.

There are over 18 billion narrative combinations of the film. Each screening is unique.



Next...

- See <http://www.scaruffi.com/singular> for the index of this Powerpoint presentation and links to the other parts

