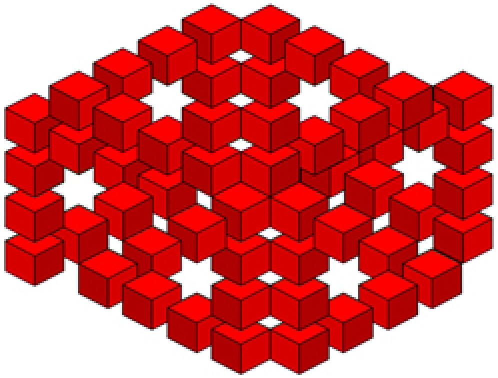
Paradoxes to Paradigms

Principles and Practice
of
Connectivity



Dr Shoumen Palit Austin Datta

Research Affiliate, Department of Mechanical Engineering, Massachusetts Institute of Technology ● shoumen@mit.edu

MIT Auto-ID Labs ● http://autoid.mit.edu/people-2

IoT Digital-by-Design Metaphor

A Connected Sense of the Future

This is an extremely incomplete & biased collection of IoT thoughts.

[0] Introduction / Context

[1] Evolution / Historical

[2] Examples (IT+OT+TELCO)
- Transport
- Digital Twins
- AI & Analytics

[3] Monetization

http://bit.ly/MIT-IOT

[0] Introduction / Context

http://bit.ly/MIT-IOT

Can my mobile phone in Boston move a taxi in Beijing ?

A2B

Technology | Fri May 13, 2016 12:09pm EDT

Apple invests $1 billion in Didi Chuxing

travis kalanick @travisk

Follow

girlfriend owns @apple shares which makes her a didi investor... #Smh #ridesharewars #domesticissues #thanksALotTim

3:10 AM - 13 May 2016

A2B

Atoms to Bits

My mobile phone in Boston can move a taxi in Beijing

Cannot transform design vision from the drawing board to customer reality without convergence of IT, OT and telecommunications (telco)

Atoms to Bits

IoT Digital-by-Design Metaphor

IT
OT
TELCO

→ **Converge**

Complement

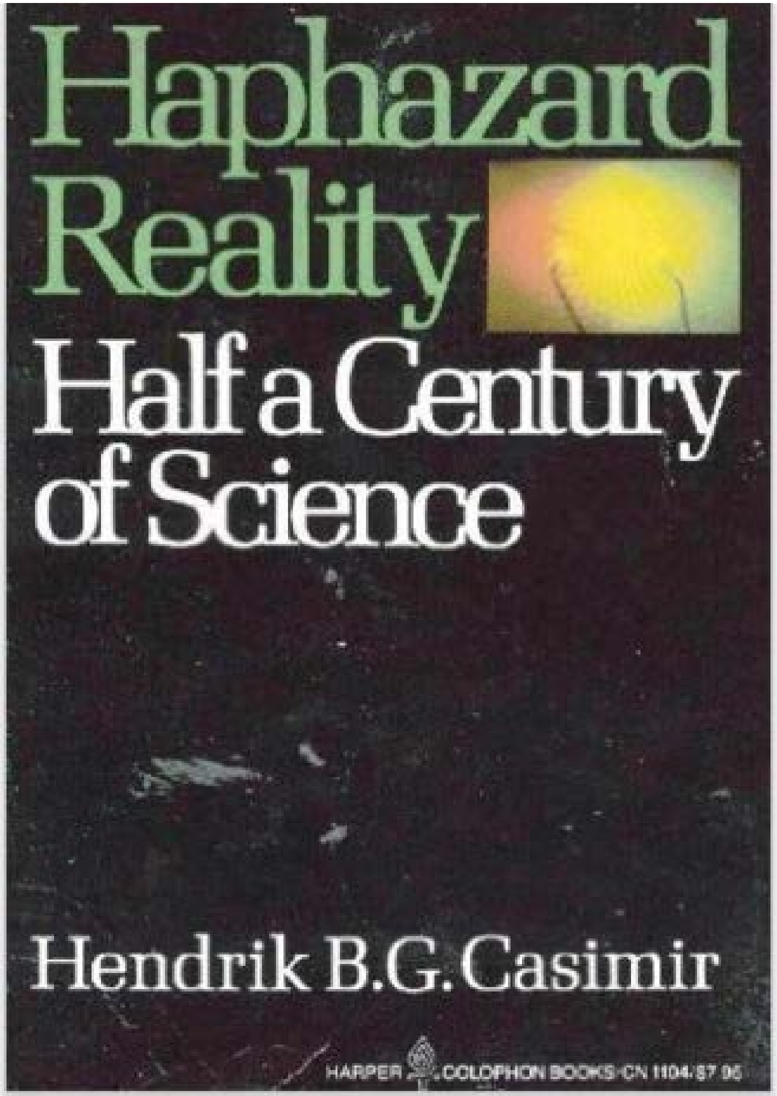
Community

Connect

Curate

Clone

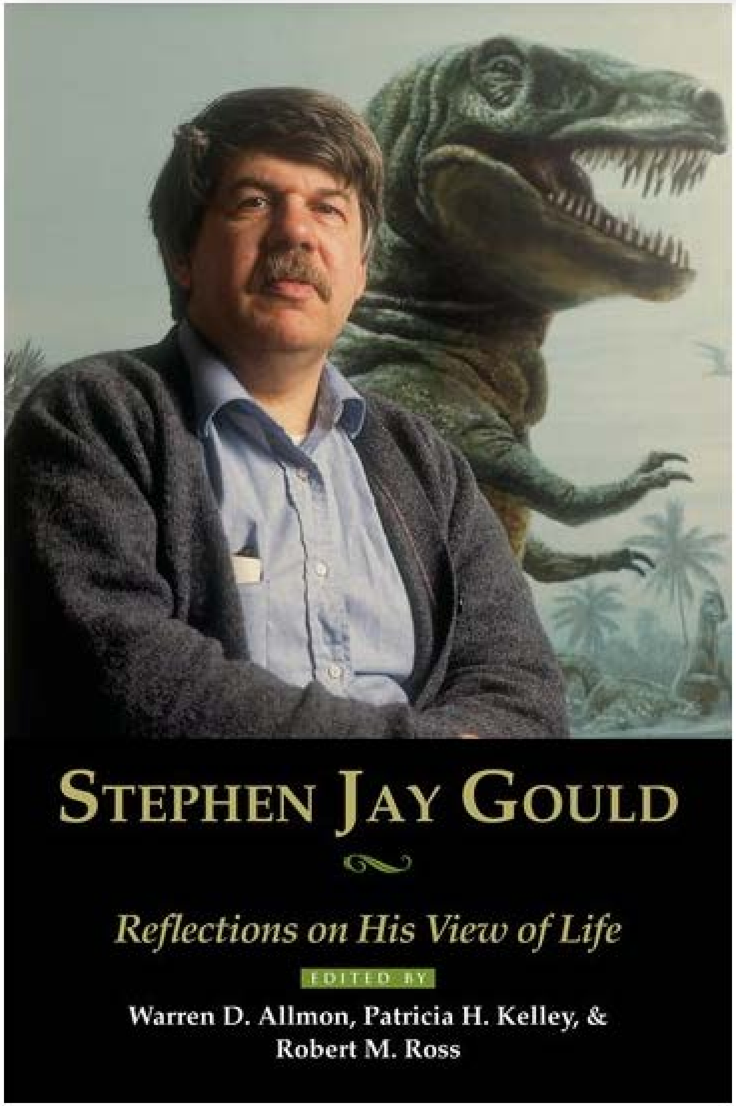
Casimir, himself a famous physician, studied and worked with three great physicists of the twentieth century: Niels Bohr, Wolfgang Pauli and Paul Ehrenfest. In his autobiography, the brilliant theoretician lets the reader witness the revolution that led to quantum physics, whose influence on modern society turned out to be many times larger than the first atomic physicists could have imagined. Through his involvement in the technical-scientific and the business aspects of physics, through management positions at Philips Research Laboratory and as a member of the Board of Directors of Philips, Professor Casimir is the ideal person to place half a century of developments in physics within the context of important events in the world.



Hendrik "Henk" Brugt Gerhard Casimir
Born 15 July 1909 ● Died 4 May 2000

Progress is not always a shrink-wrapped point solution!

BEFORE CONNECTIVITY … FIRST CONNECT THE DOTS …



If genius has any common denominator, I would propose breadth of interest and the ability to construct fruitful analogies between fields.

in *Darwin's Middle Road*

September 10, 1941 – May 20, 2002

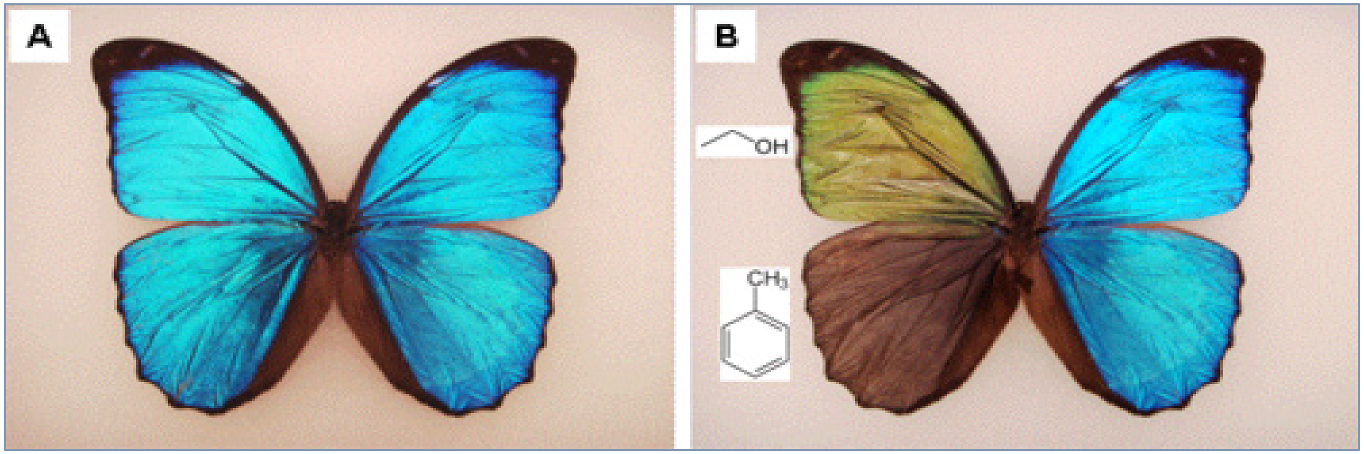
SYNTHESIZE ?

We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices, wisely.

Edward Osborne Wilson

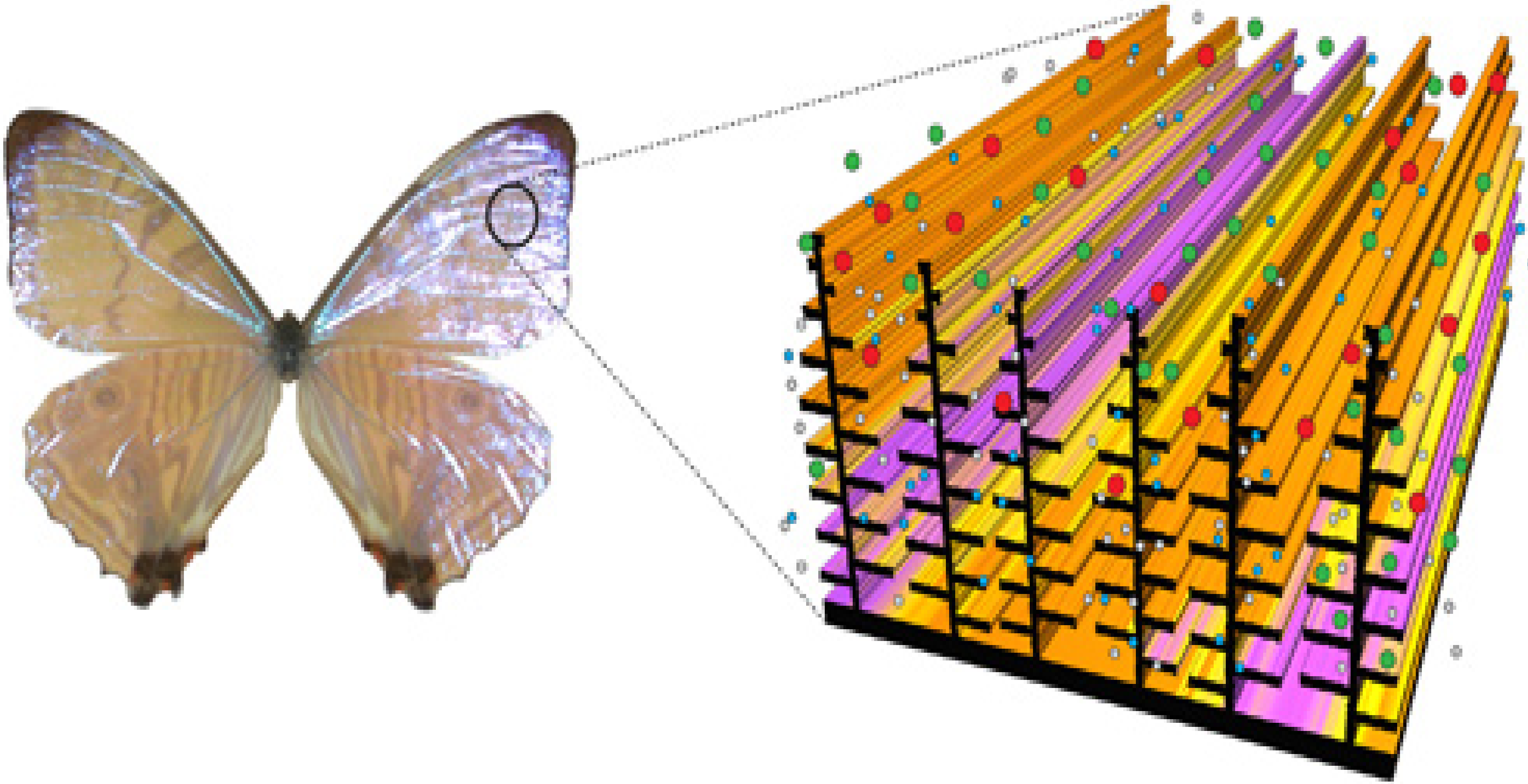
Emergence of IoS Preventive Medicine Era ● Wearable Diagnostic Devices with High Performance Ultra-Sensitive Nano-Sensors

Swiss engineer George de Mestro invented Velcro after his dog came home covered with thistle burrs, Speedo learned from sharkskin to make faster swimsuits, and chemical companies designed self-cleaning paint after studying lotus leaves.



GE scientists have observed that *Morpho* wings change their color when they come into contact with heat, gases and chemicals. The normal iridescent blue color of butterfly wings (A) changes when exposed to ethanol (panel B top) or toluene (panel B bottom). Radislav Potyrailo's team at GE wants to use their findings to develop fast, ultra-sensitive thermal and chemical imaging sensors for applications in night vision goggles, super-sensitive surveillance cameras, handheld or wearable medical diagnostic devices. ☑ www.gereports.com/post/80985289914/like-a-butterfly-out-of-hell-the-next-wave-of

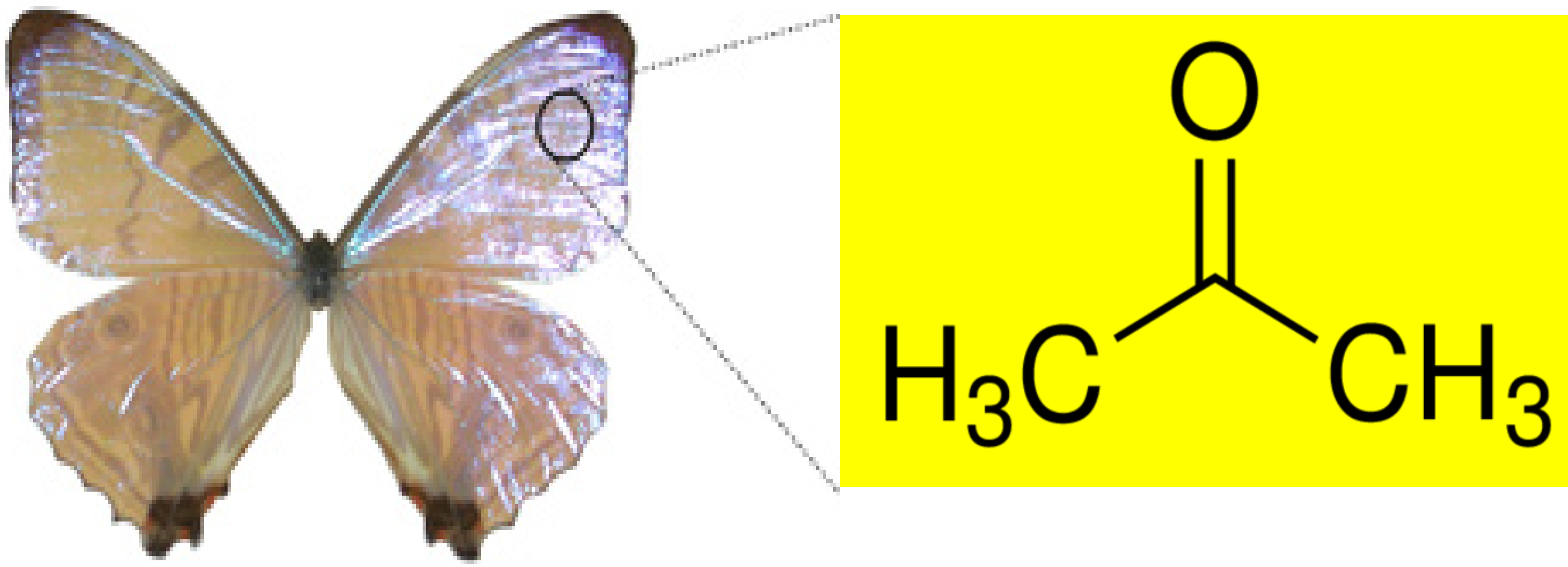
Changes to be ushered in by the connectivity potential from the IoT will shape the global economy in ways which could be limited only by our imagination



Scientists at GE Global Research discovered that the nanostructures on the wing scales of Morpho butterflies have excellent sensing capabilities. They could allow them to build sensors that can detect heat and also as many as 1,000 different chemicals. Image: GE Global Research

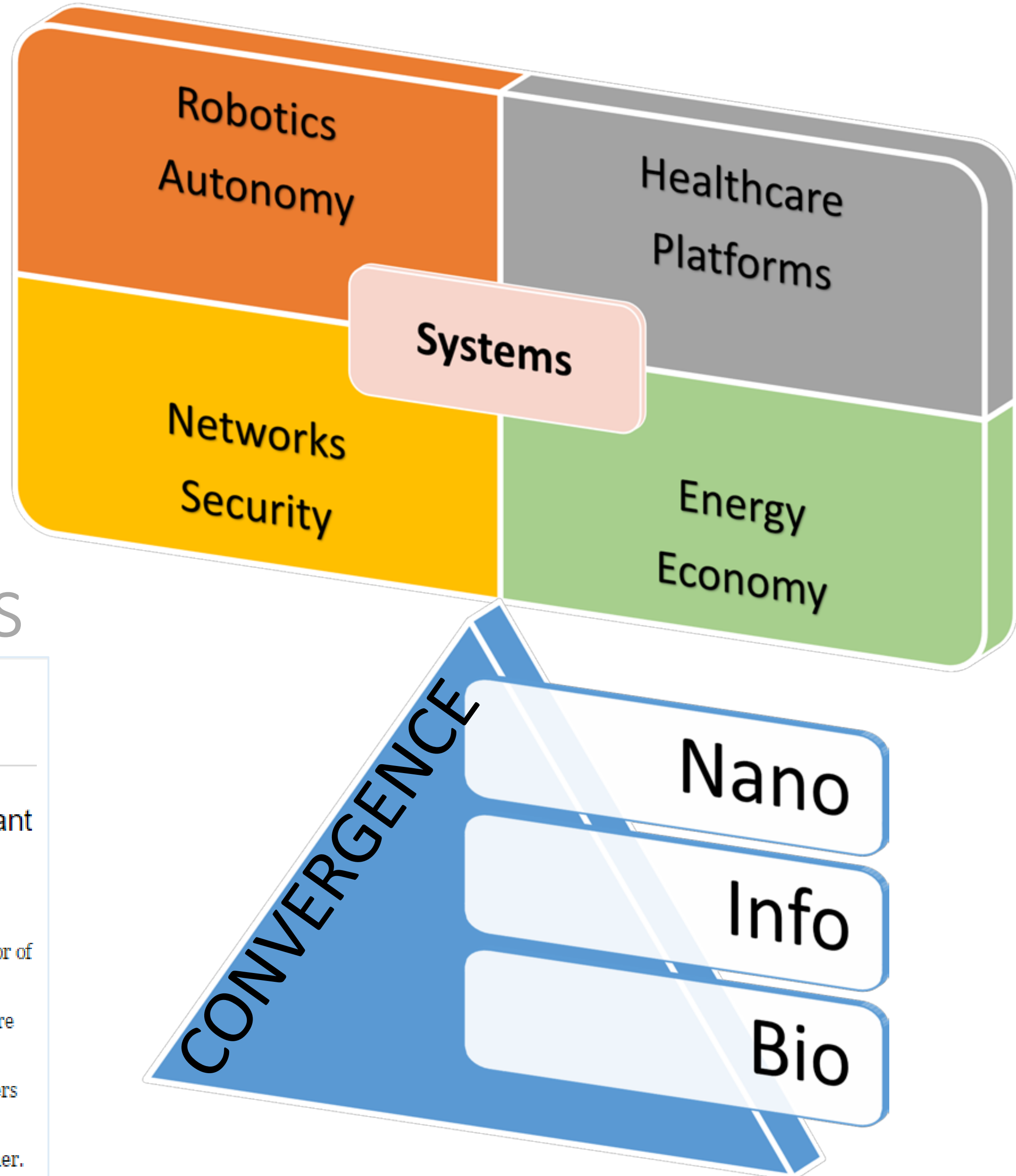
Can Butterflies Help Prevent Diabetes?

This is only a suggestion by the author and not a fact or system which is under investigation or is available at present.



Dual Acetone Sensors on a single chip may differentiate between acetone in the environment vs acetone in the blood, breath or urine of diabetics. Subtractive analysis alerts to blood ketones. Occurs when body uses fat instead of glucose. It signals insulin dysfunction. If undiagnosed, it may lead to diabetic ketoacidosis (DKA) which may result in diabetic coma and may be fatal. The acetone (ketone bodies) sensors may be able to detect trace levels (nano milli moles eq) and may help preventive care to stem the clinical onset of type II diabetes mellitus (glucose >120 mg/dl).

CONVERGENCE – WHY THE BIG PICTURE IS ESSENTIAL



Lippenbekenntnis

John Chambers

Executive Chairman

Reflecting on the Edison Awards: Why It's Important to Dream Big

Apr 26, 2016

On Thursday I attended a gala in New York where I had the tremendous honor of receiving the Edison Achievement Award, which celebrates leaders who have made significant contributions to innovation and whose efforts in the space are positively impacting the world. It was humbling to be mentioned in the same breath as Thomas Edison – the epitome of ingenuity – and past award winners like Elon Musk and Steve Jobs. I was so proud to accept this award both personally and on behalf of my Cisco family – we truly made it happen together.

● Bohr's principle of complementarity is the cornerstone of quantum mechanics.

● Complementarity is fundamental to structure of DNA & biological regulation.

Complementarity is crucial to the future of business and profitability

Revisiting BPC with a quantum device ● Jian-Shun Tang, Yu-Long Li, Chuan-Feng Li and Guang-Can Guo
Phys. Rev. A 88, 014103 – Published 22 July 2013 – DOI: http://dx.doi.org/10.1103/PhysRevA.88.014103

Software is becoming Hard

COMPLEMENTARITY

Hardware is becoming Soft

Software is becoming Hard

- Google
- Purchased 8 robotics companies in 6 months
- Amazon
- Kindle, Fire, Phone, Echo, Drones, 2lemetry
- Facebook
- Oculus, Ascenta, Drones
- Paypal
- Registers, Dongle, card readers

http://gizmodo.com/a-humans-guide-to-googles-many-robots-1509799897
http://www.cbsnews.com/news/google-buys-8-robotics-companies-in-6-months-why/
http://wearableworldnews.com/2014/11/07/amazon-moves-deeper-hardware-business-new-speaker-assistant/
http://www.reuters.com/article/2014/03/27/us-facebook-internet-idUSBREA2Q27420140327
http://www.ft.com/intl/cms/s/0/b8a6524a-b627-11e3-b40e-00144feabdc0.html#slide0
http://hothardware.com/news/PayPal-Here-A-New-Mobile-Payment-Dongle

Amazon Warehouse – Amazing Software Company?

Obsolescence imminent?

http://bit.ly/BEAM-ME-UP-SCOTTY

Hardware is becoming Soft

- GE
- Monsanto
- John Deere
- Nokia

- Quirky, Pivotal, GE Digital
- Climate Company, Precision Planting
- Farm Manager App in Apple's App Store
- Is now Microsoft

http://www.economist.com/news/business/21605916-it-has-taken-ges-boss-jeffrey-immelt-13-years-escape-legacy-his-predecessor-jack
http://www.forbes.com/sites/bruceupbin/2013/10/02/monsanto-buys-climate-corp-for-930-million/
http://www.wsj.com/articles/SB10001424052702304707604577422162132896528
https://stellarsupport.deere.com/en_US/categories/downloads/apex-update/
http://www.zdnet.com/article/microsoft-the-hardware-company/

Hardly soft

Softly hard

Apple Inc.

NASDAQ: AAPL - Feb 17 7:59 PM ET

127.83 ↑0.75 (0.59%)

After-hours: 127.67 ↓0.16 (0.13%)

1 day | 5 day | 1 month | 3 month | 1 year | 5 year | max

Open	127.49
High	128.88
Low	126.92

Market cap	**740.9B**
P/E ratio (ttm)	17.22
Dividend yield	1.47%

APPLE'S ELECTRIC CAR MAY HIT THE ROAD IN 2019

By **Trevor Mogg** — September 22, 2015

APPLE
COMPUTER

APPLE
PHONE

APPLE
CARS

outdated

Apple is "outdated" and losing momentum in China, billionaire entrepreneur Jia Yueting told CNBC in his first international television interview.

Jia is chief executive and chairman of Chinese conglomerate LeEco (formerly LeTV), which is best known for being the "Netflix of China," but has a product range that includes smartphones, televisions, mountain bikes and, most recently, electric vehicles.

Last week LeEco launched the self-driving, smart LeSEE supercar, designed to rival Tesla's Model X. In the latest evolution of the "LeEco ecosystem," Jia hopes to sell content, including movies, TV shows and music to LeSEE drivers.

VCG/VCG | Getty Images

Jia Yueting introduces the all-electric battery 'concept' car LeSEE on April 20, 2016 in Beijing,

CONVERGENCE

COMPLEMENTARITY

CONNECTIVITY

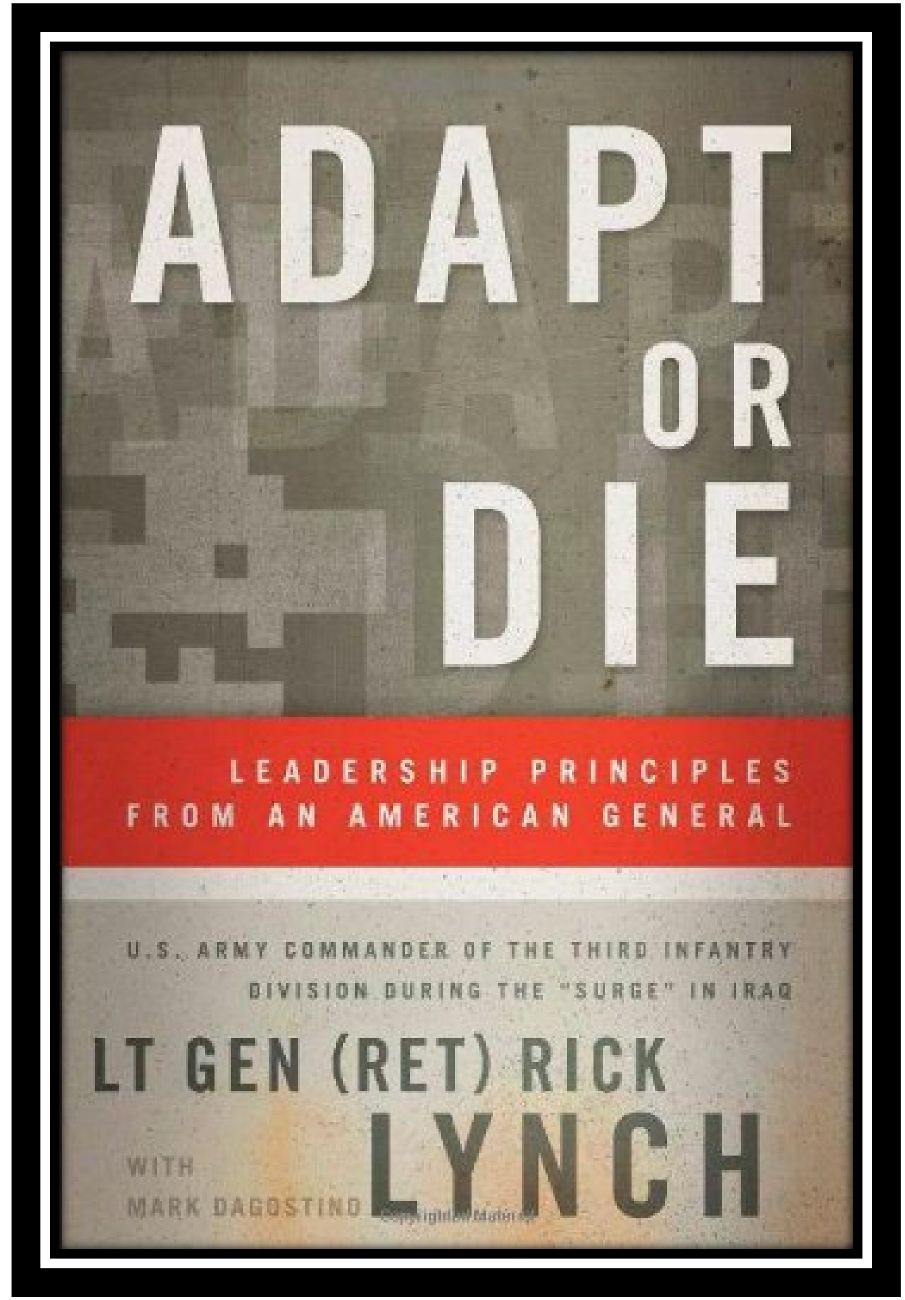
is not a point, it is a fabric, if you cannot adapt, you die

ADAPT OR DIE

Transforming Your Supply Chain into an Adaptive Business Network

CLAUS HEINRICH

with Bob Betts



Published 1 January 2003 ● http://bit.do/ADAP-or-DIE

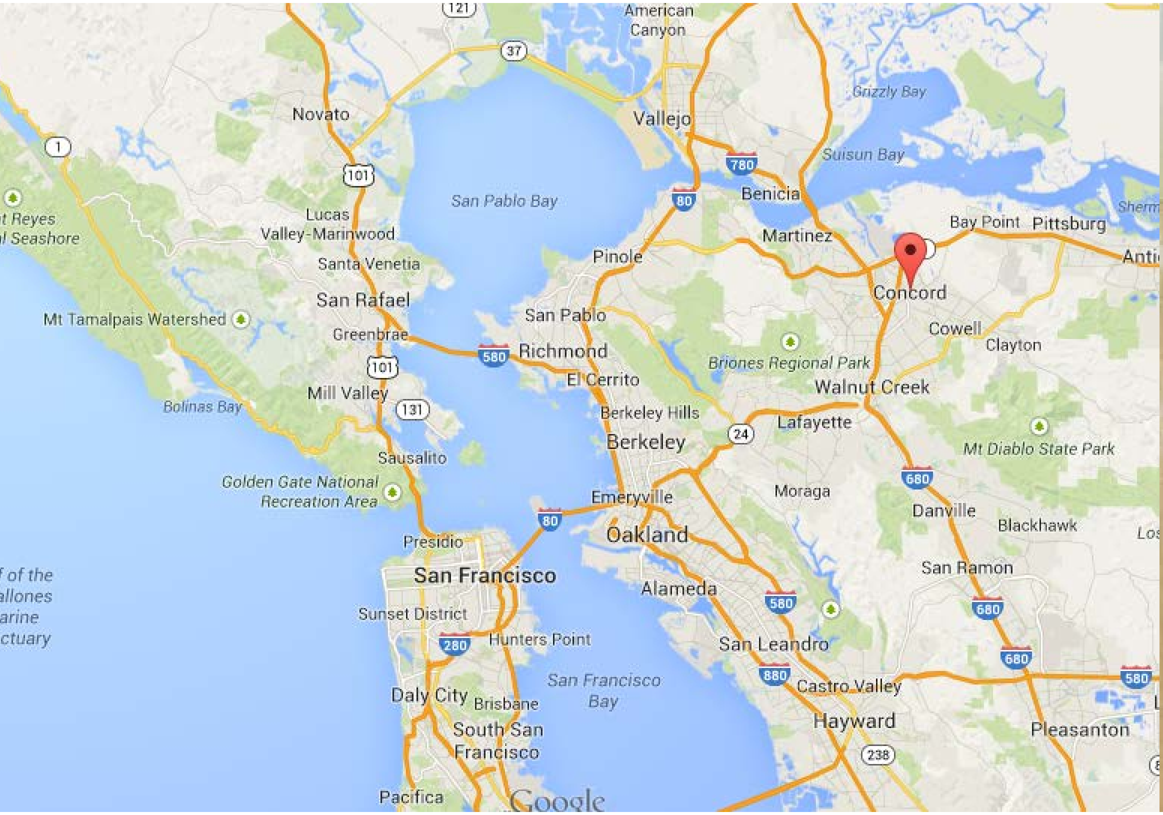
Is your imagination out of focus? Market trend?

In 1959, GE asked Arthur D. Little in Boston to conduct a study and forecast whether there was a market for portable TV sets that GE could now build using solid state transistors. Several months later in 1959, after spending $5 million in fees, focus groups and discussions, Arthur D. Little Inc. sent the forecast to GE suggesting that they do not believe there is any market for such B&W television sets. GE management pushed aside the project proposed by its engineers. Just before Christmas in 1959, Sony introduced a small B&W television in US. Sony sold 4 million television sets in a month.

First to Market, First to Fail? Real Causes of Enduring Market Leadership ▪ Gerard Tellis & Peter Golder 1996 MIT Sloan Management Rev 37 65-75

[1] Evolution / Historical

Diffusion of the Internet - NetDay 1996



President Bill Clinton installing computer cables with Vice President Al Gore on NetDay at Ygnacio Valley High School (Concord, CA - March 9, 1996)

Global Automobile Manufacturers in Silicon Valley

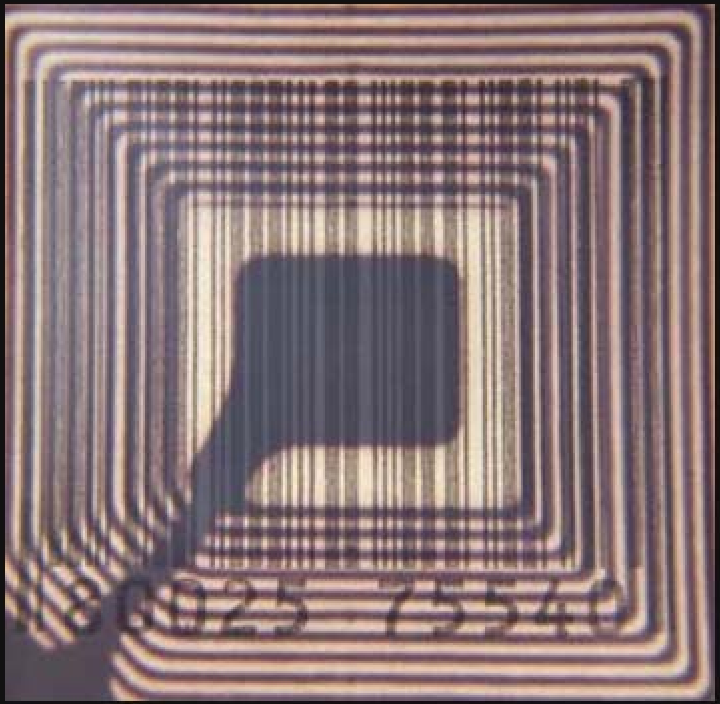
FT

http://web.mit.edu/innovate/entrepreneurship2015.pdf

http://economics.mit.edu/files/1909

A new report estimates that, as of 2014, MIT alumni have launched 30,200 active companies, employing roughly 4.6 million people, and generating roughly $1.9 trillion in annual revenues.

The Auto-ID Center at MIT and Supply Chain RFID



RFID tag developed by the Auto-ID Center

Paving the way for commercialized RFID solutions

Los Alamos National Laboratory led RFID development efforts in the 70's and 80's with RFID tags for gate access into nuclear facilities and for tracking nuclear materials, and then passive RFID technology for identifying cows and their antibiotic levels for the US Department of Agriculture. Companies commercialized the 125-kHz systems pioneered by Los Alamos and then moved on to high-frequency RFID systems that operated at 13.56-MHz. These especially caught on in Europe,

Professor Sanjay Sarma, MIT, Co-Founder, MIT Auto ID Center 1999
IoT was coined at the MIT Auto ID Center by Kevin Ashton (~ 2000)

http://bit.do/SANJAY-ODL

Professor David Clark, Research Scientist, MIT
Chief Architect (1981-1989) of DARPA created
Internet Architectures Board which hosts IETF

The Birth of the Internet of Things and the nascent Industrial Internet

1953

In my story "Sally," published in 1953, I described computerized cars that had almost reached the stage of having lives of their own. In the last few years, we do indeed have computerized cars that can actually talk to the driver. (*Robot Dreams* by Isaac Asimov aka Isaak Ozimov)

1987

Herbert Simon (June 15, 1916 – February 9, 2001) in his paper "*The Steam Engine and the Computer: What makes technology revolutionary*" framed his thoughts about the computer, "*you have to make friends with it, talk to it, let it talk to you.*"

1991

Mark Weiser (July 23, 1952 – April 27, 1999) of Xerox Palo Alto Research Center coined the term "ubiquitous computing" and suggested in 1988 that computers may *"weave themselves into the fabric of everyday life"* and influence the future of business (*Scientific American, 1991*).

2000

The seminal paper *The Networked Physical World* by Sanjay Sarma *et al* spread the concept of the Internet of Things (IoT) through the creation of the Auto ID Center at MIT.

2013

After sixty years of *Robot Dreams*, the evolution of the internet and the industrial revolution merged to conceive and create the Industrial Internet Consortium (03/27/2014) to catalyze global economic growth (www.iiconsortium.org). Sponsored by 5 founders with $1T market cap.

At the beginning ● How did the IoT concept / industrial internet start ?

The grand vision of the Industrial Internet may have started circa 1988 with the work of Mark Weiser of Xerox Palo Alto Research Center (XPARC) who predicted that computers may *"weave themselves into the fabric of everyday life"* and influence the future of business as well as lifestyle technologies, in his 1991 article in the *Scientific American*. The release of the commercial internet in 1995 paved the way for the Industrial Internet of the future. In 1998, Sanjay Sarma (MIT) extended the idea of using RFID tags to use RFID tags in supply chain management (http://bit.ly/SANJAY-SARMA). The price of the RFID tag had to be reduced and Sarma suggested RFID tags contain only a reference number EPC (electronic product code) rather than any actual data about the object. It was against the conventional wisdom. At the time, RFID tags were used and designed to contain data about the object or product. By eliminating need for data storage on the tag, the cost of the RFID tags were reduced. Sarma designed the EPC to act as an unique URL to access the object data stored on the Internet. In 1999, Sarma along with David Brock and Sunny Siu co-founded the MIT Auto ID Center to transform this vision made possible by the "emerging" medium and the platform of the internet. The internet was still immature to act as a catalyst to augment business processes and industrial productivity. Sarma, Brock and Siu were later joined by Kevin Ashton, a marketing manager at Proctor & Gamble who was loaned to the Auto ID Center at MIT. Auto ID Center at MIT developed the EPC and other technical concepts and standards prevalent today in the global RFID industry. Sarma, Brock and Ashton coined the term Internet of Things which envisioned objects /things connected to object-specific data on the internet which could be accessed using the unique EPC on the tag attached to the object. IoT is a vision, not a technology. In 2000, a paper by Sarma *et al* summarized the IoT concept as it related to the network society in general.

MIT-AUTOID-WH-001 ▪ *THE NETWORKED PHYSICAL WORLD* ▪ http://tinyurl.com/Industrial-Internet

Prof Sarma talked about the origin of IoT at the MIT Sloan Symposium http://tinyurl.com/MIT-IoT-1998

I was a part of the Auto ID initiative since 1999 as a member of the Technology Board at Auto ID Center.

Published October 1, 2000. Distribution restricted to Sponsors until January 1, 2001.

AUTO-ID CENTER

WHITE PAPER

The Networked Physical World

Proposals for Engineering the Next Generation of Computing, Commerce & Automatic-Identification

Sanjay Sarma, David L. Brock & Kevin Ashton

MIT AUTO-ID CENTER MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 77 MASSACHUSETTS AVENUE, BUILDING 3-449G, CAMBRIDGE, MA 02139-4307

ABSTRACT

The Auto-ID Center at the Massachusetts Institute of Technology is a new industry sponsored lab charged with researching and developing automated identification technologies and applications. The Center is creating the infrastructure, recommending the standards, and identifying the automated identification applications for a networked physical world. All technologies and intellectual property developed at the Auto-ID Center are freely distributed. This white paper outlines the Auto-ID Center's key conclusions and research progress after its first year of research.

2001-2002

Agents

Where Artificial Intelligence meets Natural Stupidity

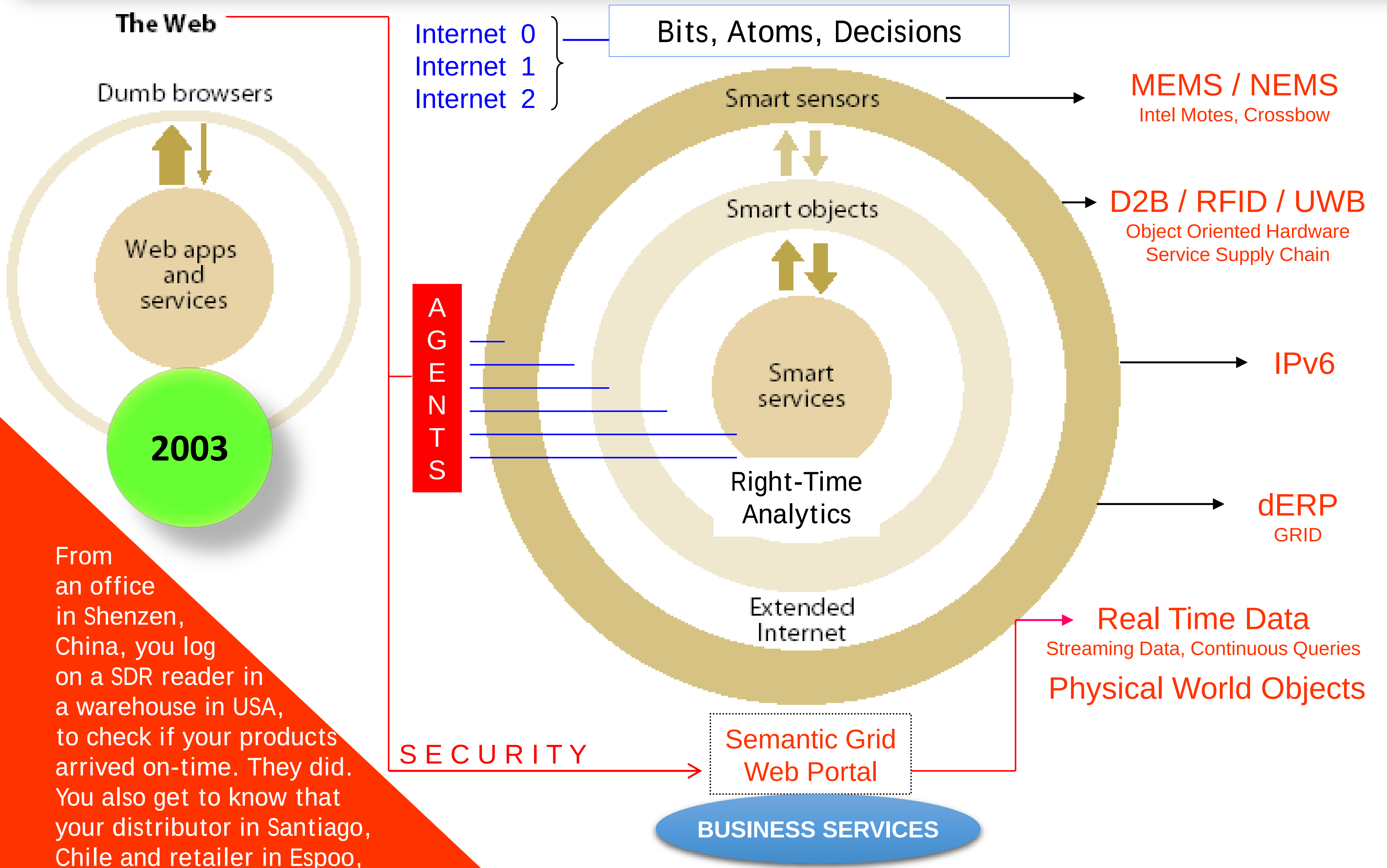
Summary Prepared by Dr Shoumen Datta
Engineering Systems Division, School of Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139

Disclaimer

This summary on **Agents** is not an original work by the author (Shoumen Datta). I have merely written it in simple English to make it suitable for understanding by a large number of non-experts, myself included. I neither have the talent nor the training to produce the concepts and formulations described in this article. Failure to represent the ideas with clarity is entirely my fault. If you have understood and appreciated the scope of Agents, then, the credit is solely due to the brilliance of the scientists whose work I have quoted/paraphrased. I have used papers from Massachusetts Institute of Technology (MIT), Carnegie-Mellon University (CMU) and University of Michigan, Ann Arbor. The monographs by H. Van Dyke Parunak deserves special acknowledgement. Email: shoumen&mit.edu

https://dspace.mit.edu/handle/1721.1/41914

Integrating Ubiquitous Analytics in Real-Time with Data, Information, Application



From an office in Shenzen, China, you log on a SDR reader in a warehouse in USA, to check if your products arrived on-time. They did. You also get to know that your distributor in Santiago, Chile and retailer in Espoo, Finland also checked the delivery status, moments before you logged on.

SDR Data Interrogators as Ubiquitous Internet Appliances in IoT (2003)

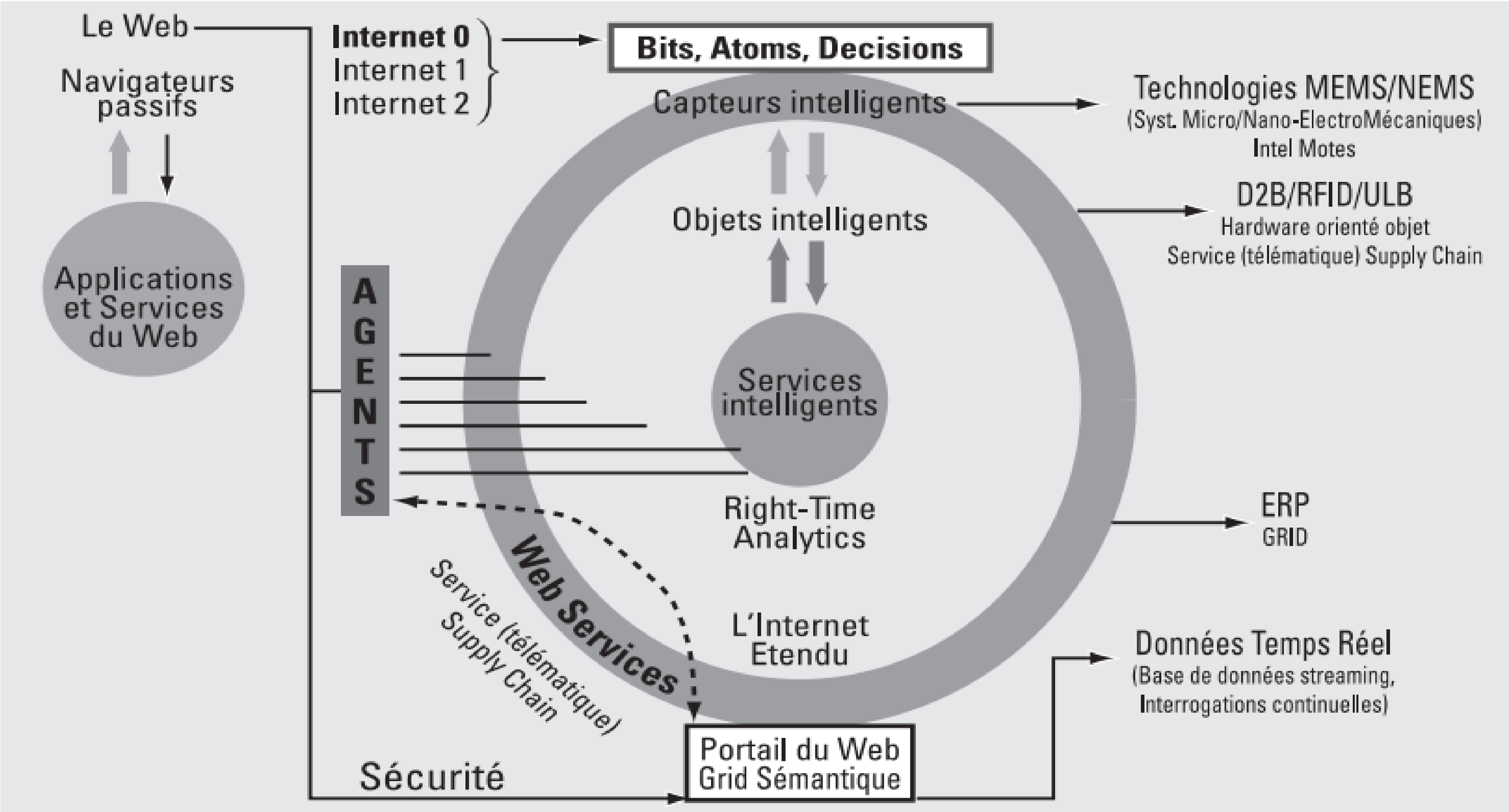
2004

ADAPTER, OPTIMISER, PRÉVOIR
La convergence des concepts, des outils, des technologies et des normes peut-elle accélérer l'innovation ?

Dr Shoumen DATTA
Chercheur, Département Ingénierie des Systèmes, Forum pour l'Innovation dans la chaîne logistique
Directeur général de l'Ecole d'Ingénierie, Massachusetts Institute of Technology

MIT DSpace http://hdl.handle.net/1721.1/41907

Figure 3 : Pour l'émergence de systèmes décisionnels adaptifs, il est nécessaire de mettre en communication bits, atomes et décisions.



Depuis un bureau à Shinzen en Chine, vous vous connectez à un lecteur SDR situé dans un entrepôt aux Etats-Unis de manière à vérifier si vos produits sont arrivés en temps voulu. Ce fut le cas. Vous allez aussi apprendre que votre distributeur à Santiago du Chili et votre détaillant à Espoo en Finlande ont eux aussi vérifié où en était la livraison quelques instants avant vous

MIT DSpace - http://hdl.handle.net/1721.1/41907

Chapter 1

ADAPTIVE VALUE NETWORKS

*Convergence of Emerging Tools, Technologies and Standards as Catalytic Drivers**

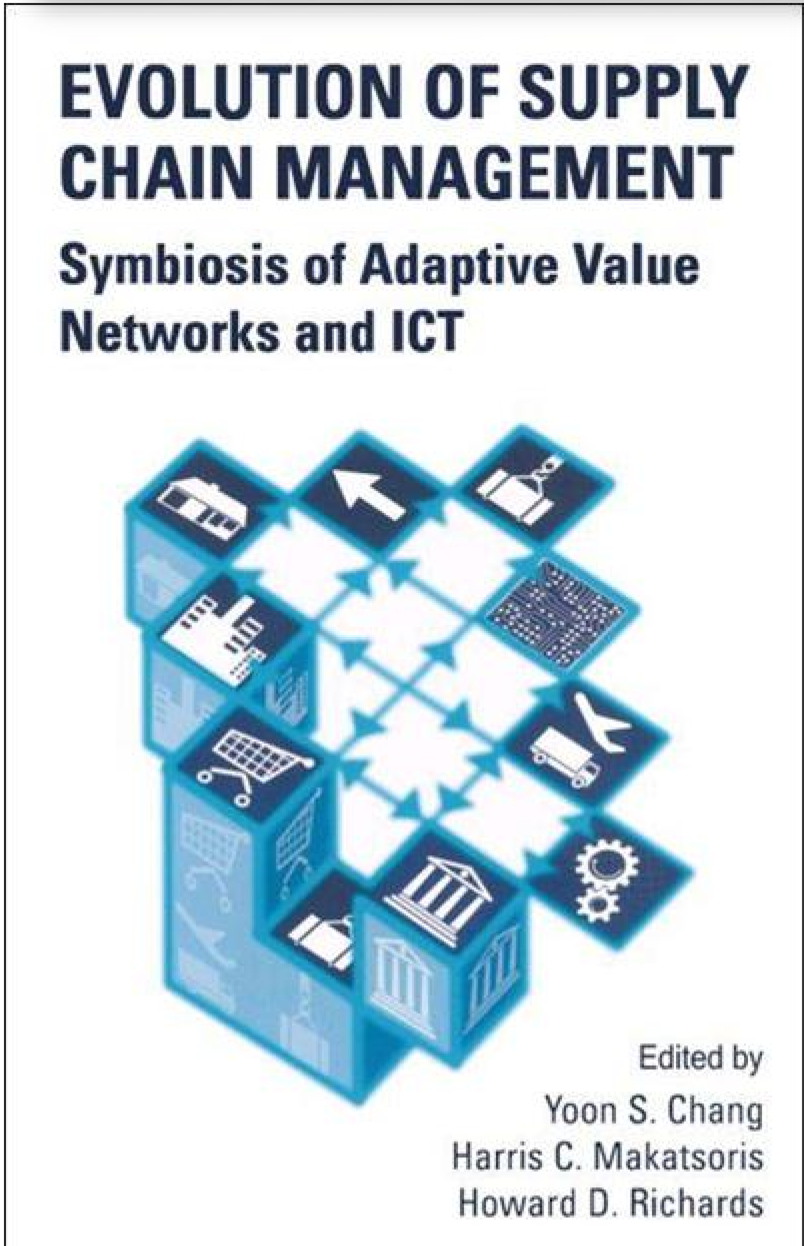
Shoumen Datta[1], Bob Betts[2], Mark Dinning[3], Feryal Erhun[4], Tom Gibbs[5], Pinar Keskinocak[6], Hui Li[1], Mike Li[1], Micah Samuels[7]

Massachusetts Institute of Technology[1], Timogen Inc.[2], Dell Corporation[3], Stanford University[4], Intel Corporation[5], Georgia Institute of Technology[6], Amazon.com[7]

Abstract: If a typhoon in the South China Sea impacts the shipment and delivery of memory chips to an assembly plant in Mexico City, you can count on the ripple effect to impact financial service providers, manufacturers and suppliers, shippers in charge of logistics and of course, the end-consumer. Can we plan to reduce the risk arising from such uncertainties? Can businesses (semiconductor plants, banks, logistics providers) cooperate to minimize uncertainties? Conventional wisdom states that uncertainties are equivalent to accidents and hence by nature remain unpredictable. However, application of tools and technologies based on emerging standards may partially disprove such wisdom. Focus on demand management may be the guiding light for supply chain practitioners. Can we collapse information asymmetries (between manufacturers and their lending institutions, for example) and add far more value to networks or demand webs? Real-time operational adaptability is key, especially in fast 'clockspeed' industries. Confluence of emerging tools, technologies and standards are required to converge to catalyze the evolution of such adaptable enterprise. Can real-time distributed data, in-network processing, Agent-based autonomy, taken together, tame the Bullwhip Effect? Can the (semantic) web catalyze the "Nash Equilibrium" of people (games) and information (theory) in our quest for real time "predictive" decision support systems? We will explore a few of these issues and how they may coalesce to enable the adaptive value network of the future.

2004

2003-2004



About Big Data before "Big Data" → Econometric Models ARCH/GARCH (Datta,2004)

$$Y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j Y_{t-j} + \sum_{k=1}^{k} \sum_{i=1}^{N_{X_{KT}}} \alpha_{ki} X_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon_{t-1}^2 + \theta_2 \varepsilon_{t-2}^2 + \ldots + \theta_q \varepsilon_{t-q}^2$$

La variance du terme d'erreur aléatoire dépend non seulement des valeurs précédentes de ε (t-1, t-2, . . . , t-q) mais aussi des valeurs précédentes de la variance σ^2(t-1, t-2, . . . , t-p).

$$Y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j Y_{t-j} + \sum_{k=1}^{k} \sum_{i=1}^{N_{X_{KT}}} \alpha_{ki} X_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \tau_j \varepsilon_{t-j}^2 \quad \textbf{(6)}$$

http://hdl.handle.net/1721.1/41907

MIT Data Center – About Big Data before "Big Data" → Datta & Granger (2003 – 2005)

$$y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j y_{t-j} + \sum_{k=1}^{K} \sum_{i=1}^{N_{x_{kt}}} \alpha_{ki} x_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon^2_{t-1} + \theta_2 \varepsilon^2_{t-2} + \dots + \theta_q \varepsilon^2_{t-q}$$

Variance of the random error term DEPENDS NOT ONLY on previous lagged errors (t-1, t-2, …., t-q) but also on LAGGED VALES OF THE VARIANCE (t-1, t-2, …, t-p)

$$y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j y_{t-j} + \sum_{k=1}^{K} \sum_{i=1}^{N_{x_{kt}}} \alpha_{ki} x_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \sum_{i=1}^{q} \theta_i \varepsilon^2_{t-i} + \sum_{j=1}^{p} \tau_j \sigma^2_{t-j}$$

Generalized Auto Regressive Conditional Heteroskedasticity

Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2006-11

ADVANCES IN SUPPLY CHAIN MANAGEMENT:
POTENTIAL TO IMPROVE FORECASTING ACCURACY

Shoumen Palit Austin Datta[1] and Clive W. J. Granger[2]

[1]Research Scientist, Engineering Systems Division
Department of Civil and Environmental Engineering
Research Director & Co-Founder, MIT Forum for Supply Chain Innovation
School of Engineering
Massachusetts Institute of Technology
shoumen@mit.edu

[2]Research Professor
Department of Economics
University of California
cgranger@ucsd.edu

SAP Launches First RFID Solution to Help Customers Automate RFID-Enabled Business Processes

January 12, 2004 | SAP -

Packaged RFID Solution for Supply Chain Management Will Deliver Value through Seamless Integration of RFID Data into Applications

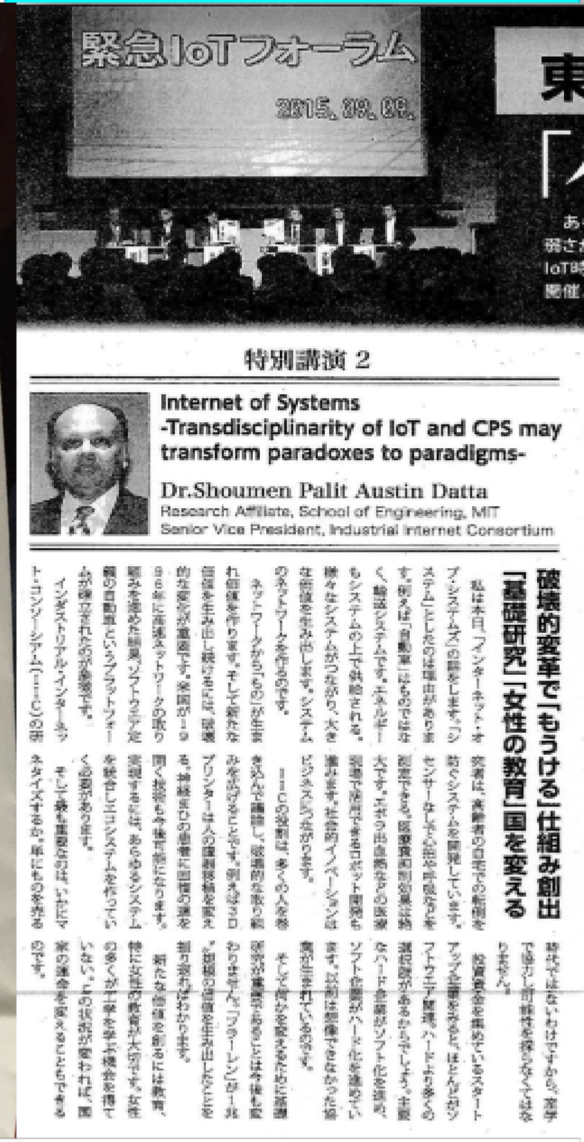
NEW YORK, NY - Delivering on its vision of adaptive supply chain networks, SAP AG (NYSE: SAP) today announced the launch of the first packaged radio frequency identification (RFID) solution for supply chain management. Demonstrating leadership in the RFID space, SAP is delivering a solution that is the first of its kind developed and built entirely from the ground up to help companies manage the data reads from and writes to RFID tags. SAP, the world's leading provider of supply chain management solutions, made its announcement at the National Retail Federation (NRF) show, being held Jan. 11-14, 2004 in New York.

Drawing upon experience from customer projects with leading companies like Procter & Gamble and the METRO Group, as well as six years of RFID research and involvement in RFID standards organizations, SAP has developed technology that will dramatically change supply chain management in the retail and consumer product industries. Companies can leverage data captured through RFID tags in their business processes by integrating ERP and SCM functionalities with RFID-enabled applications. Examples include packing and unpacking, shipping and receiving and tracking and tracing across the supply chain.

The Java-based RFID solution packages the new SAP Auto-ID Infrastructure, SAP® Event Management (SAP EM), a component of mySAP™ Supply Chain Management (mySAP SCM), and SAP® Enterprise Portal (SAP EP), a component of SAP NetWeaver™, the industry's leading integration and application platform. Currently available to pilot customers, the SAP RFID packaged solution will be more widely available to customers in mid-2004.

RFID JAPAN 2005

IoT JAPAN 2015



http://bit.ly/MIT-IOT

Tekes

2005

Technology Review 196/2006
Helsinki 2006

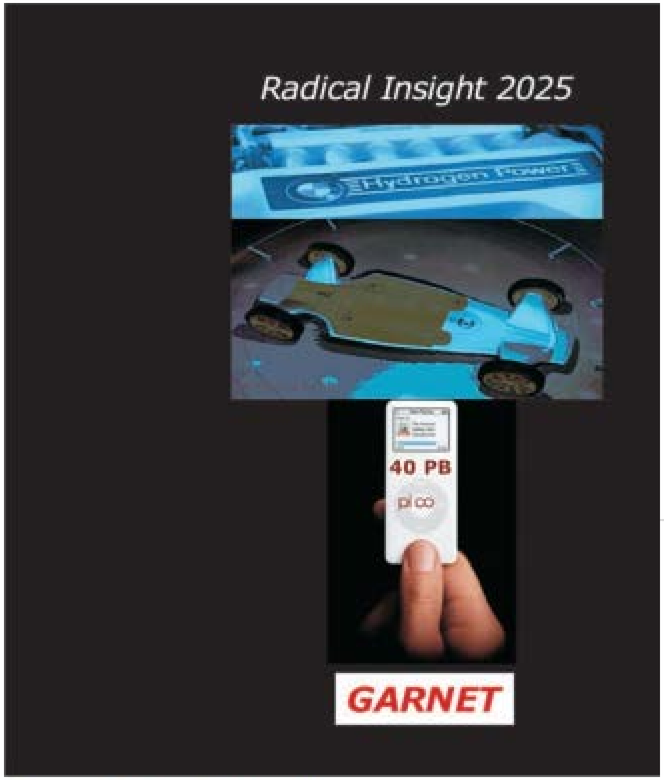


Figure 26. Radical Insight?

POC ● 2009 ● http://bit.do/Smooth-Operator

Connecting (each instance) Objects, Data and Decisions

2006

Identification of information with a digital signature at every instance when (time) property, relationship, attribute, dependency, links or status may change.

Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2007-17

UNIFIED THEORY OF RELATIVISTIC IDENTIFICATION OF INFORMATION IN A SYSTEMS AGE:

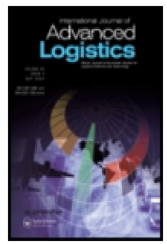
Proposed Convergence of Unique Identification with Syntax and Semantics through Internet Protocol version 6

Shoumen Palit Austin Datta

Research Scientist, Engineering Systems Division
Department of Civil and Environmental Engineering
Research Director & Co-Founder
MIT Forum for Supply Chain Innovation
School of Engineering
Massachusetts Institute of Technology
shoumen@mit.edu

International Journal of Advanced Logistics

Volume 1, Issue 1, 2012



Original Articles

An Unified Theory of Relativistic Identification of Information in the Systems Age: Proposed Convergence of Unique Identification with Syntax and Semantics through Internet Protocol version 6 (IPv6)

DOI: 10.1080/2287108X.2012.11006070

S. P. A. Datta[a*]

pages 66-82

http://hdl.handle.net/1721.1/41902 ● http://bit.do/UTRI-IPv6

Connecting (each instance) Objects, Data and Decisions
Is it conceptually a precursor to the idea of blockchain?

Identification of information with a digital signature at every instance when (time) property, relationship, attribute, dependency, security or/if status changes.


Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2007-17

UNIFIED THEORY OF RELATIVISTIC IDENTIFICATION OF INFORMATION IN A SYSTEMS AGE:

Proposed Convergence of Unique Identification with Syntax and Semantics through Internet Protocol version 6

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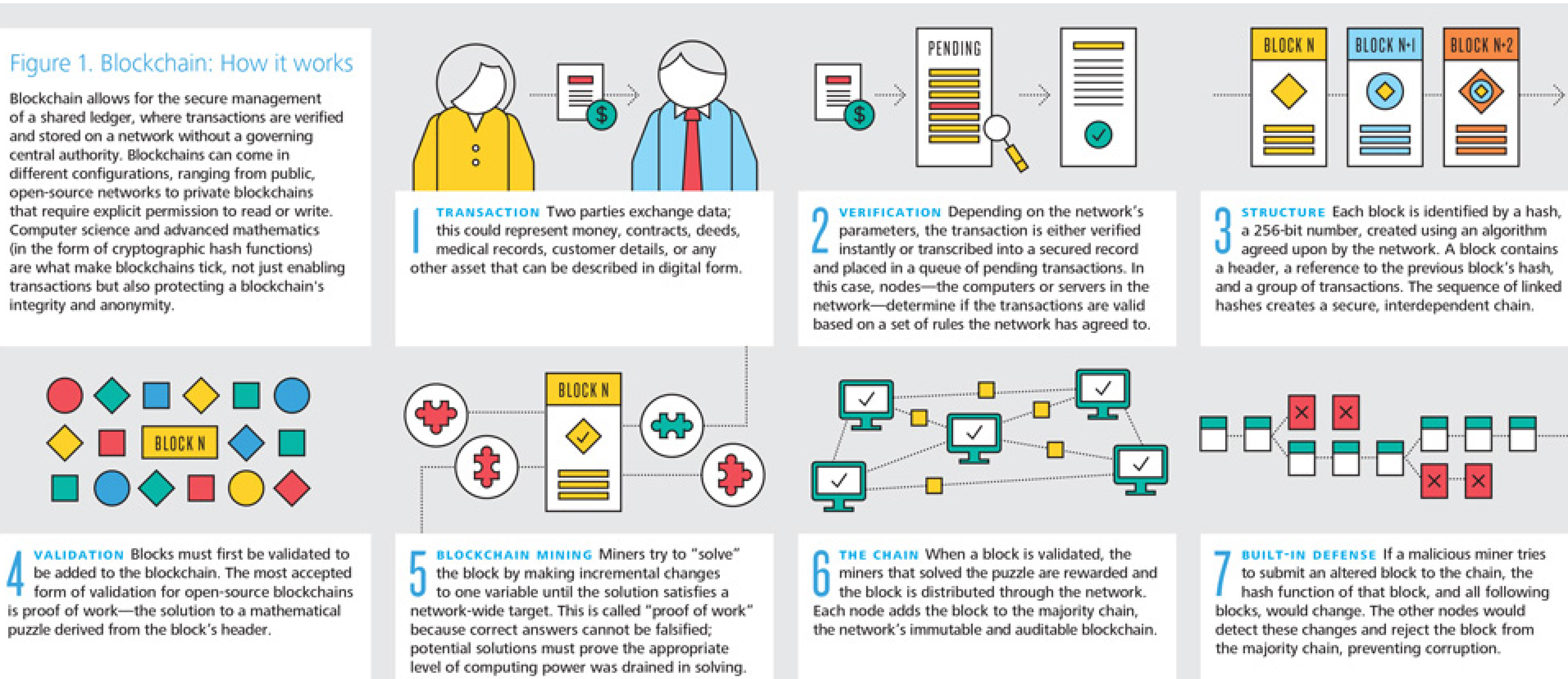
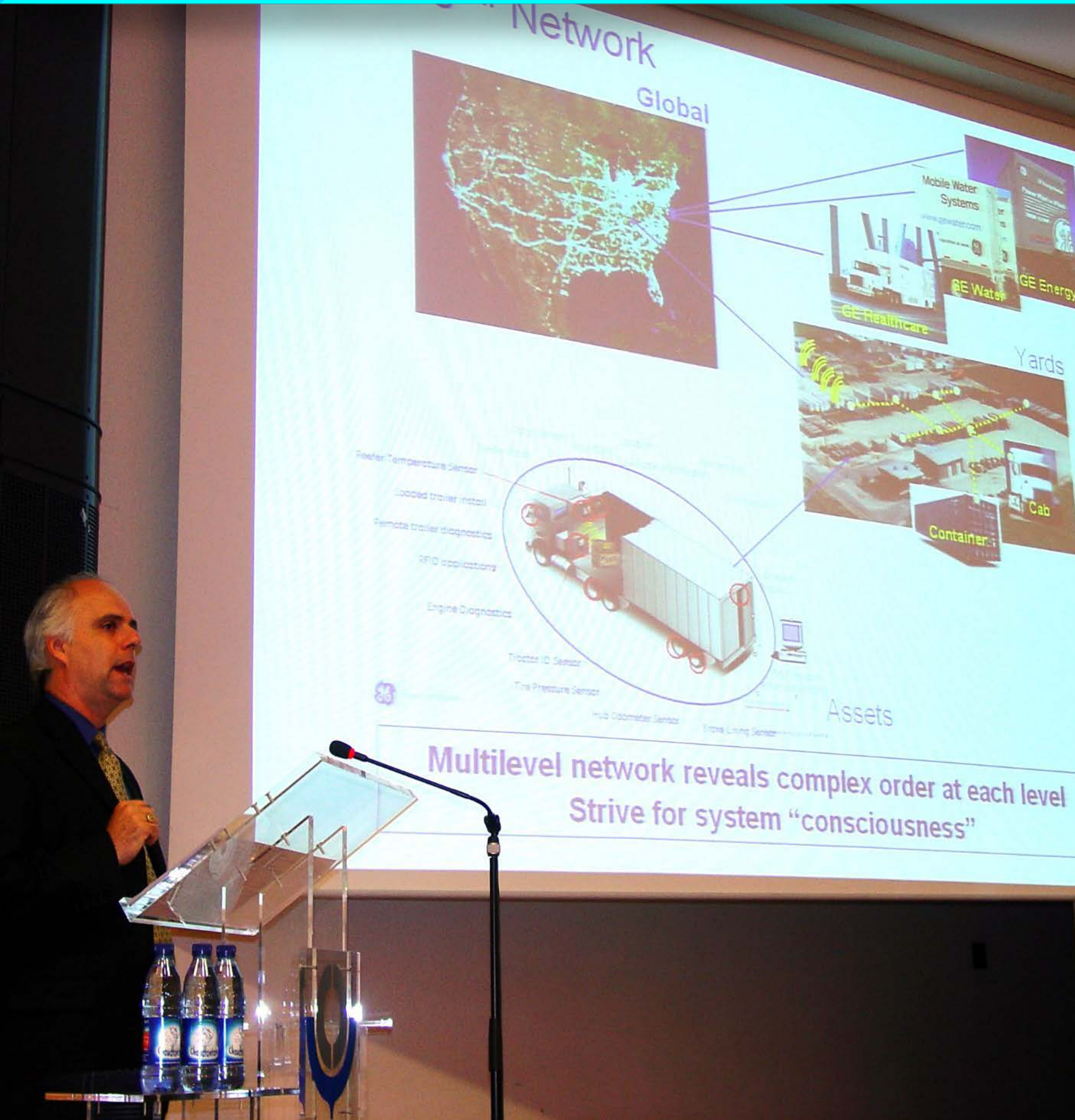
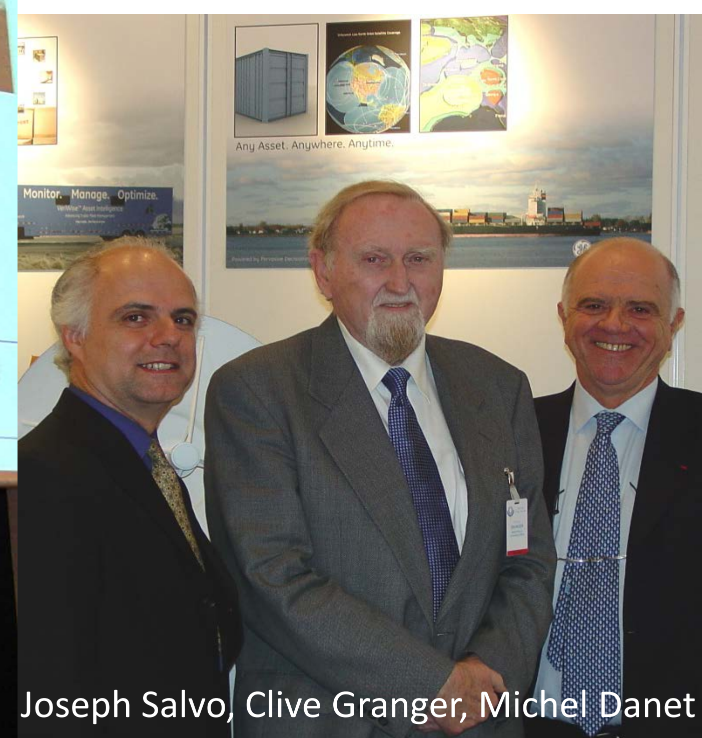


http://d27n205l7rookf.cloudfront.net/wp-content/uploads/2016/02/DUP_TechTrends2016.pdf

Graphic: Deloitte University Press | DUPress

Why we needed more than RFID? Why connect objects with data and intelligent decision support? (World Customs Organization Brussels 2006)





Joseph Salvo, Clive Granger, Michel Danet

industrial internet
CONSORTIUM

Dr Joseph James Salvo
Founder, IIC (2013-2016)
Founder & Director IIC, GE

[2] Examples (IT+OT+TELCO) - Transport

http://bit.ly/MIT-IOT

- 3/31/16 - 11:50pm - At end of the reveal, Musk announced Tesla already had 115,000 reservations
- 4/1/16 - 12:07am - TheVerge reports Tesla is over 133k pre-orders.

Tesla "sales" isn't $11 billion but 325,000 orders ($1K advance for $35K) is an order book ***worth*** $11 billion. The world delivered $11B capital to Tesla on the books (may not have to sell more shares of the company to acquire capital).

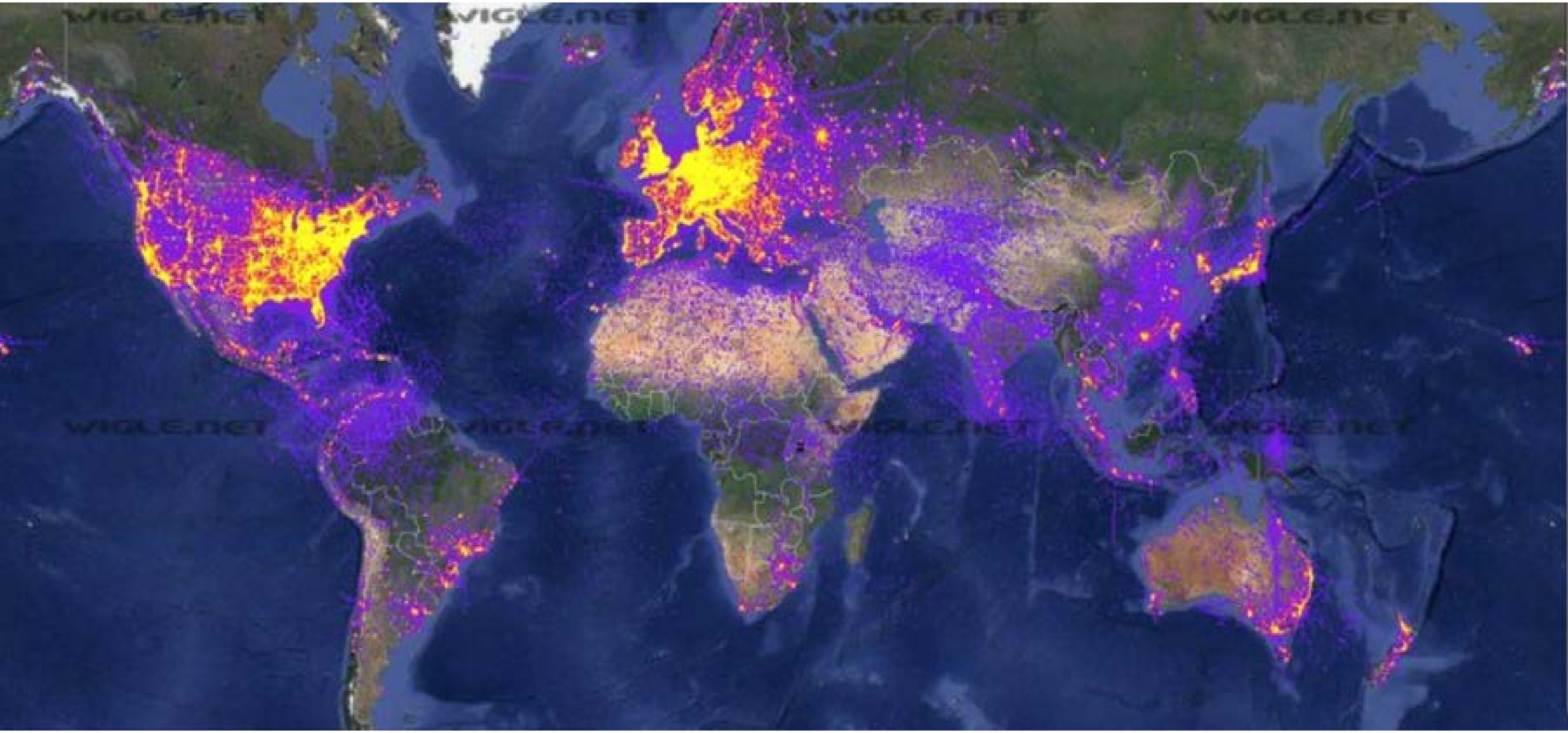
Auto industries in other countries routinely use the pre-order mechanism and it is a standard in the aircraft industry but it is still a Musky move given the volume and volume of publicity as the single biggest 1-week pre-order of a car.

- 4/1/16 - 10:23am - Musk says he thought the reservations would slow, but they haven't & they're up to 198k
- 4/1/16 - 7:26pm - Elon tweeted they were up to 232k pre-orders.
- 4/2/16 - 12:09pm - Elon updated as of 7am, they're at 253k
- 4/3/16 - 11:28am - up to 276k by end of day on Saturday, the 2nd
- 4/7/16 - 10:45am EST - More than 325,000 reservations received "making this the single biggest one-week any product ever"

Now Book Your Tata Nano GenX AMT with Advance Payment of Rs 5,000

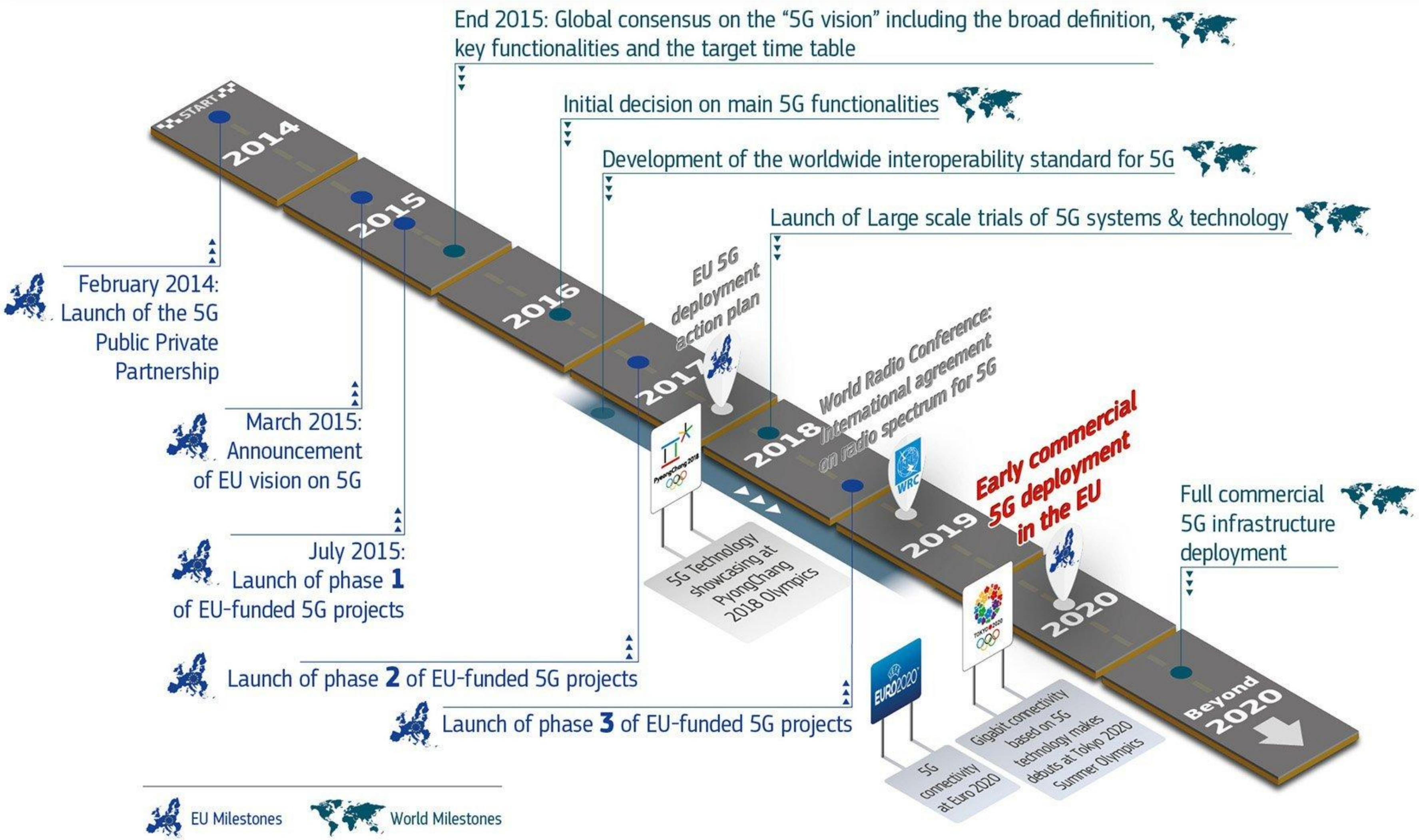
Published On April 28, 2015 12:13 PM By Sourabh Sharma at CarDekho.com

Reality Check



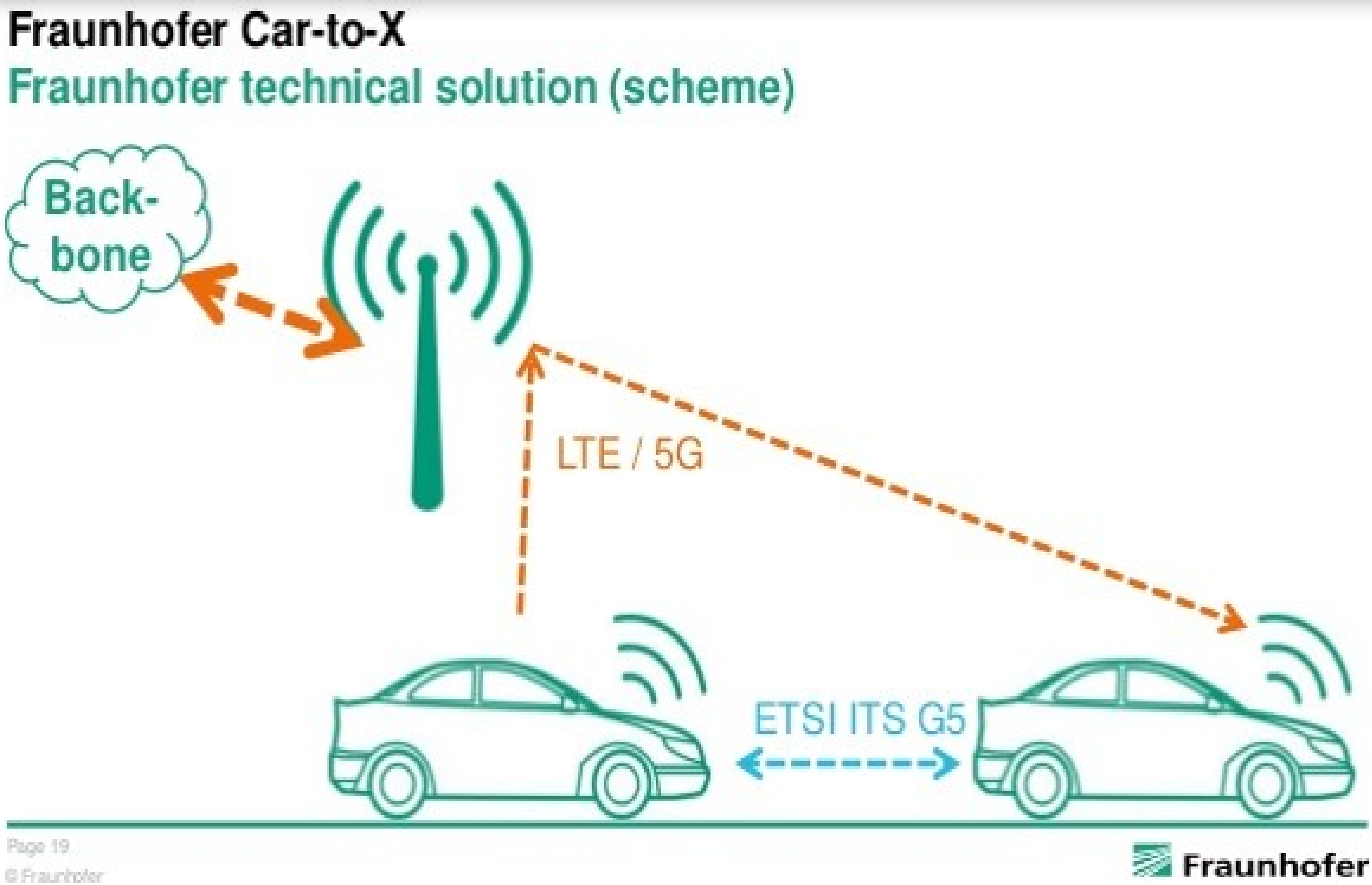
Global WiFi Networks

5G ROADMAP



End 2015: Global consensus on the "5G vision" including the broad definition, key functionalities and the target time table
Initial decision on main 5G functionalities
Development of the worldwide interoperability standard for 5G
Launch of Large scale trials of 5G systems & technology
START
2014
2015
2016
2017
2018
2019
2020
Beyond 2020
EU 5G deployment action plan
World Radio Conference: International agreement on radio spectrum for 5G
Early commercial 5G deployment in the EU
Full commercial 5G infrastructure deployment
February 2014: Launch of the 5G Public Private Partnership
March 2015: Announcement of EU vision on 5G
July 2015: Launch of phase 1 of EU-funded 5G projects
Launch of phase 2 of EU-funded 5G projects
Launch of phase 3 of EU-funded 5G projects
5G Technology showcasing at PyongChang 2018 Olympics
5G connectivity at Euro 2020
Gigabit connectivity based on 5G technology makes debuts at Tokyo 2020 Summer Olympics
EU Milestones
World Milestones

2035 ?



Fraunhofer Car-to-X
Fraunhofer technical solution (scheme)
Back-bone
LTE / 5G
ETSI ITS G5
Page 19
© Fraunhofer
Fraunhofer

1st Place – Carnegie Mellon University
3rd DARPA GRAND CHALLENGE – 2007

Autonomous Driving in Urban Environments: Boss and the Urban Challenge

Chris Urmson[1,*], Joshua Anhalt[1], Drew Bagnell[1], Christopher Baker[1], Robert Bittner[1], M.N. Clark[1], John Dolan[1], Dave Duggins[1], Tugrul Galatali[1], Chris Geyer[1], Michele Gittleman[1], Sam Harbaugh[1], Martial Hebert[1], Thomas M. Howard[1], Sascha Kolski[1], Alonzo Kelly[1], Maxim Likhachev[1], Matt McNaughton[1], Nick Miller[1], Kevin Peterson[1], Brian Pilnick[1], Raj Rajkumar[1], Paul Rybski[1], Bryan Salesky[1], Young-Woo Seo[1], Sanjiv Singh[1], Jarrod Snider[1], Anthony Stentz[1], William "Red" Whittaker[1], Ziv Wolkowicki[1], Jason Ziglar[1], Hong Bae[2], Thomas Brown[2], Daniel Demitrish[2], Bakhtiar Litkouhi[2], Jim Nickolaou[2], Varsha Sadekar[2], Wende Zhang[2], Joshua Struble[3], Michael Taylor[3], Michael Darms[4], and Dave Ferguson[5]

Boss Wins!

[1] Carnegie Mellon University
Pittsburgh, Pennsylvania 15213
curmson@ri.cmu.edu
[2] General Motors Research and Development
Warren, Michigan
[3] Caterpillar Inc.
Peoria, Illinois 61656
[4] Continental AG
Auburn Hills, Michigan 48326
[5] Intel Research
Pittsburgh, Pennsylvania 15213

Chris Urmson

Roboticist

+GoogleSelfDrivingCars

Chris Umson is the Director of Self-Driving Cars at Google[x].

Why you should listen

Since 2009, Chris Urmson has headed up Google's self-driving car program. So far, the team's vehicles have driven over three quarters of a million miles. While early models included a driverless Prius that TEDsters got to test- ... um, -not-drive in 2011, more and more the team is building vehicles from the ground up, custom-made to go driverless.

Prior to joining Google, Umson was on the faculty of the Robotics Institute at Carnegie Mellon University, where his research focused on motion planning and perception for robotic vehicles. During his time at Carnegie Mellon, he served as Director of Technology

Raj Rajkumar (CEO, Ottomatika) provides the brain and nervous system any automaker can use.

www.wired.com/2014/11/delphi-automated-driving-system/

ottomatika™ *Connected Automation*

www.ctvnews.ca/sci-tech/dutch-approve-driverless-cars-for-public-large-scale-testing-1.2203969

Adapt "brain and nervous system" for cargo/commercial vehicles for large scale deployment ?

http://bit.ly/KATHLEEN-CAR-HACKED

Prof Raj Rajkumar (CMU) + House Transportation and Infrastructure Committee Chairman Rep Bill Shuster (R-PA) in DC on 06/24/14 [↓]

AUTONOMOUS TRANSPORTATION

www.wired.com/2015/03/delphis-self-driving-car-taking-cross-country-road-trip/

WIRED An Autonomous Car Is Going Cross-Country for the First Time

ALEX DAVIES GEAR 03.13.15 6:15 PM

AN AUTONOMOUS CAR IS GOING CROSS-COUNTRY FOR THE FIRST TIME

Delphi's self-driving technology, packed into an Audi SQ5, is headed across the country.

MARCH 22, 2015

CARNEGIE MELLON SPINOFF OTTOMATIKA ACQUIRED BY DELPHI

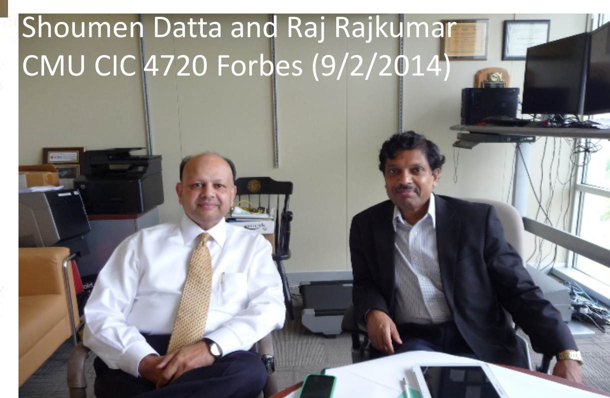
Company Builds on University Strengths in Pioneering Autonomous Vehicle

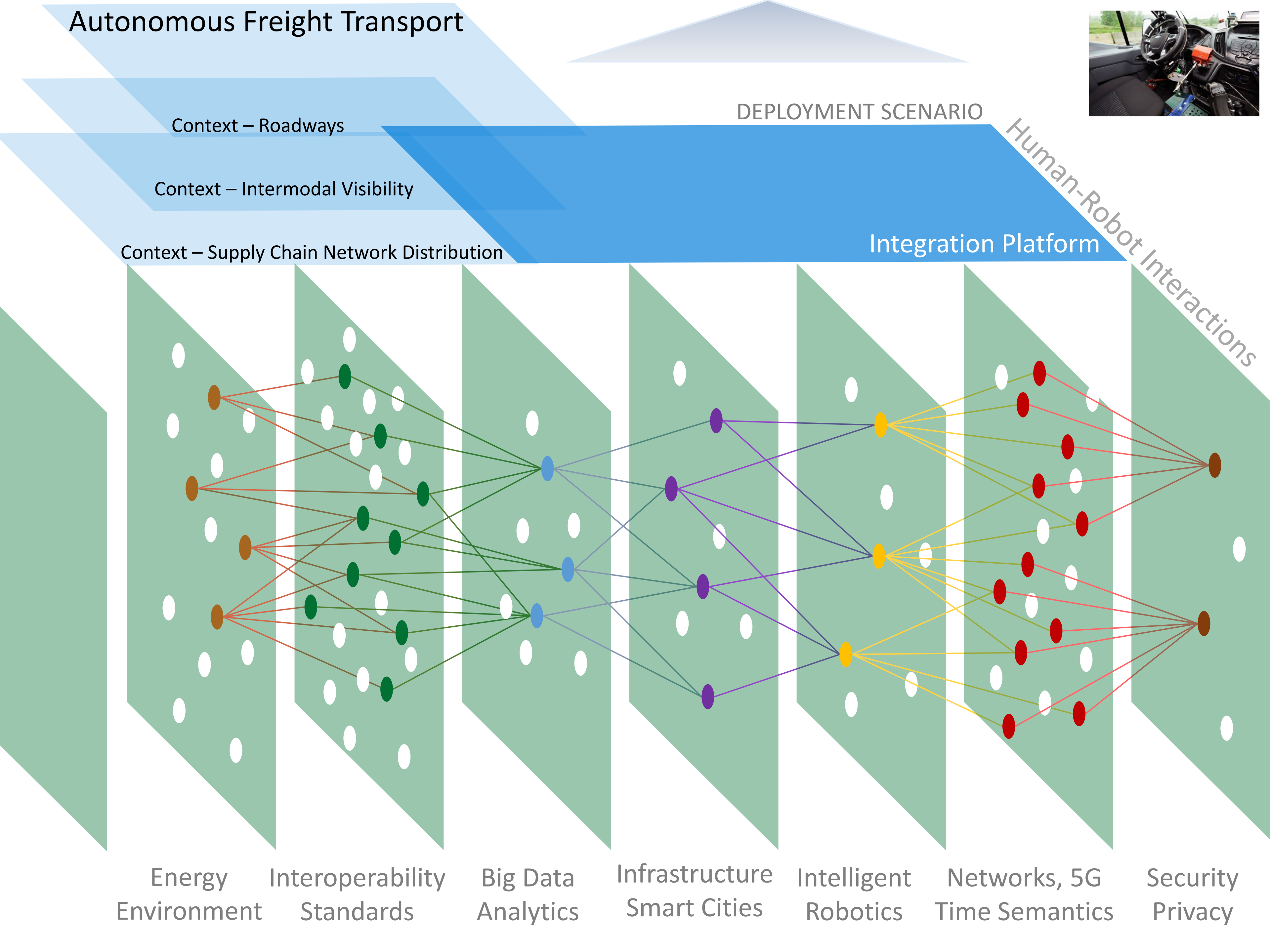
Tuesday 4th August 2015 www.cmu.edu/news/stories/archives/2015/august/spinoff-acquired.html

Professor Raj Rajkumar poses between CMU's latest self-driving car, a Cadillar SRX, and the university's first autonomous vehicle 30 years ago.

Ottomatika Inc., a Carnegie Mellon University spinoff company that provides software and systems development for self-driving vehicles, has been acquired by the global vehicle technology company Delphi Automotive PLC.

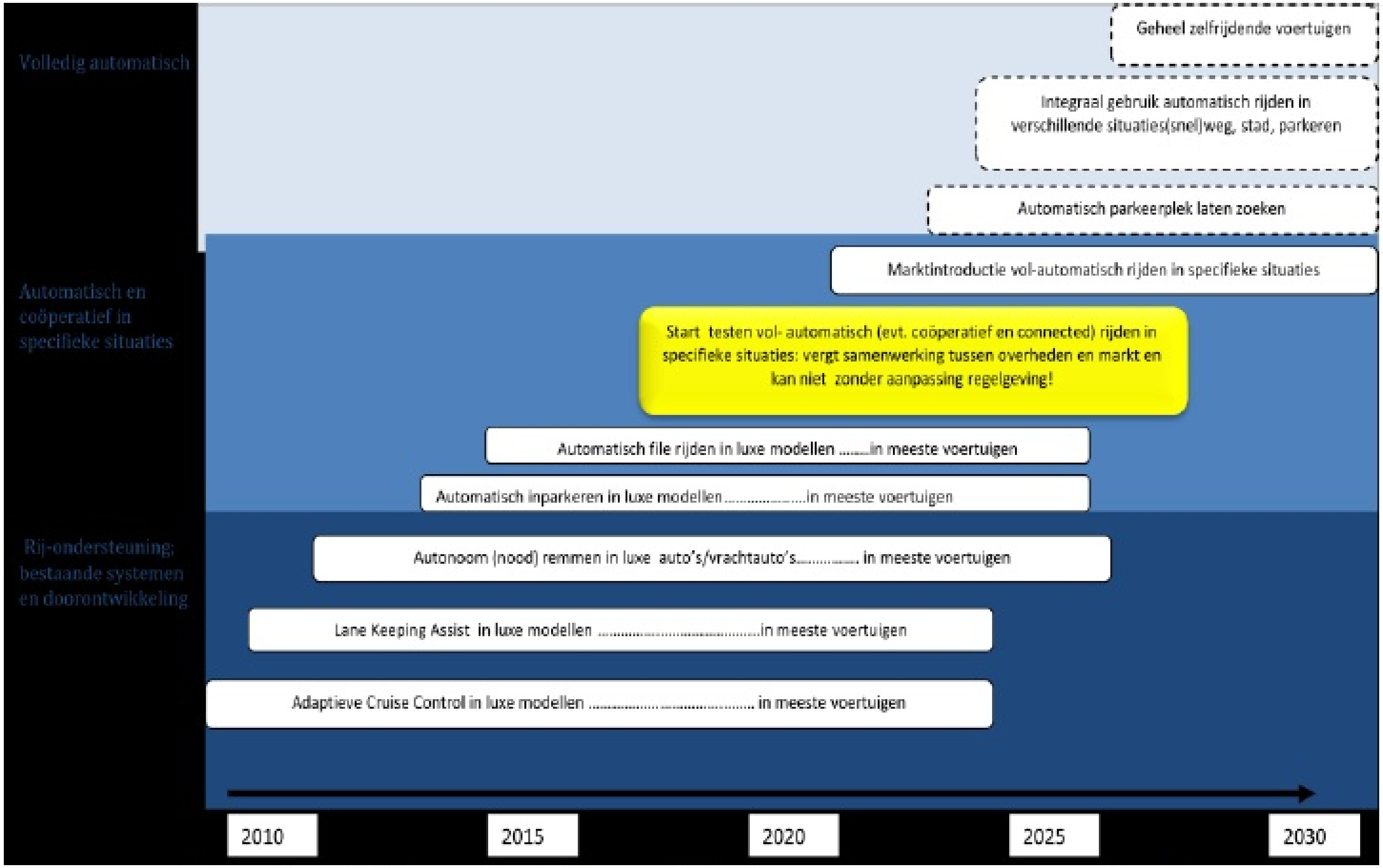
Led by Electrical and Computer Engineering Professor Raj Rajkumar, Ottomatika spun off from Carnegie Mellon in 2013 and received an investment from Delphi in November 2014.





Autonomous Freight Transport
Context – Roadways
Context – Intermodal Visibility
Context – Supply Chain Network Distribution
DEPLOYMENT SCENARIO
Integration Platform
Human-Robot Interactions
Energy Environment
Interoperability Standards
Big Data Analytics
Infrastructure Smart Cities
Intelligent Robotics
Networks, 5G Time Semantics
Security Privacy

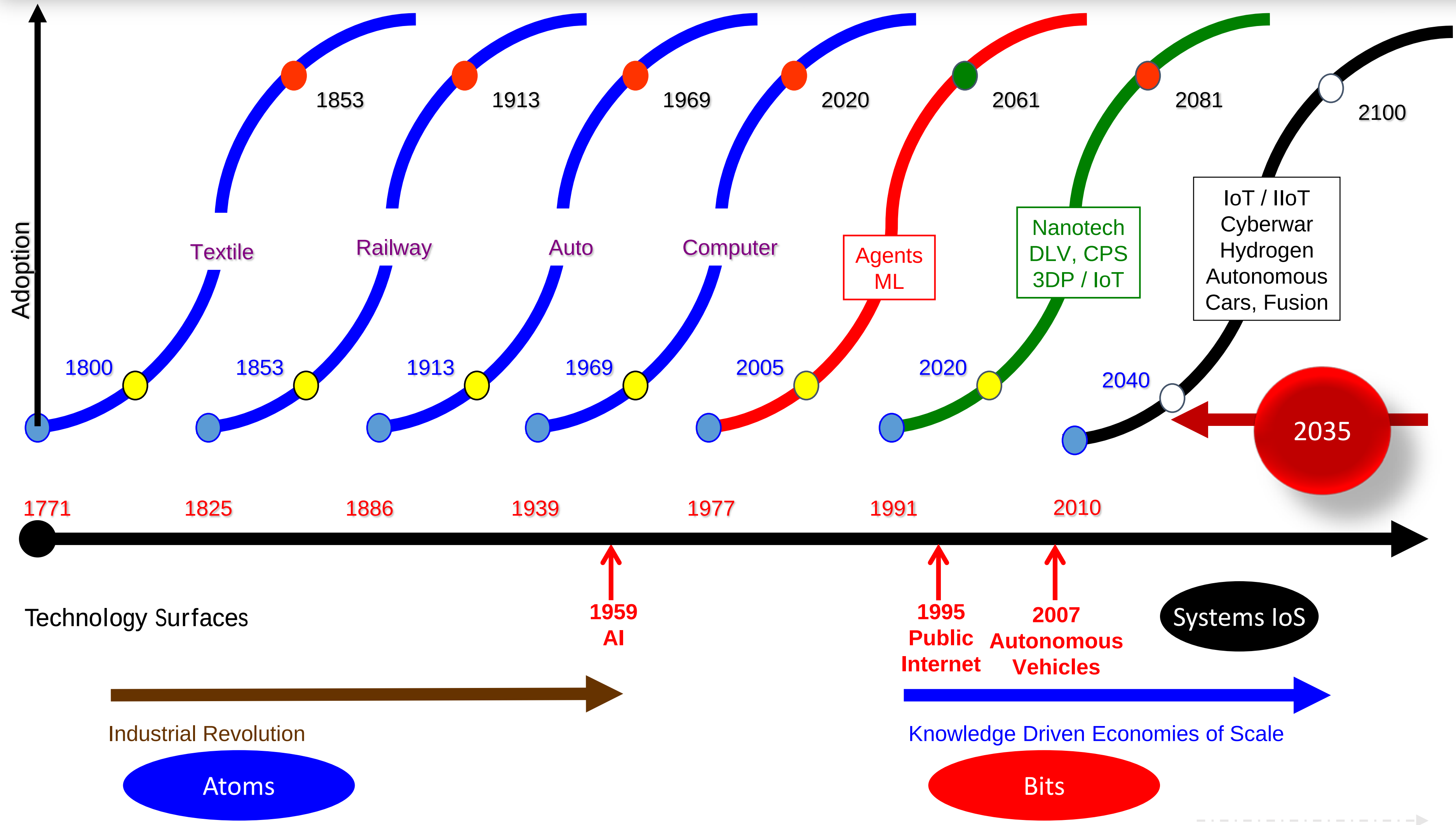
Go Dutch – Autonomous Vehicles by 2030 ?



Figuur 1 Globaal beeld (mogelijke) ontwikkelingen van automatische functies

The Wealth of Nations ● Nature of the Firm (Transaction Cost Economics)

Economic history and data related to Textile, Railway, Automobiles and Computers taken from work by Norman Poire



It takes about 28-30 years for an idea to be socialized before it is accepted and adopted. 1999 was the birth year for IoT concept. Expect exponential growth of IoS ~ 2025-2026.

Simple Problem

EXAMPLE

How does an autonomous vehicle understand the difference between an object without threat in a run time collision avoidance context?

Without algorithmic solutions, even a harmless plastic bag in the air may cause an accident.

plastic bag

Oh I see a plastic bag

What is the "brain" of the autonomous vehicle thinking?

The Wolfram Language

Image Identification Project

person

cement mixer

person

spotlight

flying boat

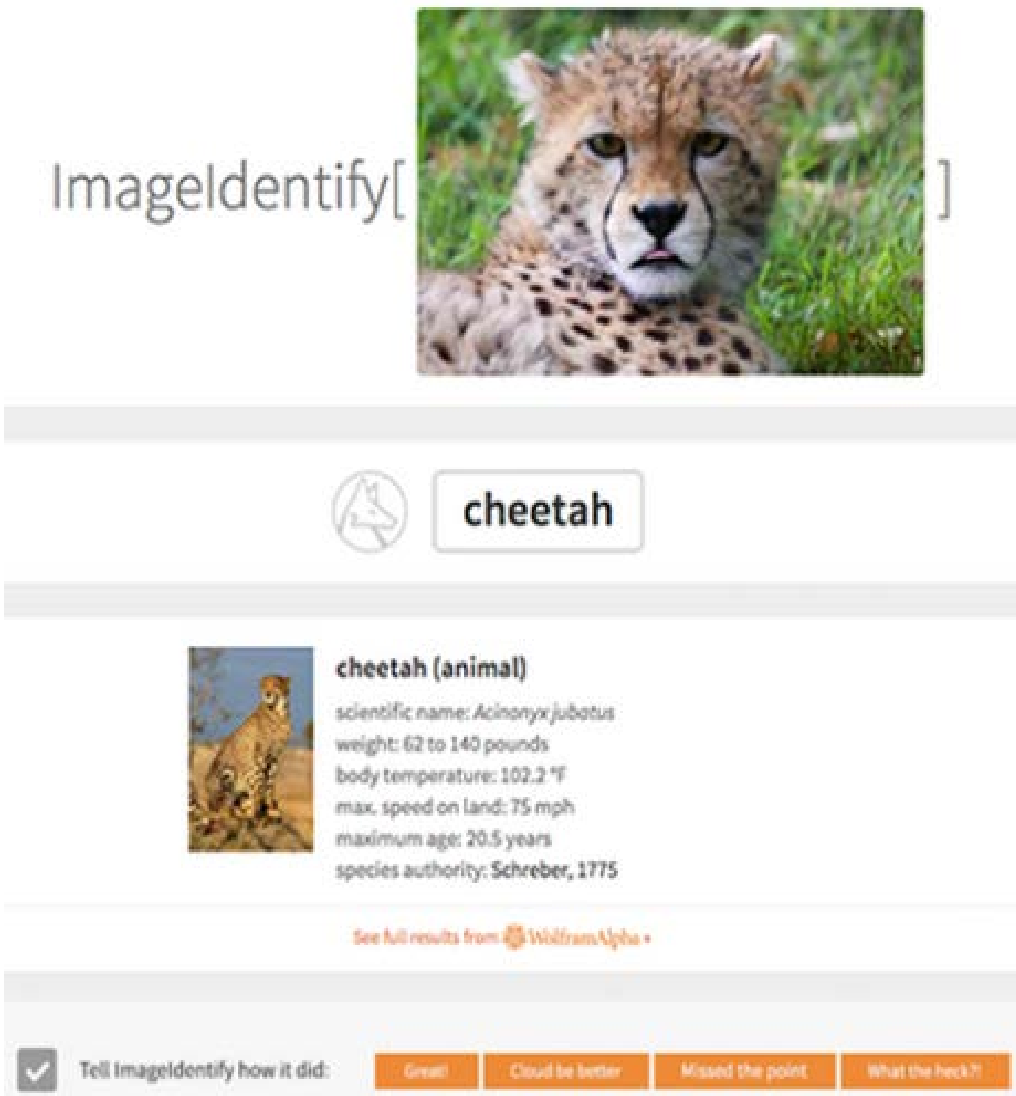
American lobster

hunting dog

stealth bomber

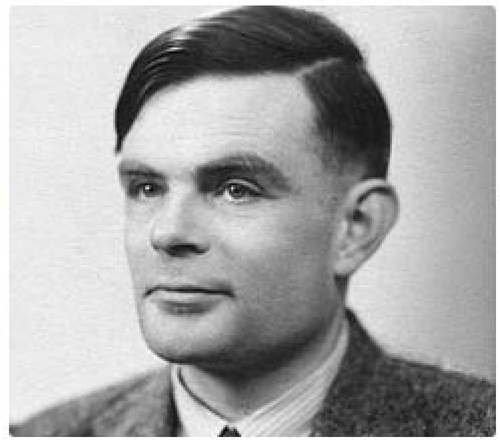
The Wolfram Language

Image Identification Project



The Wolfram Language

Image Identification Project

ImageIdentify[]

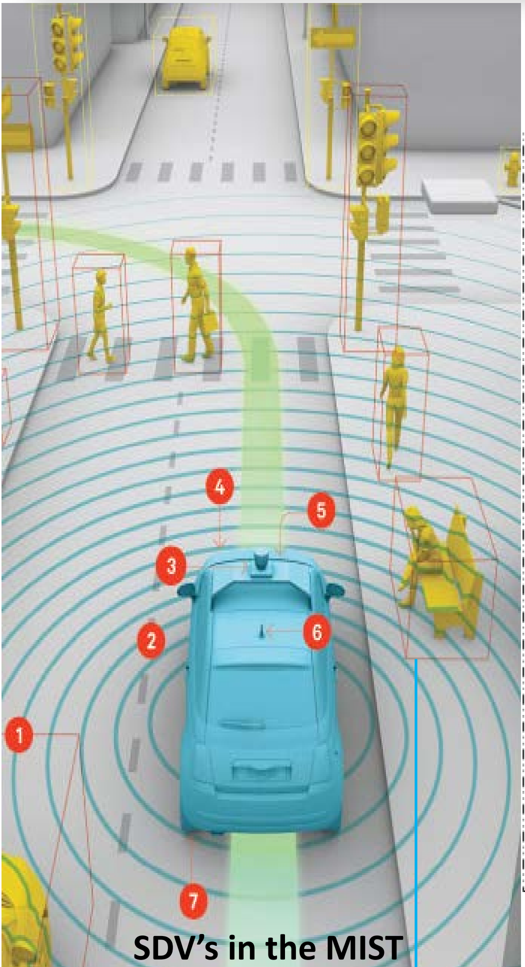
person

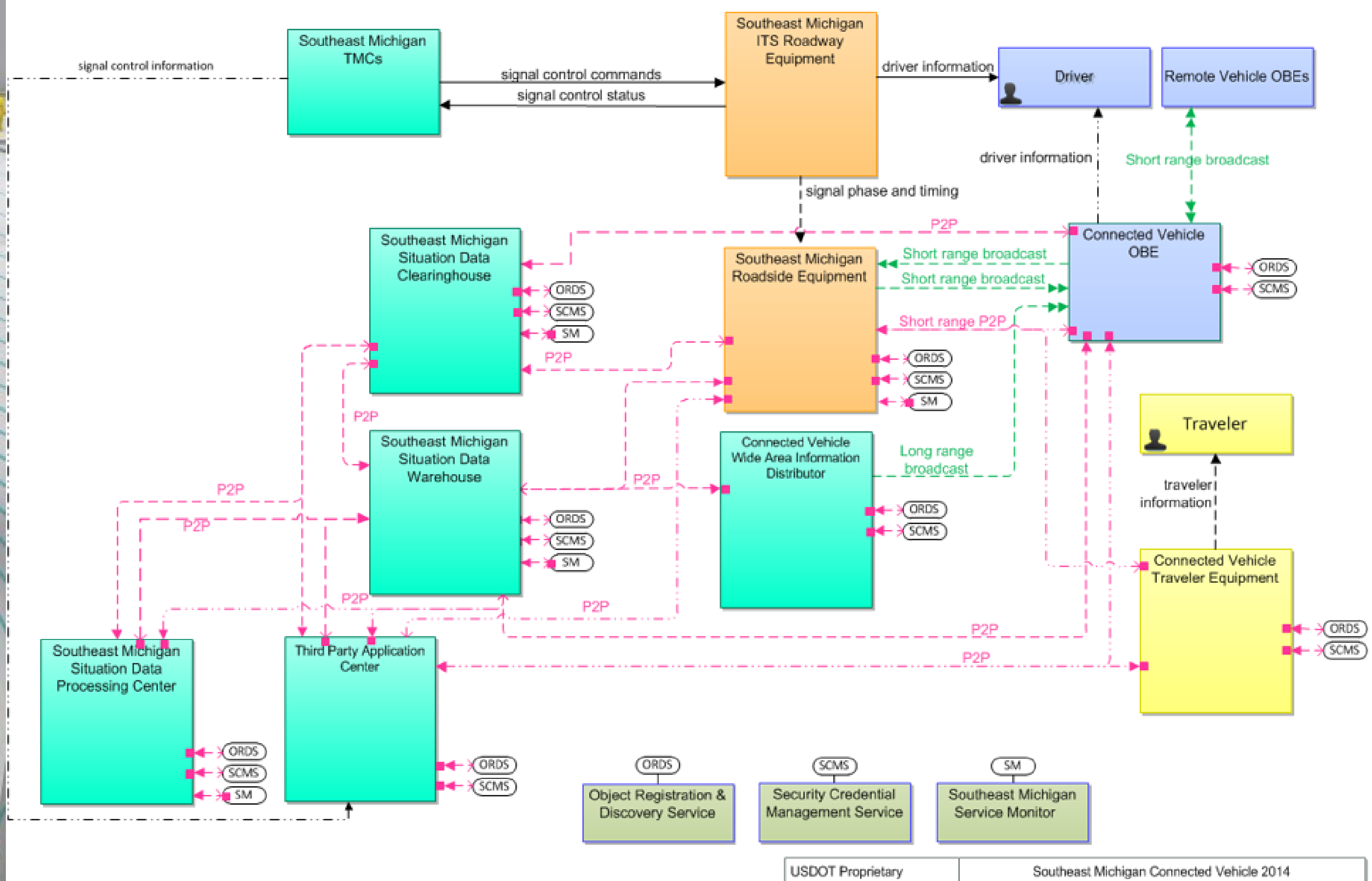
Classify["NotablePerson", ]

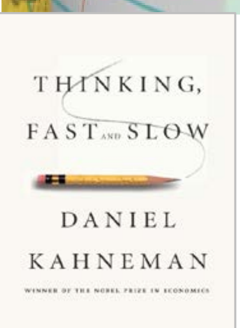
Tools for real-time image identification & semantic (context/relevance) image for autonomous vehicle

Critical real-time AI/ANN/CNN computation at the edge and collision avoidance guidance to autonomous vehicle

Hellabytes of images and other data from road side scenarios for analysis by SDV







Run-time Uncertainty Estimation?

Where is the data? Where are the sense and response run time analytical engines?

- Depends on bounded latency
- Cloud or Fog for Software Defined Vehicles? Think closer, think Mist Computation.

What is the Mist ? Ad hoc Composable Mobile Dynamic Grid Computing

Access available computing power in near field vehicles for run time analytics (Mist)

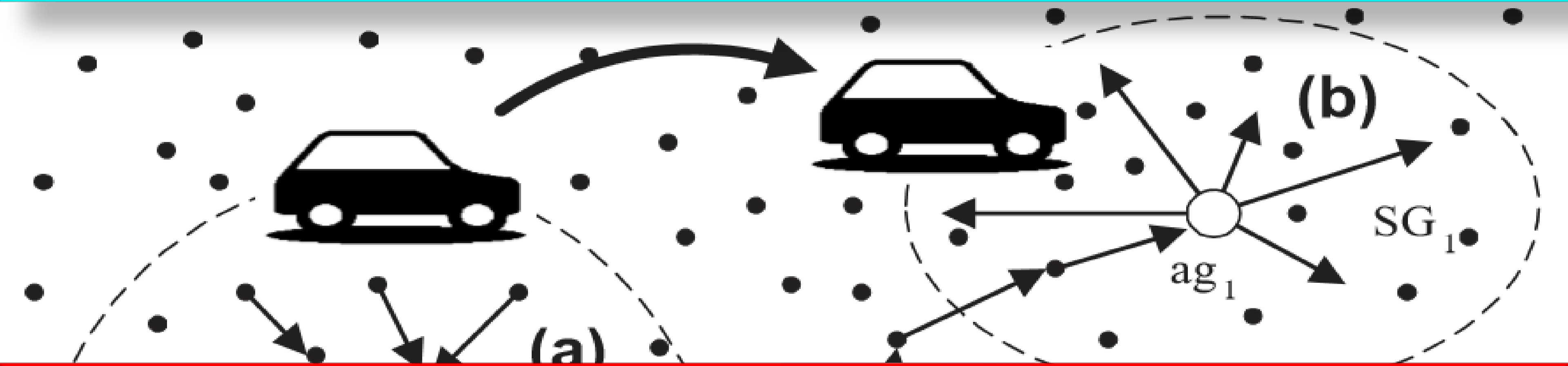
Reuse concept of "grid computing to solve protein structure by using idle computers"

Globus Tool Kit by Steve Tuecke (do not confuse with marketing material by MS Cloud)

Mist Computing

"Mist Computing" does not exist. It is a suggestion by the author.

CNN ● Edge Network Processing



Convolutional Networks for Fast, Energy-Efficient Neuromorphic Computing

Steven K. Esser, * Paul A. Merolla, * John V. Arthur, * Andrew S. Cassidy, * Rathinakumar Appuswamy, * Alexander Andreopoulos, * David J. Berg, * Jeffrey L. McKinstry, * Timothy Melano, * Davis R. Barch, * Carmelo di Nolfo, * Pallab Datta, * Arnon Amir, * Brian Taba, * Myron D. Flickner, * and Dharmendra S. Modha *

*IBM Research – Almaden

MIT
Open Access Articles

EDGE INTELLIGENCE

Eyeriss: An Energy-Efficient Reconfigurable Accelerator for Deep Convolutional Neural Networks

EYERISS

Citation	Chen, Yu-Hsin, Tushar Krishna, Joel Emer, and Vivienne Sze. "Eyeriss: An Energy-Efficient Reconfigurable Accelerator for Deep Convolutional Neural Networks." in ISSCC 2016, IEEE International Solid-State Circuits Conference, Jan. 31-Feb. 4, 2016. San Francisco, CA.
As Published	https://submissions.mirasmart.com/isscc2016/PDF/ISSCC2016AdvanceProgram.pdf
Publisher	Institute of Electrical and Electronics Engineers (IEEE)

DLED

•

DEEP

LEARNING

AT

THE

EDGE

ON

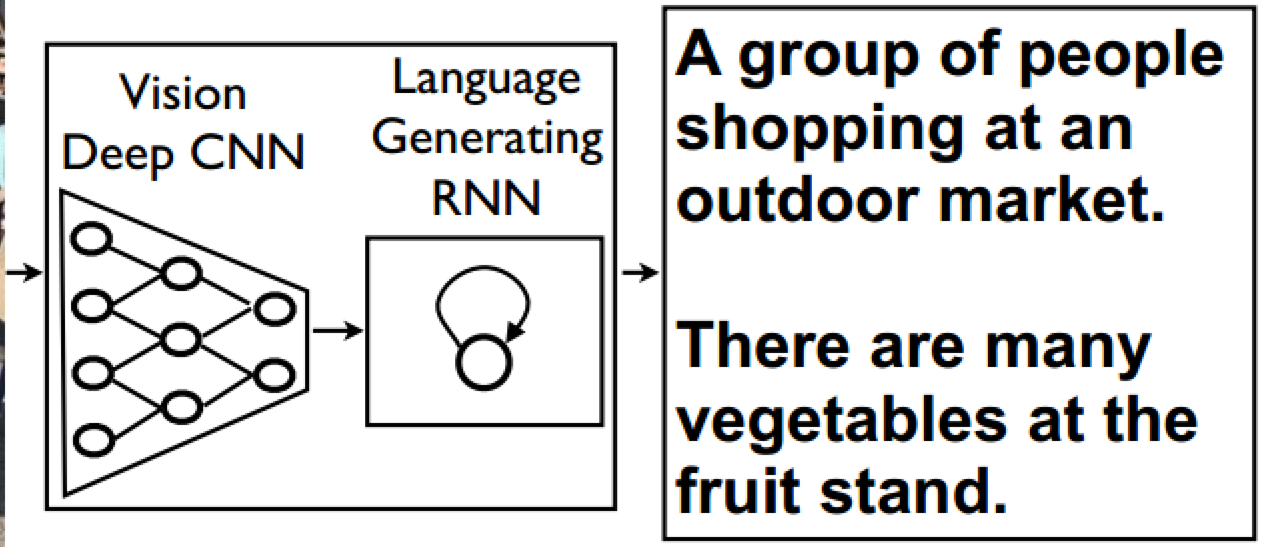
DEMAND

www.theverge.com/2016/4/28/11510430/movidius-fathom-neural-compute-stick-myriad-2-chip

Movidius puts deep learning USB drive

By Alex Brokaw on April 28, 2016 11:45 am

Neural Image Caption (NIC) Generator Translates images to natural language

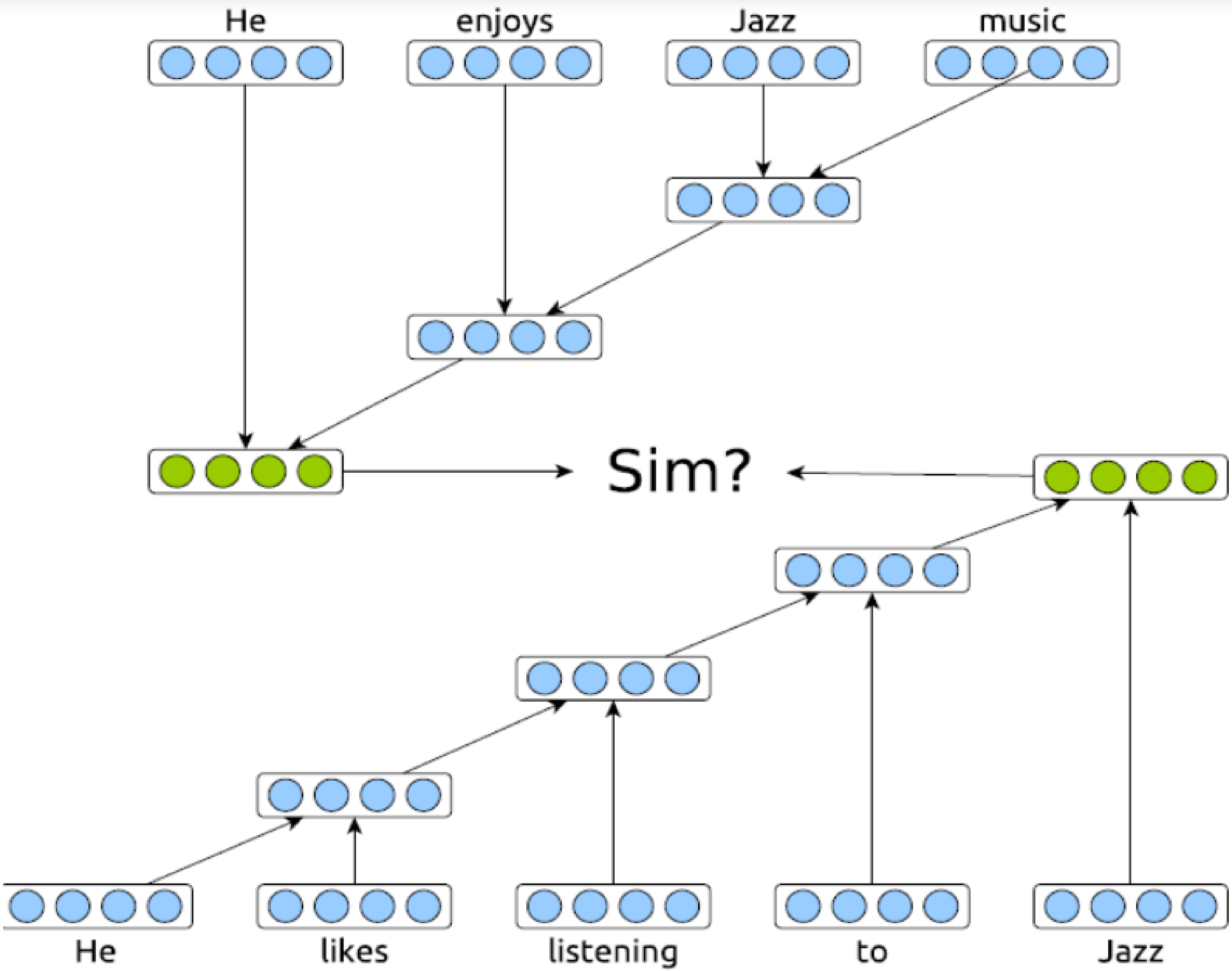


http://arxiv.org/pdf/1411.4555v1.pdf

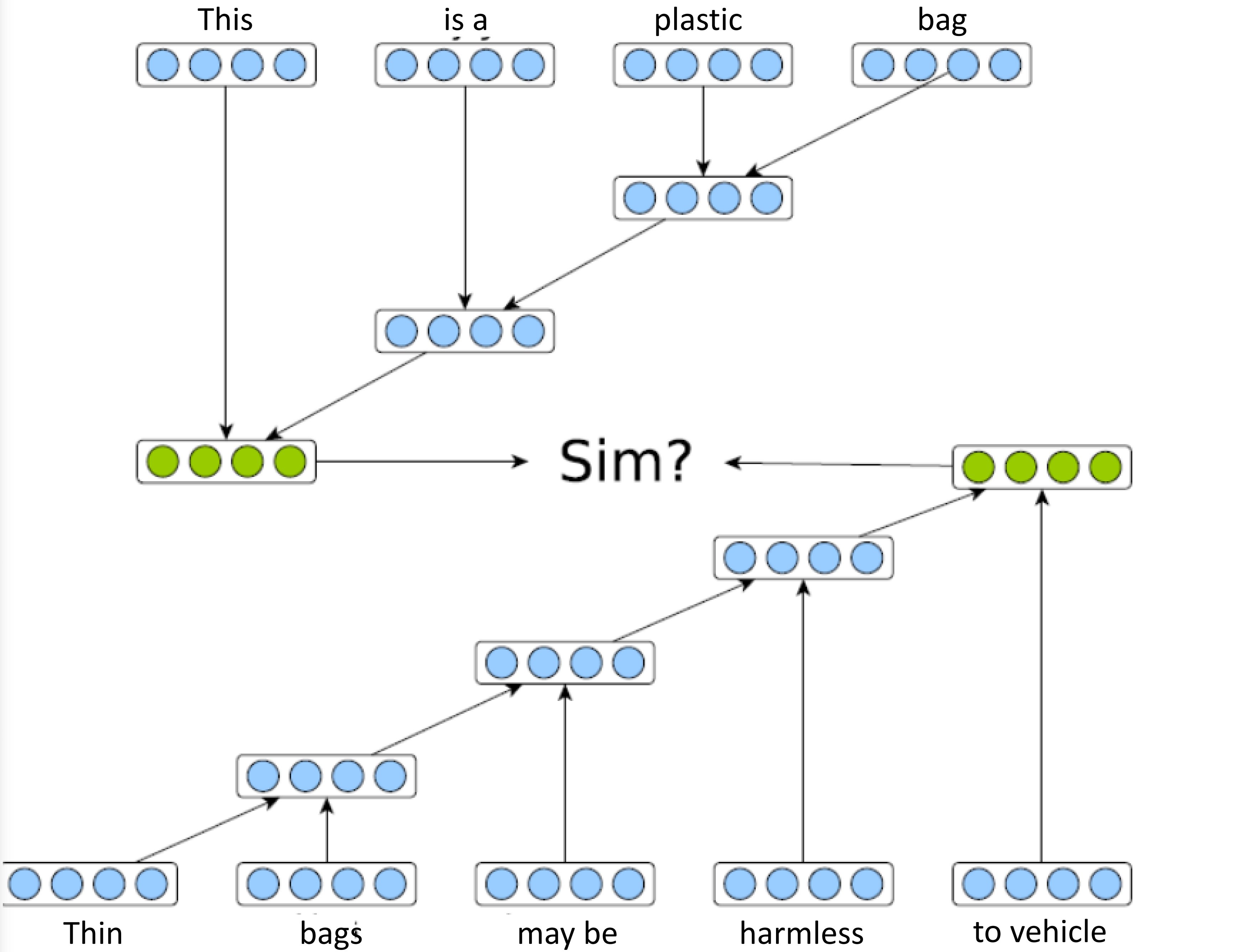
To translate languages, Recurrent Neural Network (RNN) transforms a French sentence into a vector representation, and a second RNN uses that vector representation to generate a target sentence in German. Replace first RNN and input words with deep Convolutional Neural Network (CNN) trained to classify objects in images and add known classes of objects in semantic baffles with corresponding behavior (plastic bag versus wooden plank) with assigned probability of object in the image (environment). Feed CNN's rich encoding of the image into a RNN designed to produce phrases. We can then train the whole system directly on images and their captions, so it maximizes the likelihood that descriptions it produces best match the training descriptions for each image. The natural language spoken by human (inside vehicle) better trains the algorithms.

Author's idea is adapted from → http://googleresearch.blogspot.co.uk/2014/11/a-picture-is-worth-thousand-coherent.html

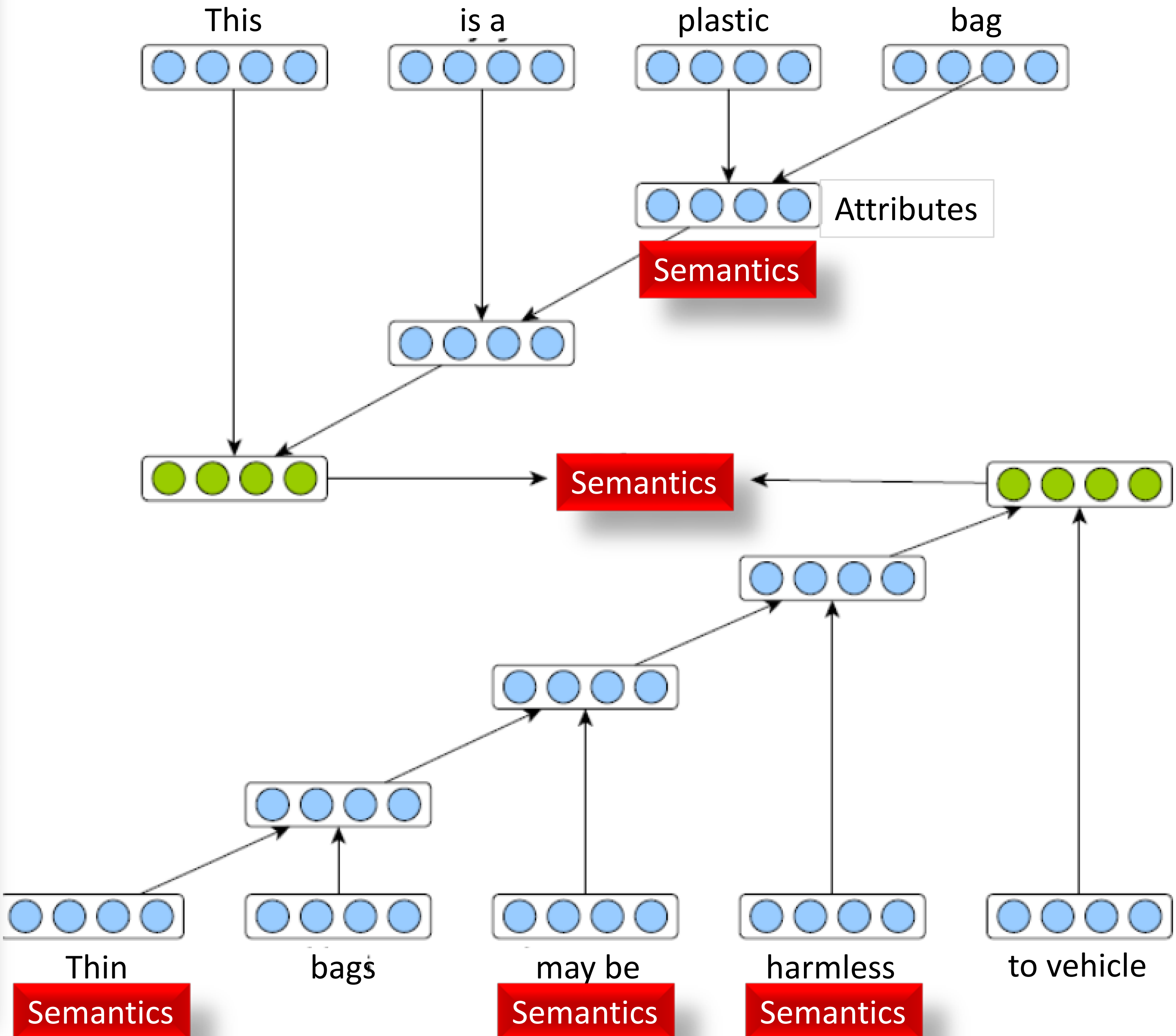
Siamese Networks – Paraphrase Detection



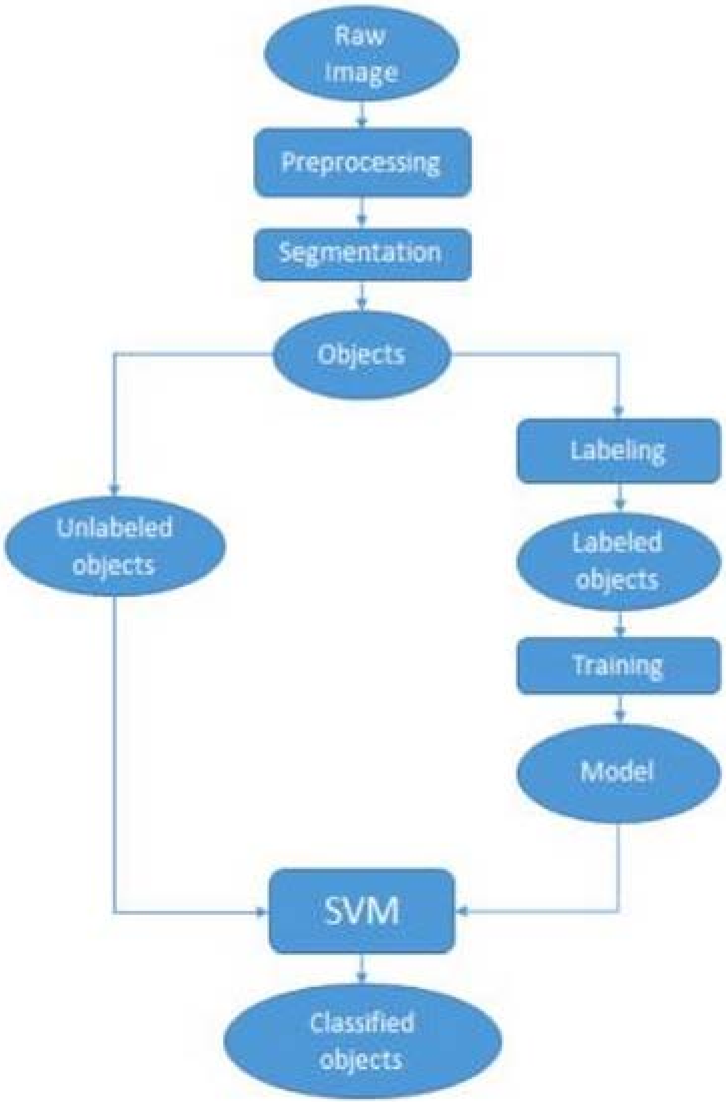
Siamese Networks – Paraphrase Detection



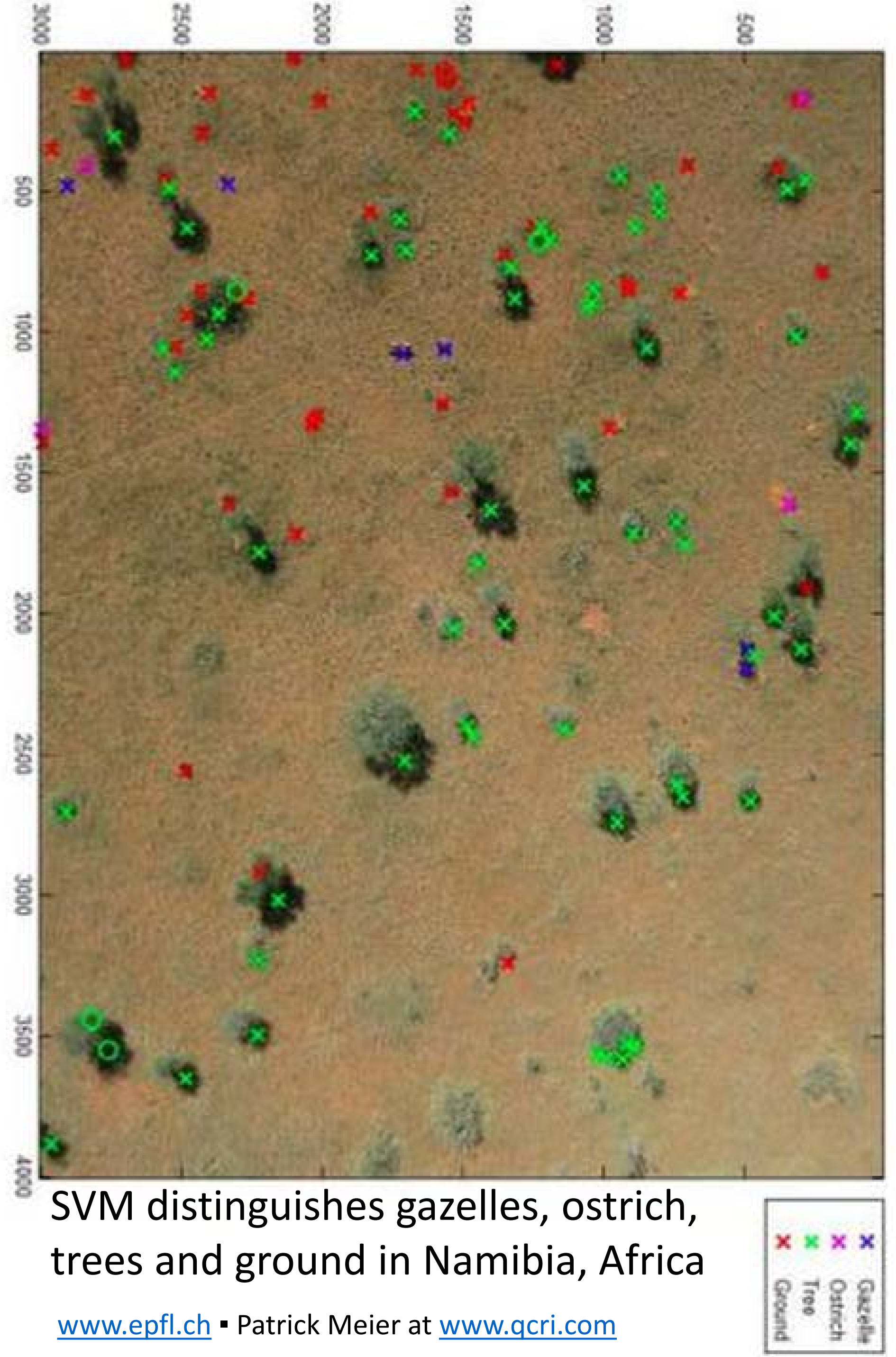
Siamese Networks – Paraphrase Detection



Connected Vehicle
Mist Computing Tool
Support Vector Machine



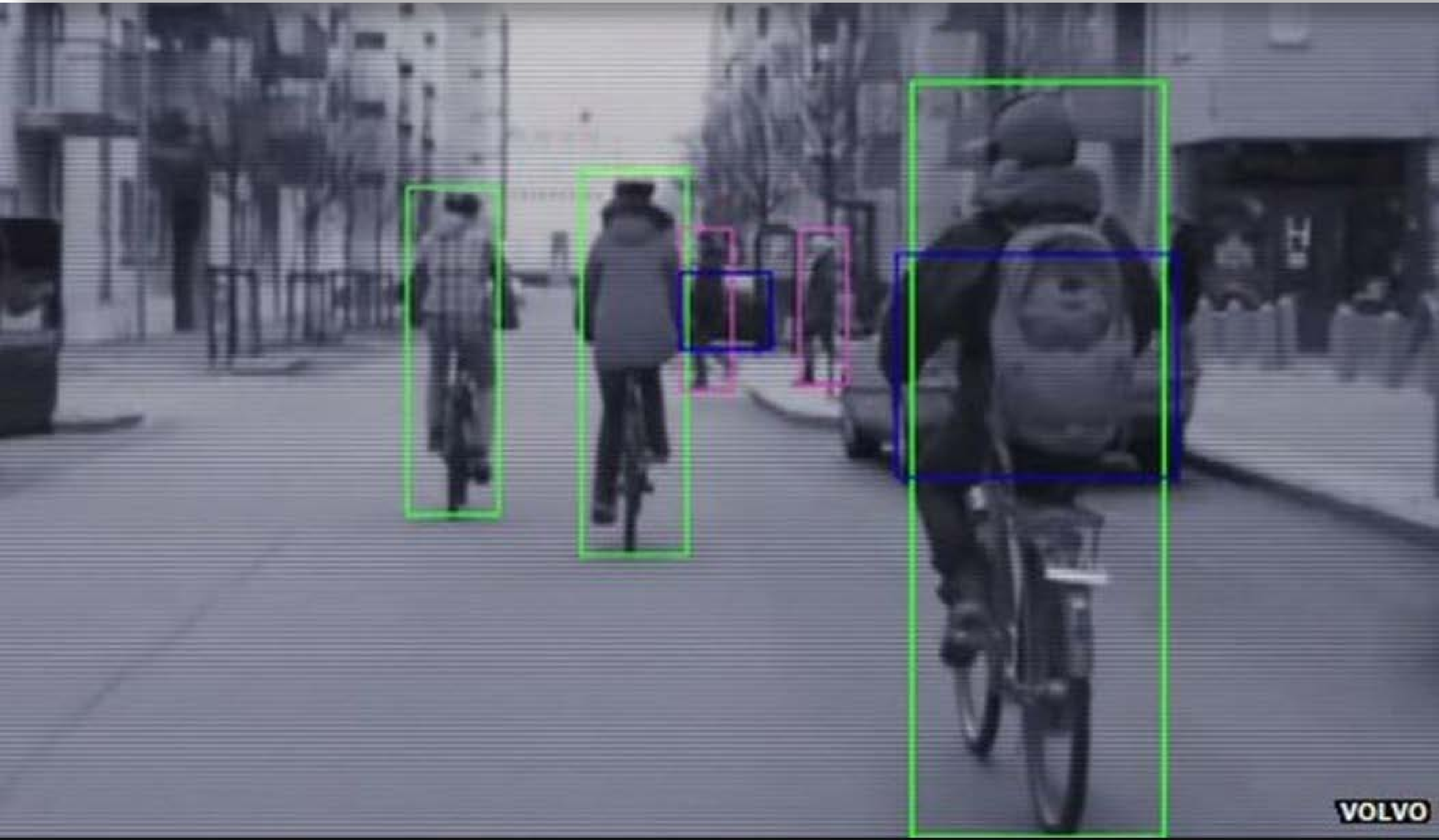
www.cs.toronto.edu/~hinton/csc2515/notes/lec10svm.ppt



SVM distinguishes gazelles, ostrich, trees and ground in Namibia, Africa

www.epfl.ch ▪ Patrick Meier at www.qcri.com

Support Vector Machines for ITS in China



Volvo has fitted some of its cars with sensors and software that can tell cyclists apart from other objects

Google Autonomous Vehicle *"baffled by a man" on a bike*

Google's self-driving cars are very careful.

When Google released its first accident reports in June, the company revealed that in the combined 1.8 million miles its cars had been on the road, they had been involved in 12 minor accidents, none of which were their fault.

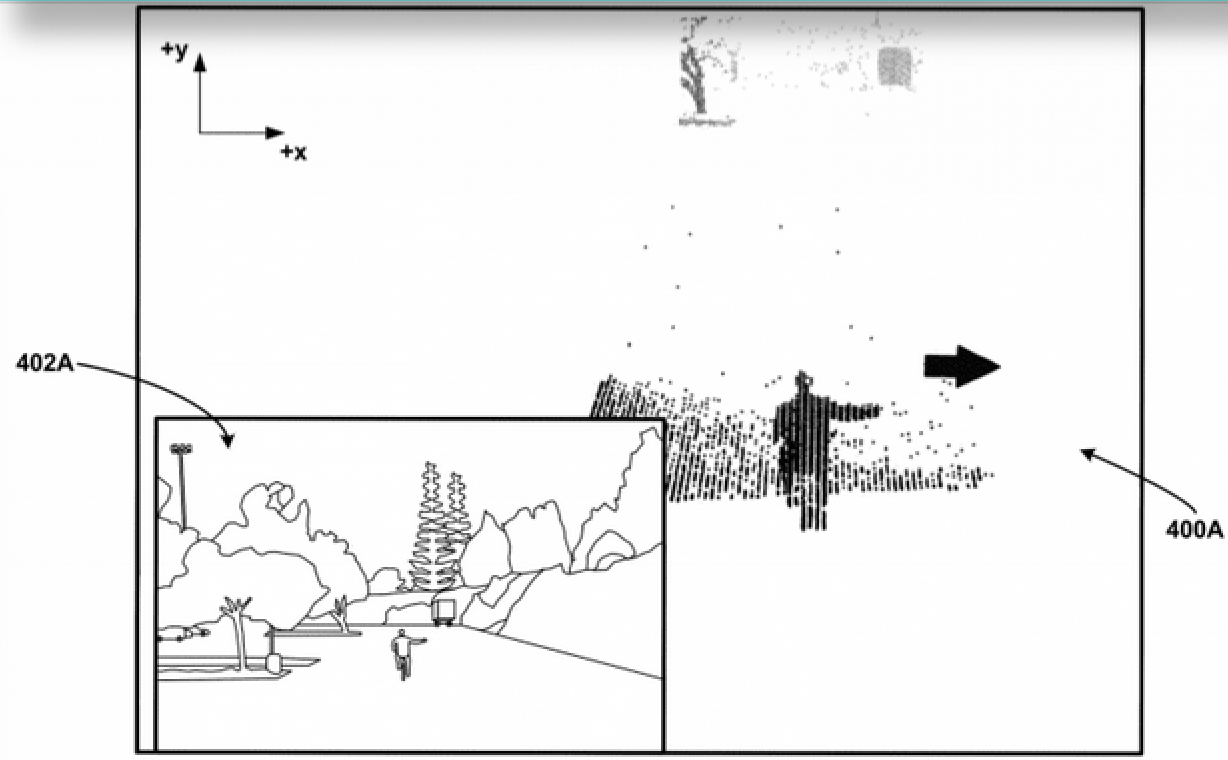
But this default to caution can cause strange incidents when Google cars run into humans engaging in nonstandard behavior.

One of Google's self-driving cars.

One such incident reportedly occurred earlier this month in Austin, when a robot car was baffled by a man riding a fixed-gear bike — aka a fixie, a favorite of so-called hipsters around the world — The Washington Post reports.

http://bit.ly/GOOGLE-PATENT-CYCLISTS

Autonomous Vehicles - interpreting hand signals of cyclists



Here we see how the driverless car's sensors identify the cyclist and his intent to turn right. (U.S. Patent and Trademark Office)

A year ago, Google made an impressive announcement. Its self-driving cars were capable of interpreting the hand signals of cyclists.

Google didn't offer much detail then on how this system worked, but a patent issued to the tech giant in April gives a window into how it plans to use machine learning to make self-driving cars a reality on city streets.

Google granted patent for interpreting hand signals of cyclists

United States Patent	**9,014,905**
Kretzschmar , et al.	**April 21, 2015**

Cyclist hand signal detection by an autonomous vehicle

Abstract

Methods and systems for detecting hand signals of a cyclist by an autonomous vehicle are described. An example method may involve a computing device receiving a plurality of data points corresponding to an environment of an autonomous vehicle. The computing device may then determine one or more subsets of data points from the plurality of data points indicative of at least a body region of a cyclist. Further, based on an output of a comparison of the one or more subsets with one or more predetermined sets of cycling signals, the computing device may determine an expected adjustment of one or more of a speed of the cyclist and a direction of movement of the cyclist. Still further, based on the expected adjustment, the computing device may provide instructions to adjust one or more of a speed of the autonomous vehicle and a direction of movement of the autonomous vehicle.

Inventors: **Kretzschmar; Henrik** (Freiburg, **DE**), **Zhu; Jiajun** (Palo Alto, CA)

Applicant:

Name	City	State	Country	Type
Google Inc.	Mountain View	CA	US	

Assignee: **Google Inc.** (Mountain View, CA)

Family ID: **52822648**

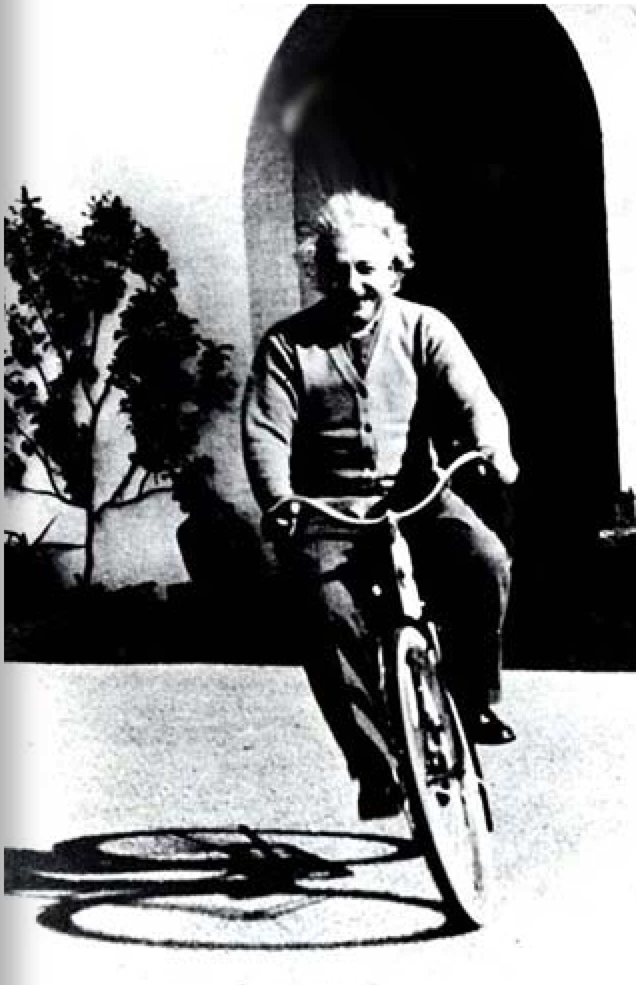
Appl. No.: **14/166,502**

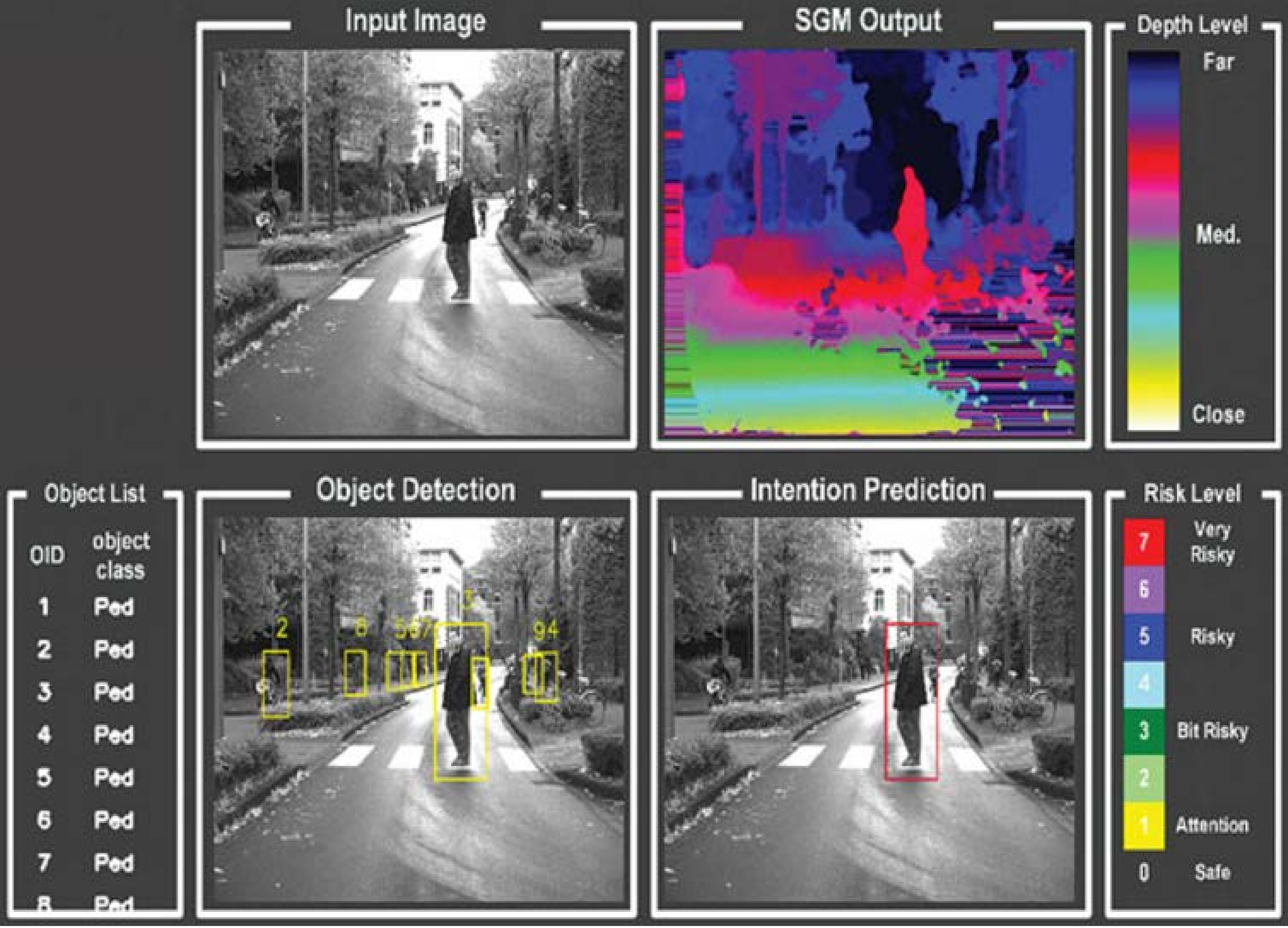
Filed: **January 28, 2014**

Can machine learning semantics distinguish between scenarios?


gettyimages
Thomas Grass
87987647

Viktor Weisskopf, Maria Göppert, Max Born
Göttingen (1920)





http://spectrum.ieee.org/computing/embedded-systems/bringing-big-neural-networks-to-selfdriving-cars-smartphones-and-drones

Can machine learning semantics distinguish between scenarios?

Sufficient run-time accuracy for collision avoidance by autonomous vehicles?

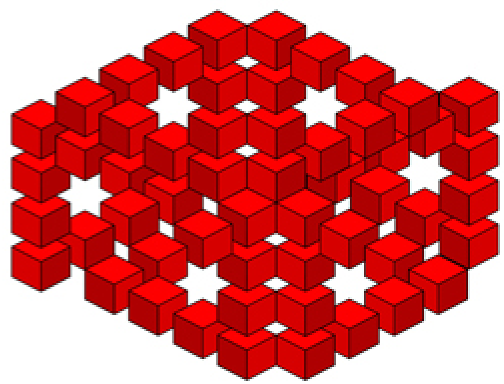
For additional discussion related to transport, please see 05_TRANSPORT (PDF) available in the zipped folder 'REVIEW IOT' which is here – http://bit.ly/MIT-IOT

[2] Examples (IT+OT+TELCO)

- Digital Twins

http://bit.ly/MIT-IOT

Digital Twins

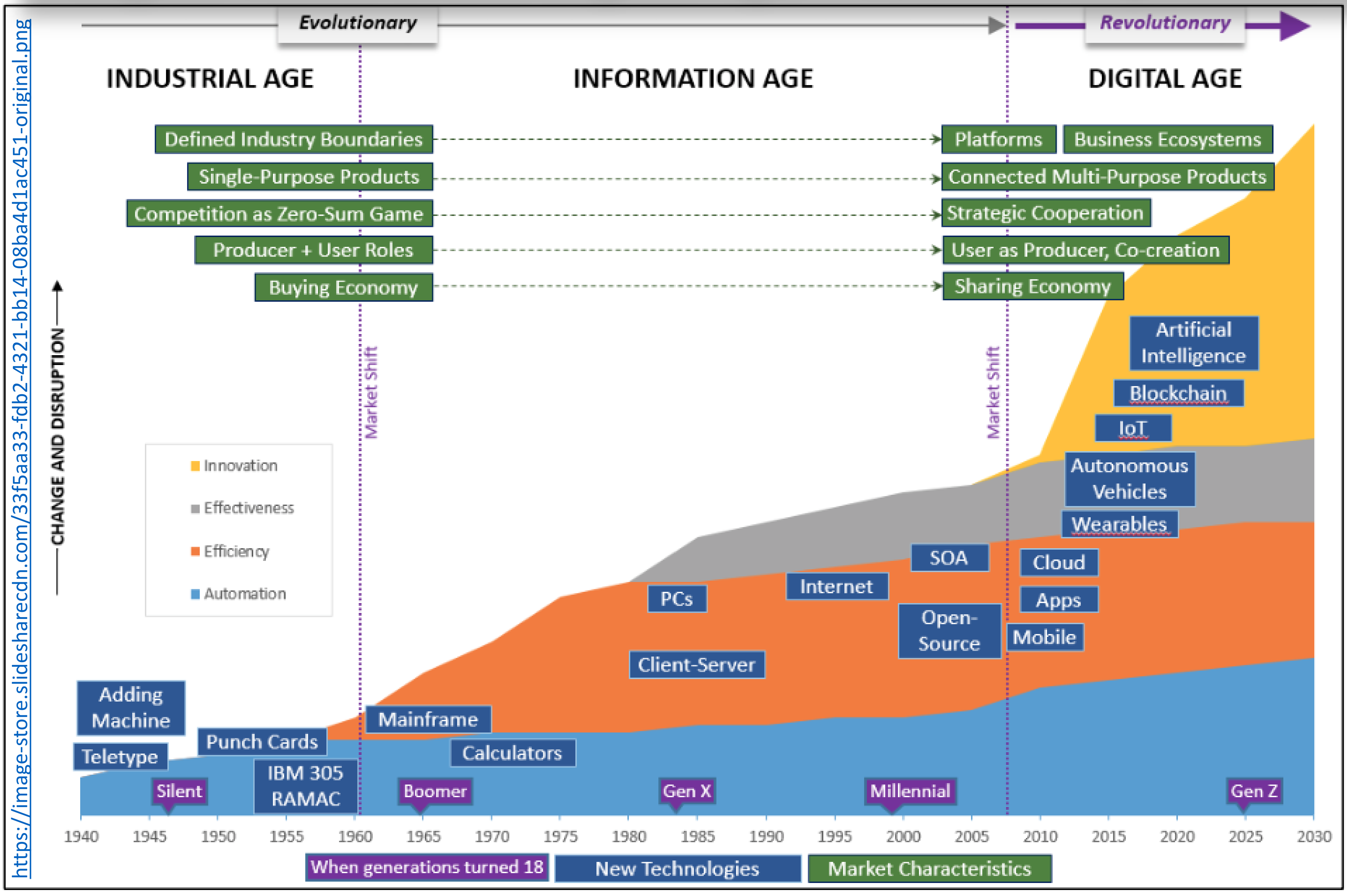


Dr Shoumen Palit Austin Datta

Research Affiliate, Department of Mechanical Engineering, Massachusetts Institute of Technology ● shoumen@mit.edu

MIT Auto-ID Labs ● http://autoid.mit.edu/people-2

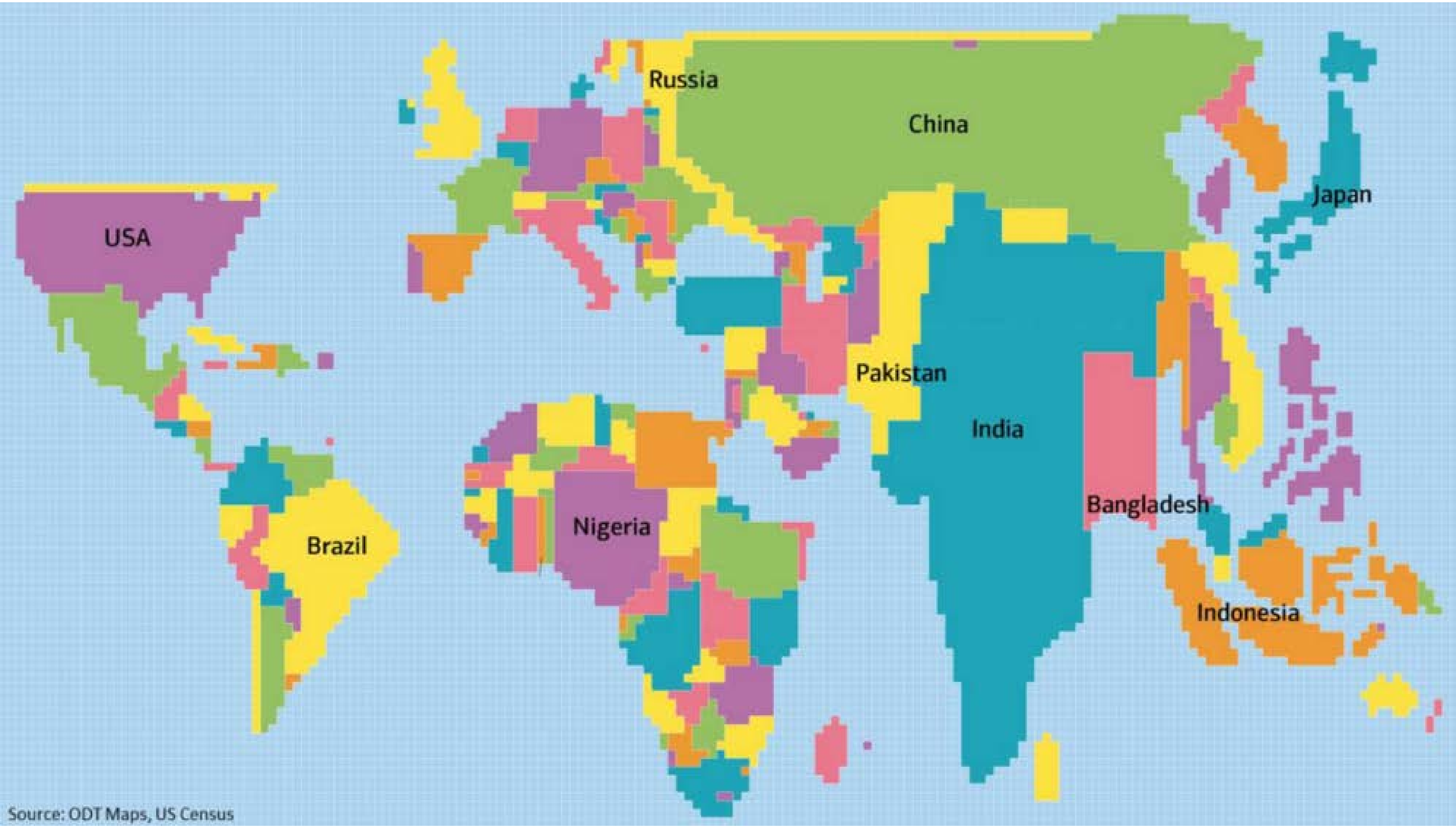
Digital Twins in the Digital Age – The Journey Ahead



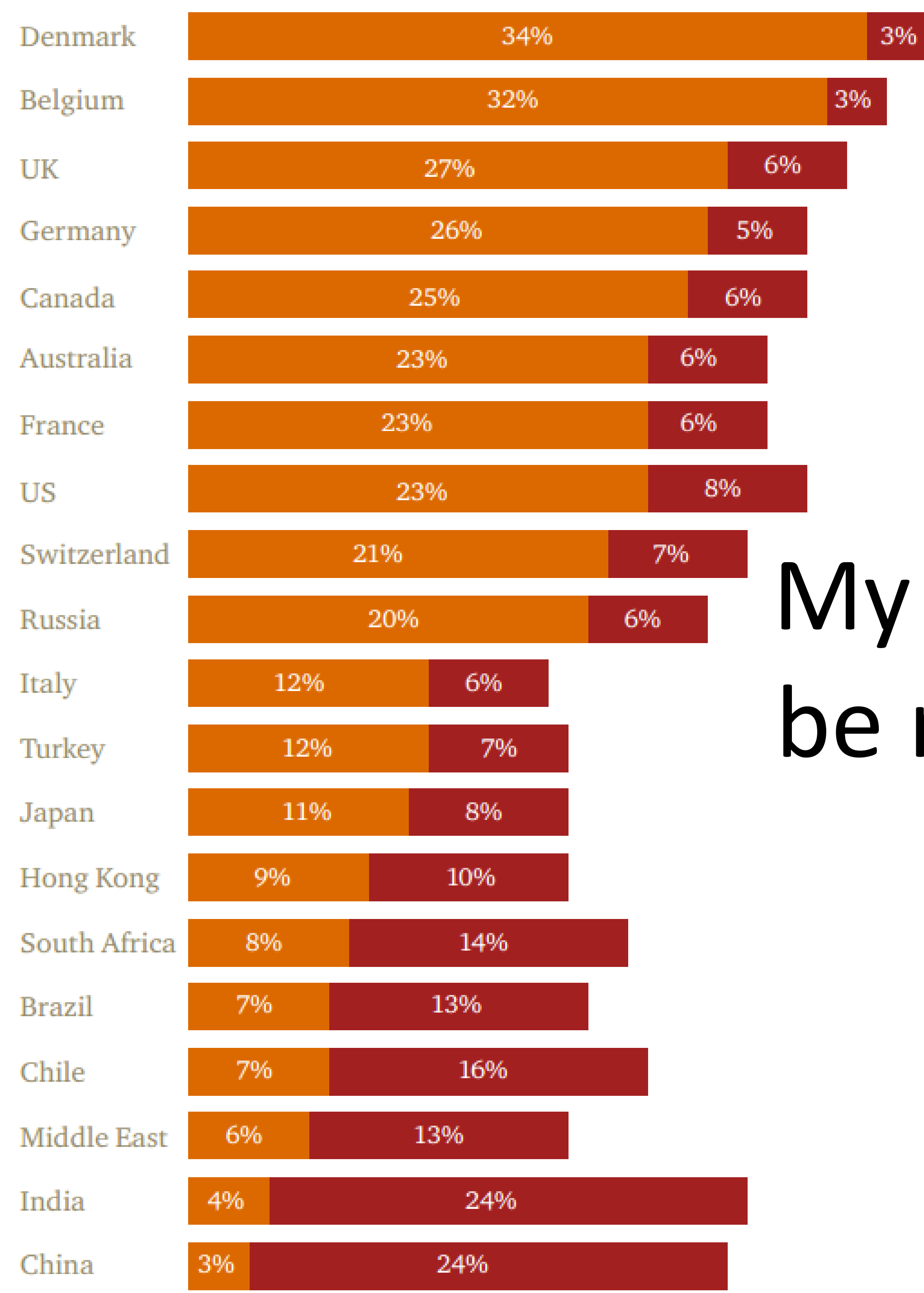
Will Digitalization Re-Configure the World Map?

What if we re-draw the world map based on population?

Is population synonymous with market for digital goods?



Digitalization Morphs Behavior?

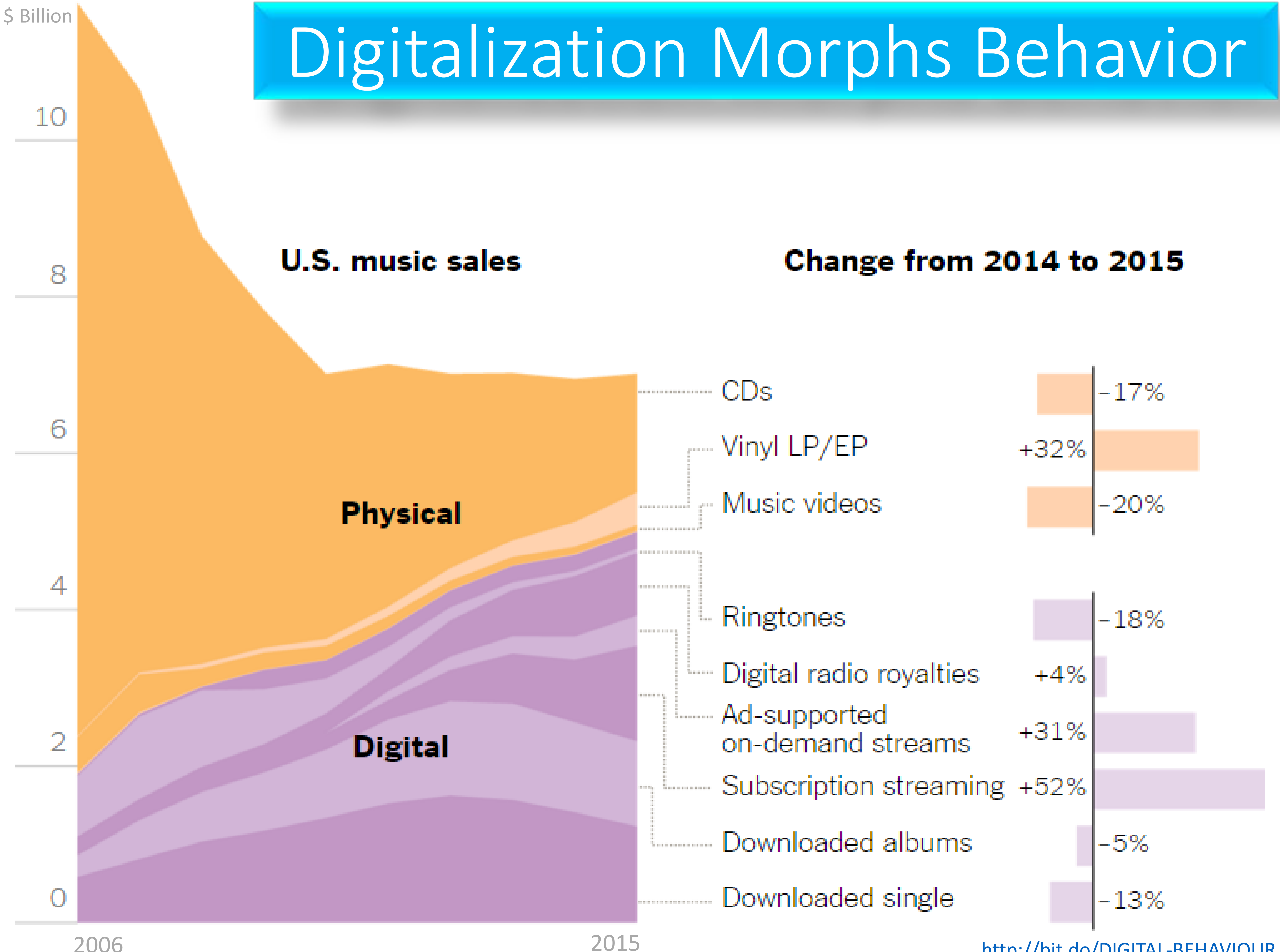


My mobile phone will be my purchasing tool

http://bit.do/PURCHASING-TOOL

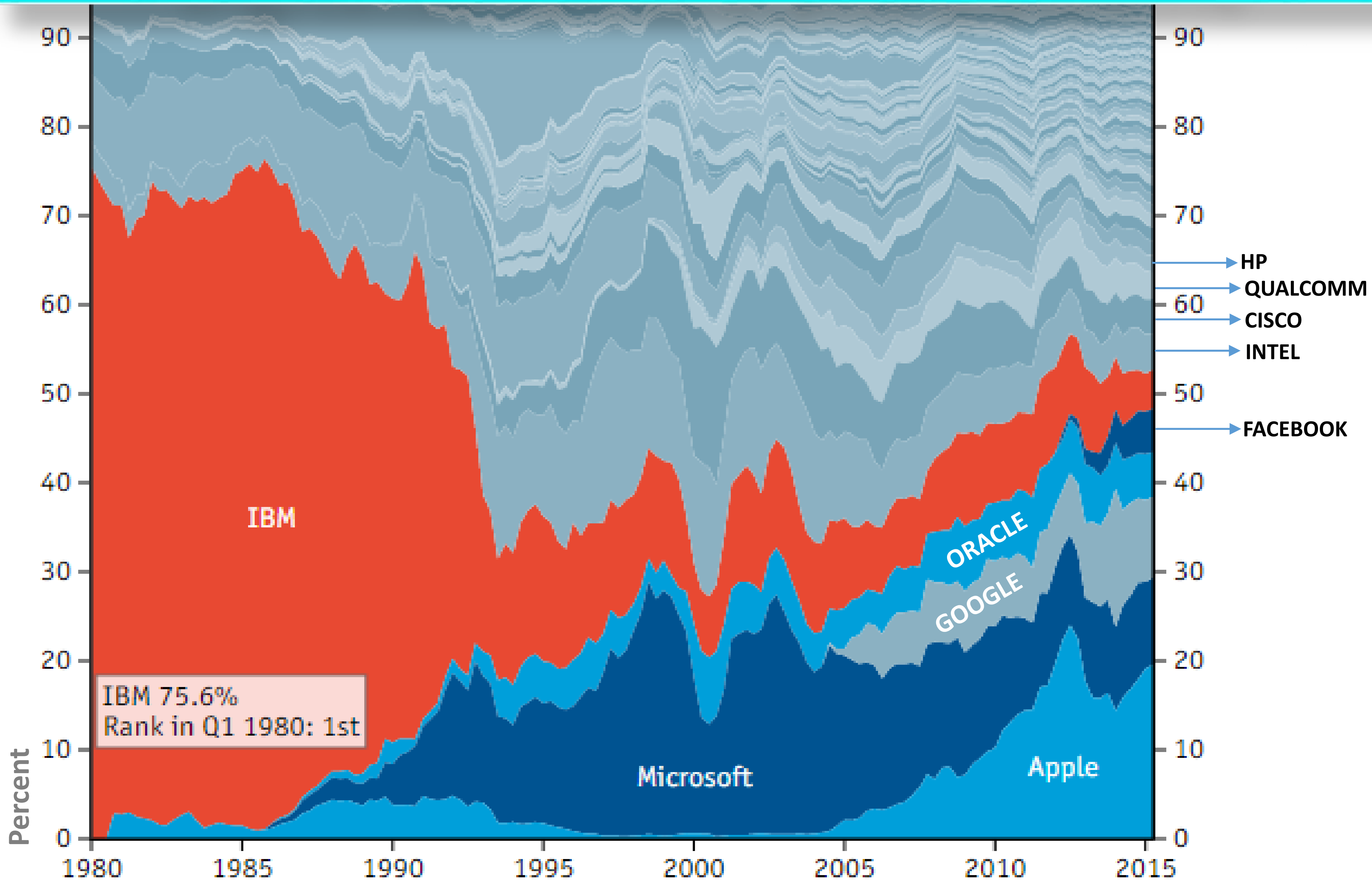
Median Age
DE / JP – 46
Belgium – 43
DK / FR – 42
CAN / UK – 41
US / CN – 37
India – 27
Niger – 15

Digitalization Morphs Behavior



http://bit.do/DIGITAL-BEHAVIOUR

Digitalization Morphs Outcome



Sources: Thomson Reuters; *The Economist*

*As of Q2 2015

Disclaimer – This is not a panacea (nothing is). This presentation on Digital Twins is one of many possible solutions, approaches and the need for conceptual "digital by design" forward-thinking.

Digital Twin (like IoT) is a concept which must be part of the design

It may be applied to almost any object and/or system,

eg: smart cities, oil and gas, energy grid, healthcare,

automotive, aviation, machines, buildings and tools.

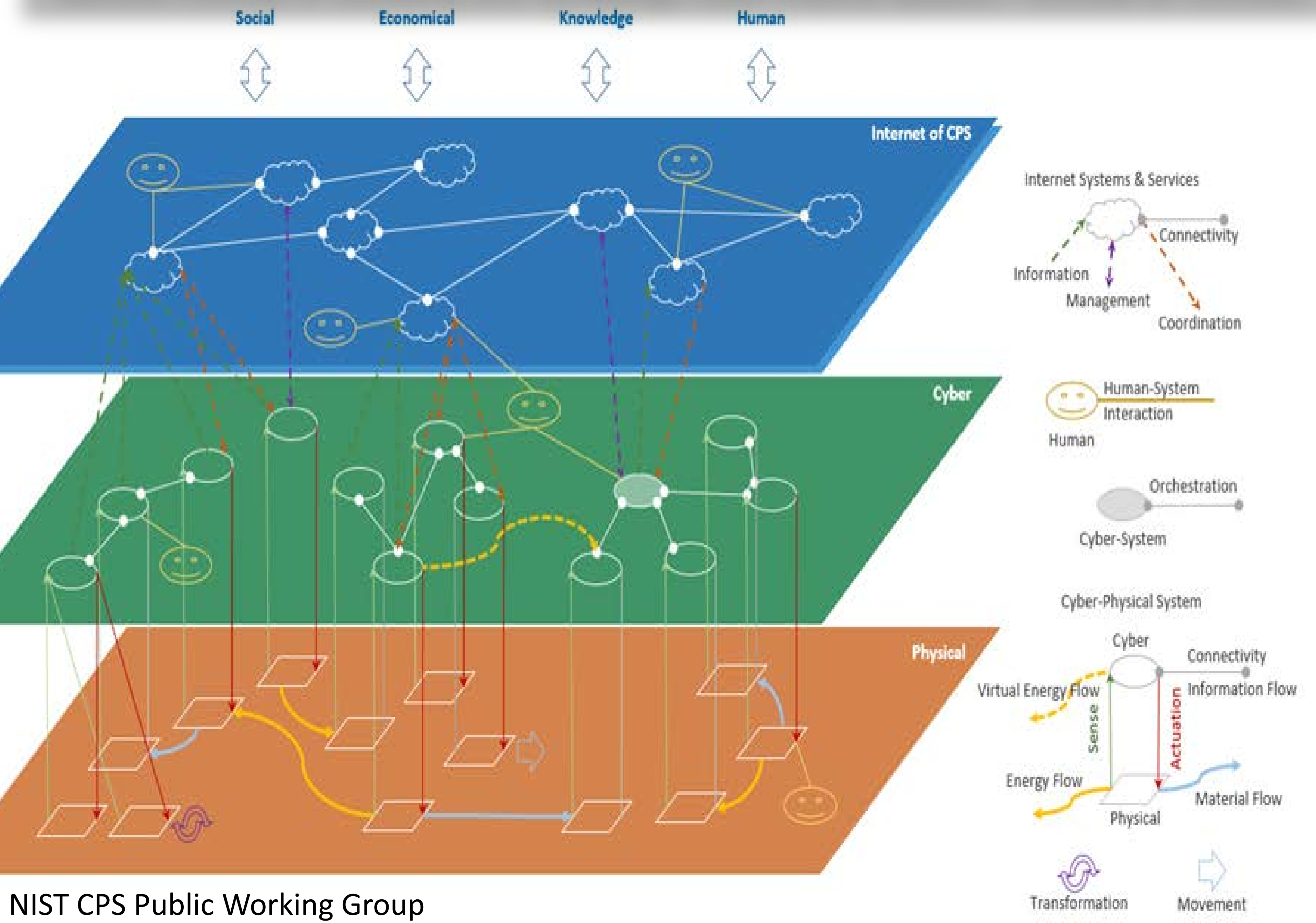
Objects must evolve to foster a digital by design era.

Physical Model of the Conceptual Introduction of Digital Twins

http://history.nasa.gov/computers/Ch8-2.html • www.nasa.gov/sites/default/files/80660main_ApolloFS.pdf

The movie, Apollo 13, depicts (1970) grounded crew member, Ken Mattingly (Gary Sinise), working in a Lunar Module simulator to sequence the space-based power up of the Command Module without shorting the electrical systems. The “successful failure” of the Apollo 13 mission was described by a few as NASA’s finest hour.

National Institute of Standards and Technology Cyber Physical Systems – SYSTEM OF SYSTEMS



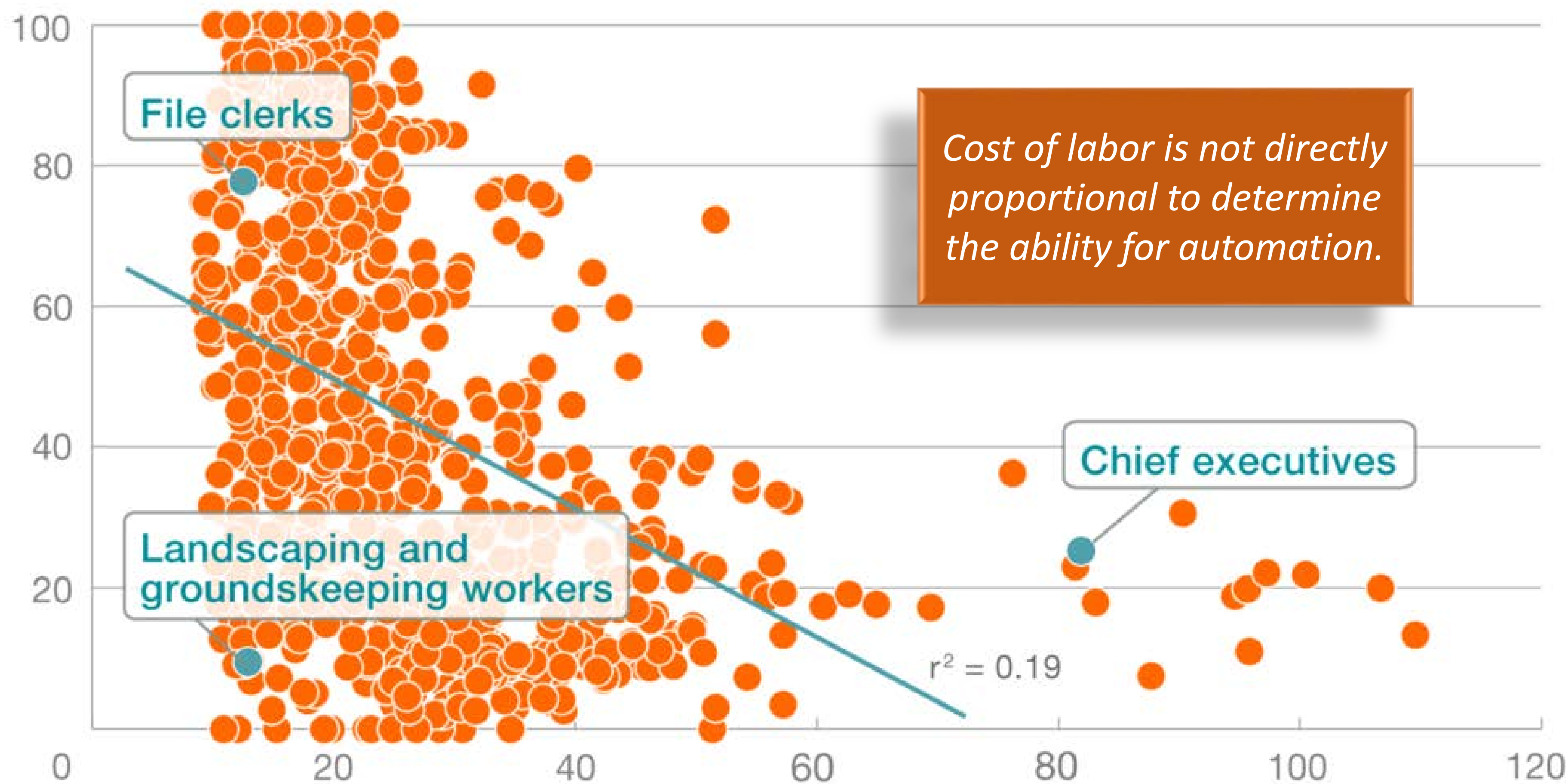
NIST CPS Public Working Group

Evolution of Autonomy

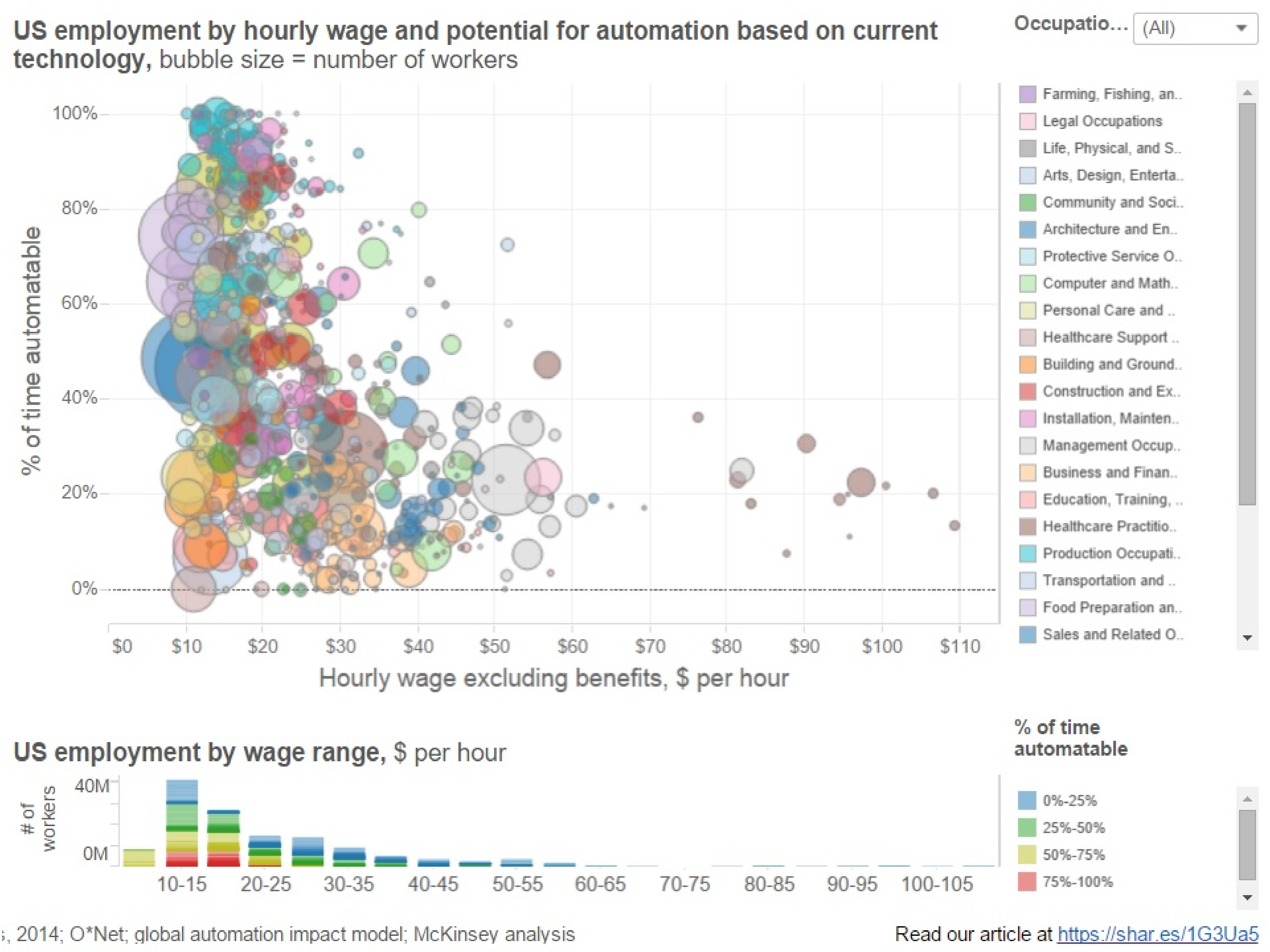
RATIONALE FOR DIGITAL BY DESIGN TWINS ?

The quest for autonomy is at the heart of our pursuit of the algorithm economy in the era of the industrial internet. Digital Twins may be a tool which may serve the dual task of [1] simulation of tasks/activities and [2] simulation of tasks/activities that we may prefer to automate. Models of autonomy are key to understand the value of automation and monitor automation efficiencies.

Ability to automate, % of time spent on activities[1] that can be automated by adapting currently demonstrated technology



Hourly wage, \$ per hour[2]


US employment by hourly wage and potential for automation based on current technology, bubble size = number of workers
Occupatio...
(All)
% of time automatable
100%
80%
60%
40%
20%
0%
$0
$10
$20
$30
$40
$50
$60
$70
$80
$90
$100
$110
Hourly wage excluding benefits, $ per hour
Farming, Fishing, an..
Legal Occupations
Life, Physical, and S..
Arts, Design, Enterta..
Community and Soci..
Architecture and En..
Protective Service O..
Computer and Math..
Personal Care and ..
Healthcare Support ..
Building and Ground..
Construction and Ex..
Installation, Mainten..
Management Occup..
Business and Finan..
Education, Training, ..
Healthcare Practitio..
Production Occupati..
Transportation and ..
Food Preparation an..
Sales and Related O..
US employment by wage range, $ per hour
# of workers
40M
0M
10-15
20-25
30-35
40-45
50-55
60-65
70-75
80-85
90-95
100-105
% of time automatable
0%-25%
25%-50%
50%-75%
75%-100%
;, 2014; O*Net; global automation impact model; McKinsey analysis
Read our article at https://shar.es/1G3Ua5

The Algorithm Economy

fuzzy boundaries

rule-based decision making

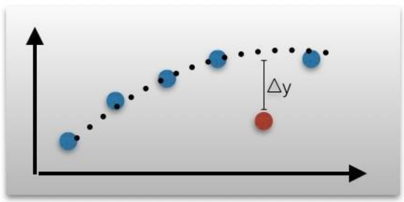
if condition fulfilled *then*
activity 1
else
activity 2

boolean data
(yes or no)

Examples:

- phone notification
- time- or threshold-based alarms
- simple pattern matching

statistical reasoning



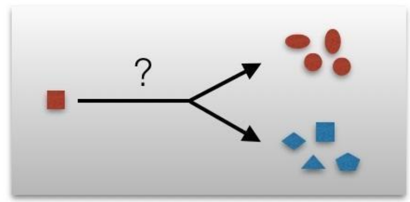
simple regression

numerical data
allowing for curve fitting

Examples:

- extra- and interpolation
- outlier detection
- predictive maintenance

machine learning



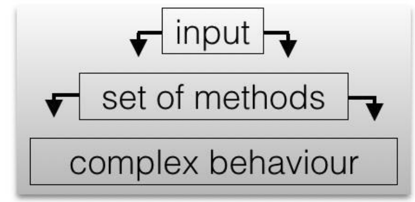
classification tasks

arbitrary data
that needs to be abstracted into numbers

Examples:

- identification of relevant features from large input datasets
- quality control using various metrics

artificial intelligence



dynamic adaptation to novelty

autonomous selection of best methodology when presented with **arbitrary data**

Examples:

- autonomous vehicles
- human-like conversational skills
- intelligent digital assistant

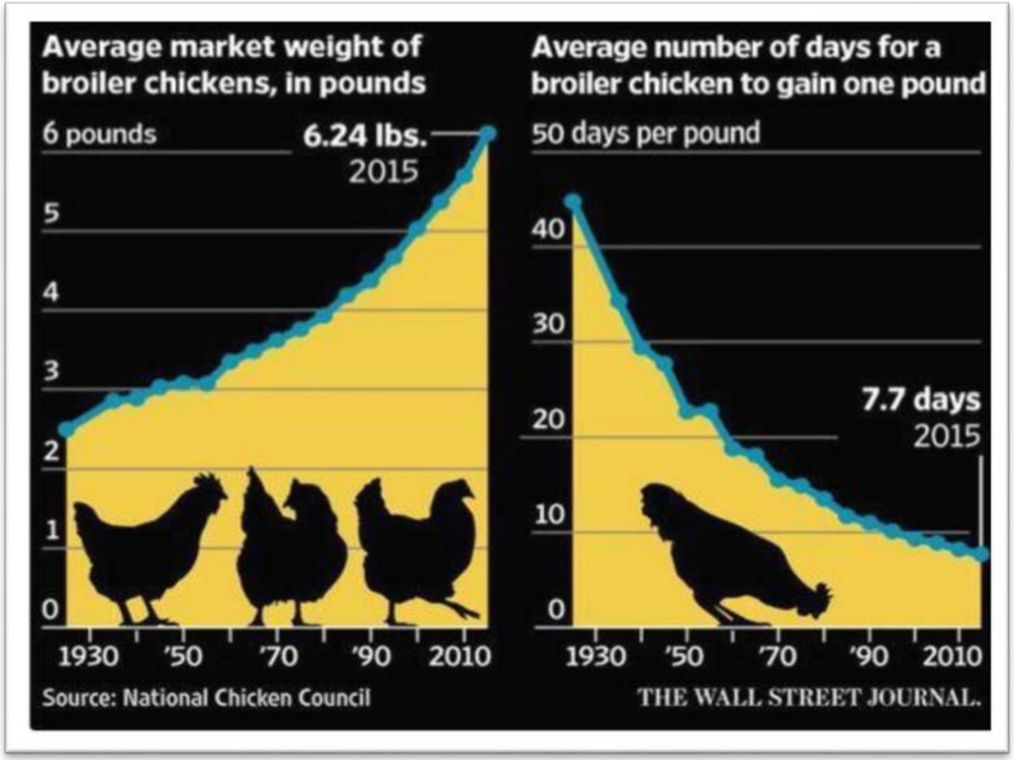
every programmer

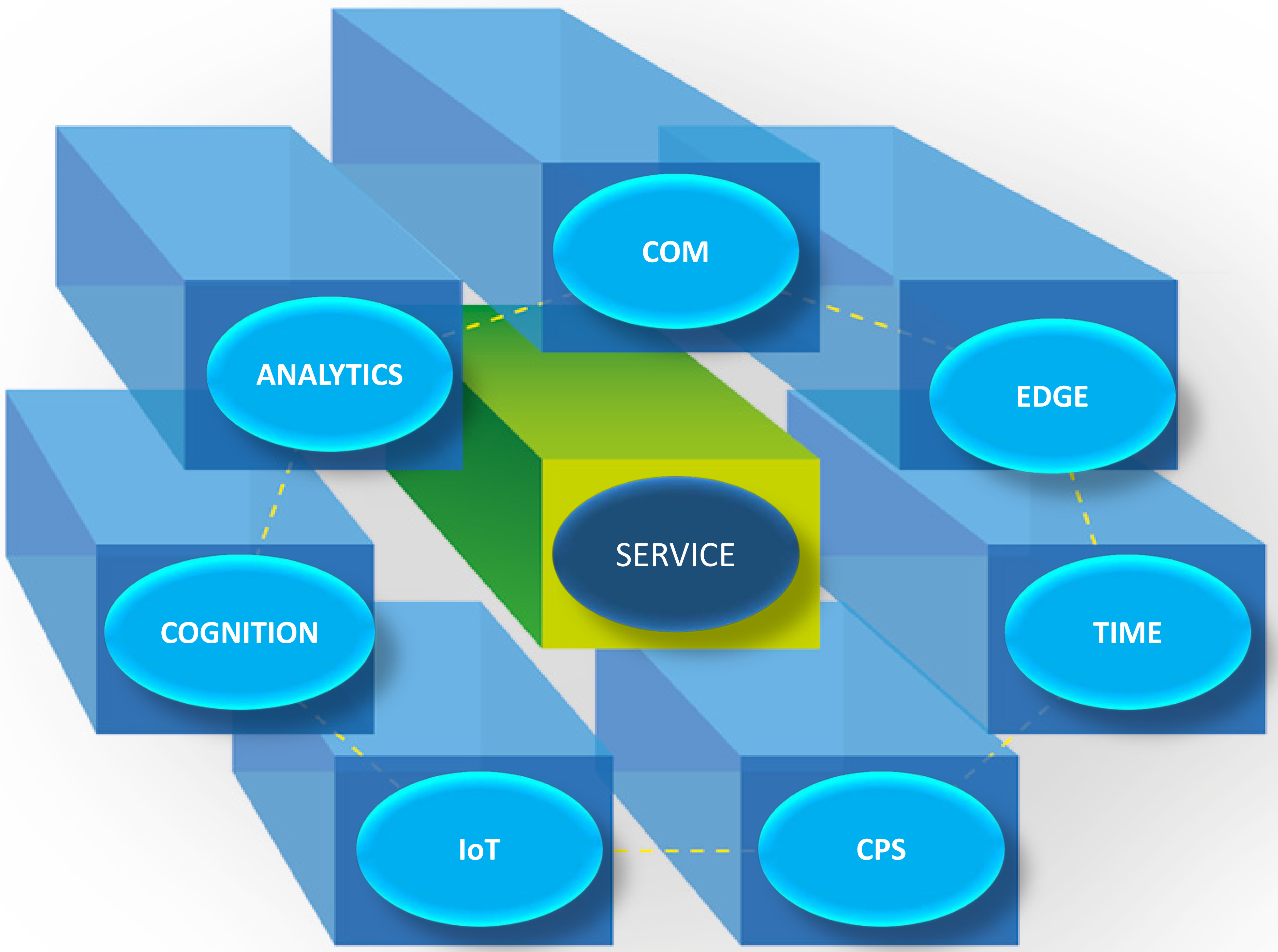
data science types

complex systems specialists

The Primordial Quest for Monetization

- The Algorithm Economy
- GE Mantra 1% Savings
- Improve Efficiency
- Reduce Downtime
- Conserve Fuel
- Mitigate Risk
- Save Lives?
- Profit
- Data
- DDS




COM
ANALYTICS
EDGE
SERVICE
COGNITION
TIME
IoT
CPS

MONETIZATION

Analytics Layer
Machine Learning, Data Science Algorithms

PREDICTIVE / COGNITIVE INTELLIGENT SERVICES ?


PER ASSET ANALYTICS
=
NEW SERVICES
Exact data on usage and environment for a single machine to optimize its performance
Digital Twin + Controls + Predix
DIGITAL TWIN
THE FUTURE OF SERVICES FOR GE
Animated with real-world data, the Digital Twin is a virtual replica of any product, and is designed to help GE predict and respond to customer problems.

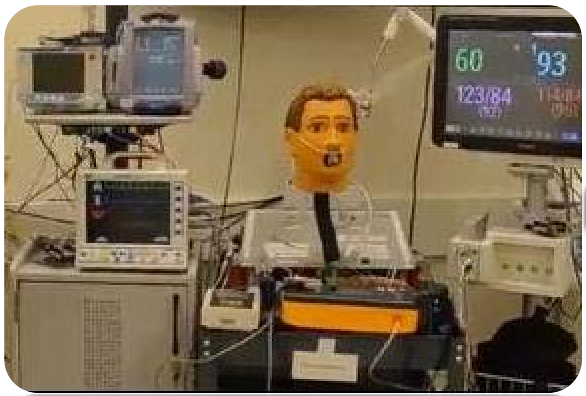
Post-Surgical Morphine Infusion System as a Finite State Machine?

Infusion Pump

Capnometer

PATIENT
Simulator
Ventilator

Intelligent Monitor



Vital Signs Monitor

Simulator connected to vital signs monitor

Fluke ProSim 8 connected to intelligent monitor

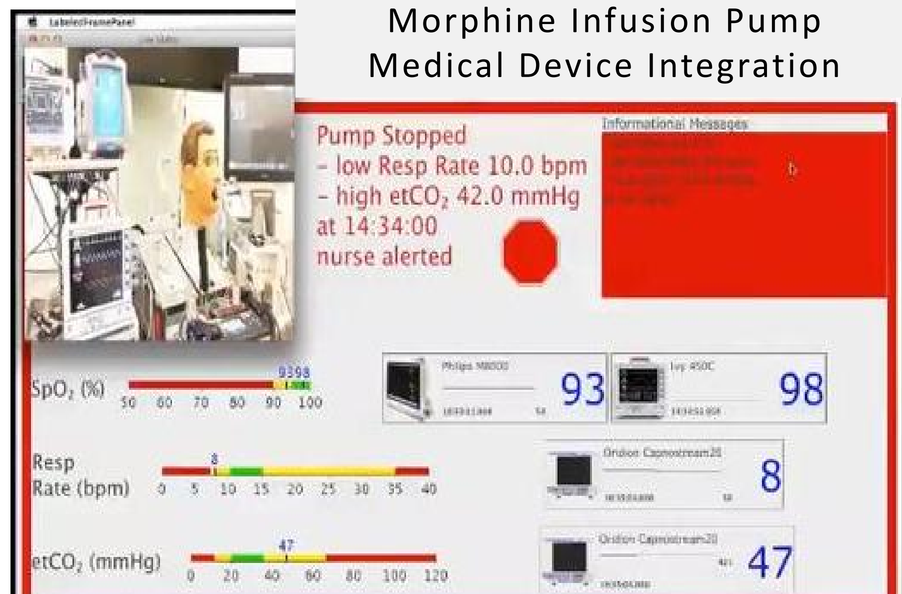
↓ O_2 Saturation

↓ Respiratory Rate

↑ end-tidal CO_2

Connected Data
Collective Analysis
Automated Response

Morphine Infusion Pump
Medical Device Integration



Patient Controlled Analgesia Safety Application

Dr Julian M Goldman MD (MDPnP.org and Partners.org)
Massachusetts General Hospital, Harvard Medical School
Harvard – MIT Center for Integrative Medicine and Information Technology

Neonatal ICU as a Finite State Automaton? Transition states?

http://bit.ly/OULU-HEALTH-2015-CNN

Neonatal ICU – Crying out for Digital Twins?

Professor Dina Katabi (MIT) presenting RF Reflection to President Obama (White House Demo, 4 August 2015)

http://bit.do/WiVi

Pictured left to right: graduate student Fadel Adib, Professor Dina Katabi, President Barack Obama, and graduate student Zachary Kabelac.

WHITE HOUSE VIDEO ● http://bit.ly/President-Obama-with-Dina-Katabi

President Obama invites MIT entrepreneurs to give demo at the White House

http://newsoffice.mit.edu/2015/president-obama-meets-mit-entrepreneurs-white-house-demo-day-0806

State Machines & Agent Models are not limited to machinery, oil and gas, auto or aerospace industry.
Any object with a transition state may be modeled as a Digital Twin – eg human heart for cardiologists.

National Science Foundation
WHERE DISCOVERIES BEGIN

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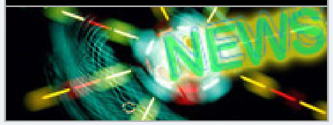
News



- News
- News From the Field
- For the News Media
- Special Reports
- Research Overviews
- NSF-Wide Investments
- Speeches & Lectures
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News by Research Area

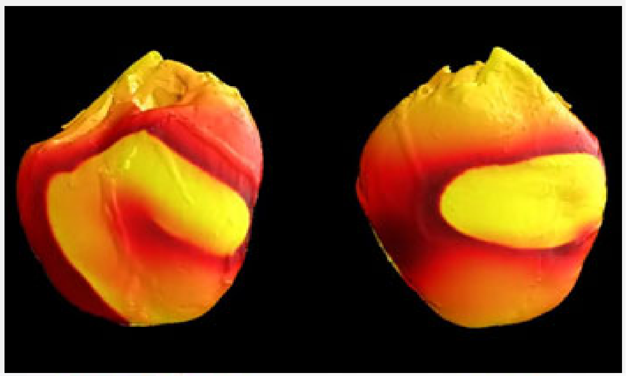
- Arctic & Antarctic

Digital Twin ☑ Delivered

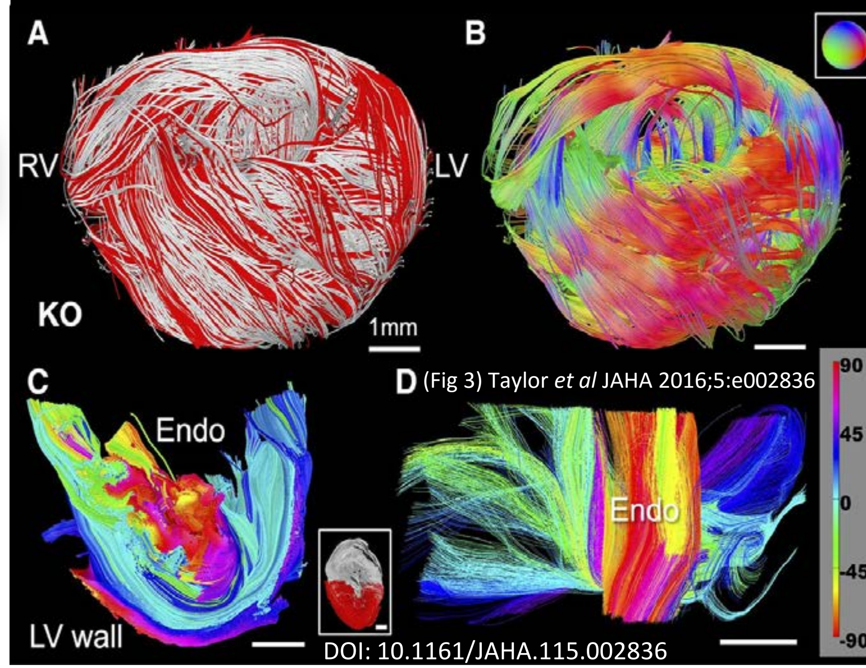
Press Release 15-052

Exploring a new frontier of cyber-physical systems: The human body

NSF supports projects to design virtual heart models and robot-cell hybrids



Myo-architectural phenotype associated with the ablation of MYBPC3



D (Fig 3) Taylor *et al* JAHA 2016;5:e002836

DOI: 10.1161/JAHA.115.002836

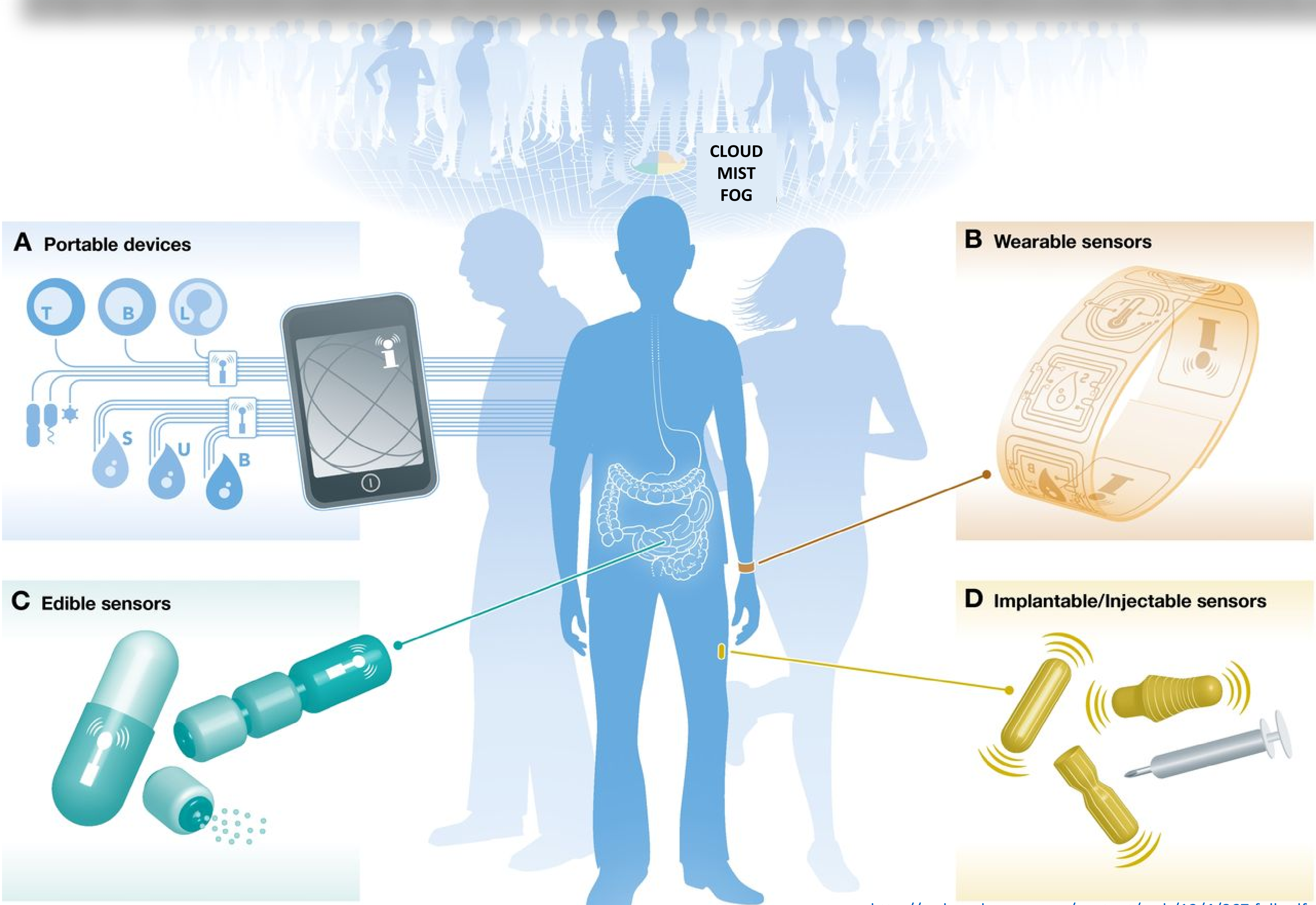
http://bit.do/HEART-2-HEART

The Trustees of the University of Pennsylvania [US] https://www.seas.upenn.edu/~rahulm/

Penn Engineering

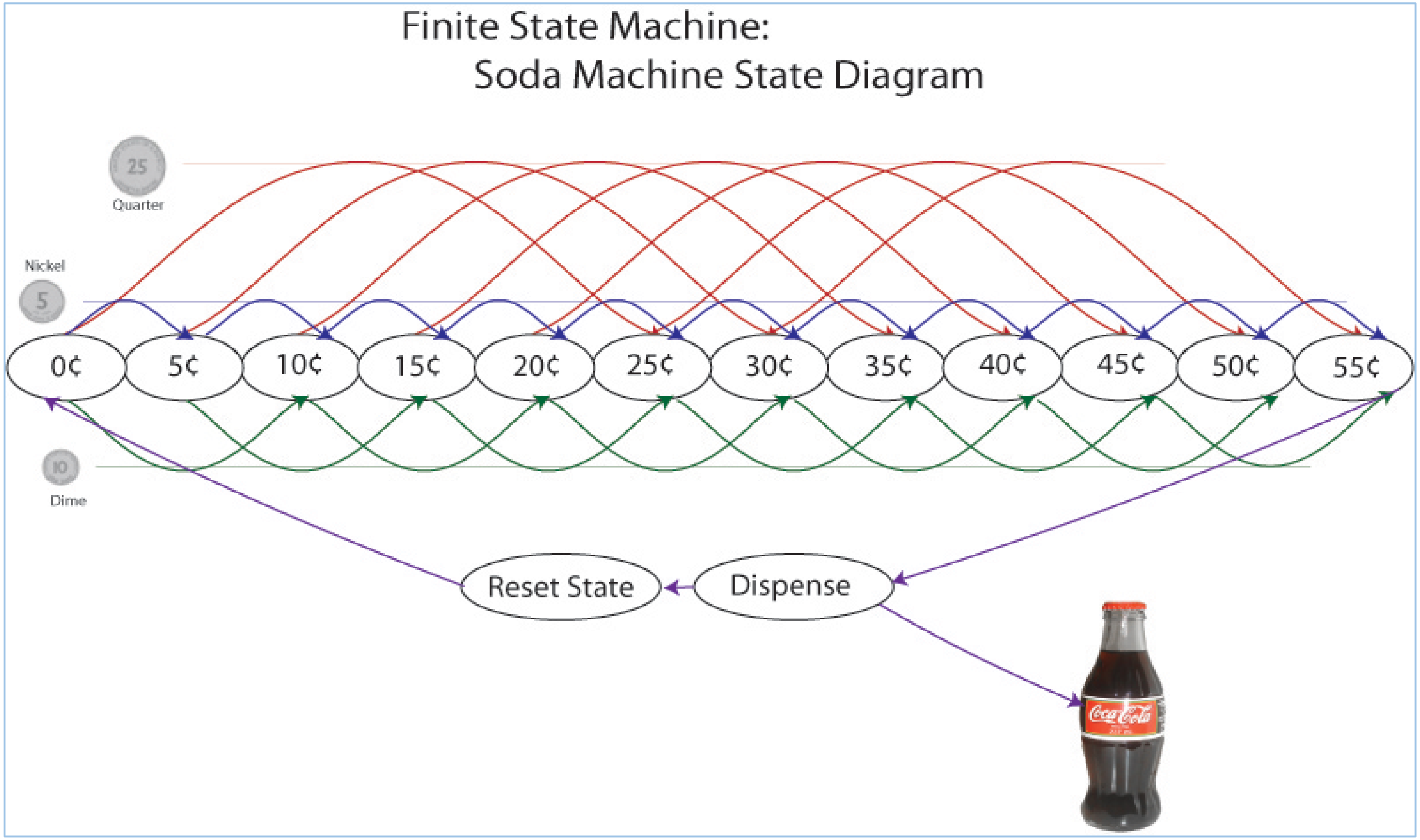
January 2015: Rahul Mangharam is the Penn PI for the newly awarded **$4.2MM NSF CPS Frontiers** project on *CyberHeart: Compositional, Approximate, and Quantitative Reasoning for Medical Cyber-Physical Systems.* More.

Digital representation of biosensors – the personal health mesh network ?



Lars M Steinmetz and Allan Jones in Molecular Systems Biology (2016) 12:867

http://msb.embopress.org/content/msb/12/4/867.full.pdf

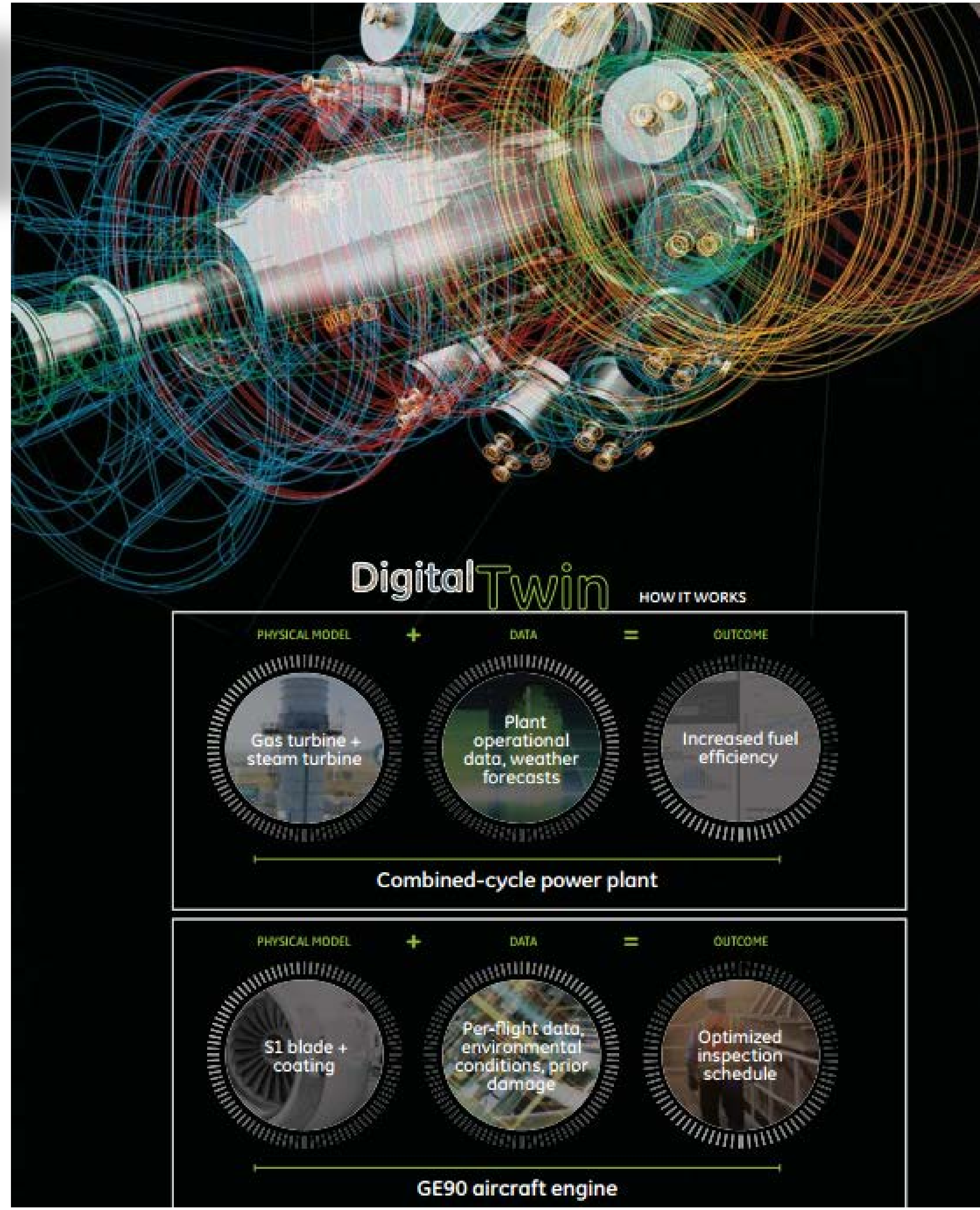


The concept of finite state machines (FSM) is applicable to digital twins, but it will be remiss not to mention that traditional state based approach (cartoon, above) may have reached its limit in engineering. It is imperative to develop tools which allows and accommodates for non-linearity, adaptability, self-organization and self-repair.

Dawn of Industrial Digital Twins

case specific, expert driven, equation based, hard coded, data islands which are not digital by design http://bit.do/RR-ROCKS

Expert Driven DT Instantiation



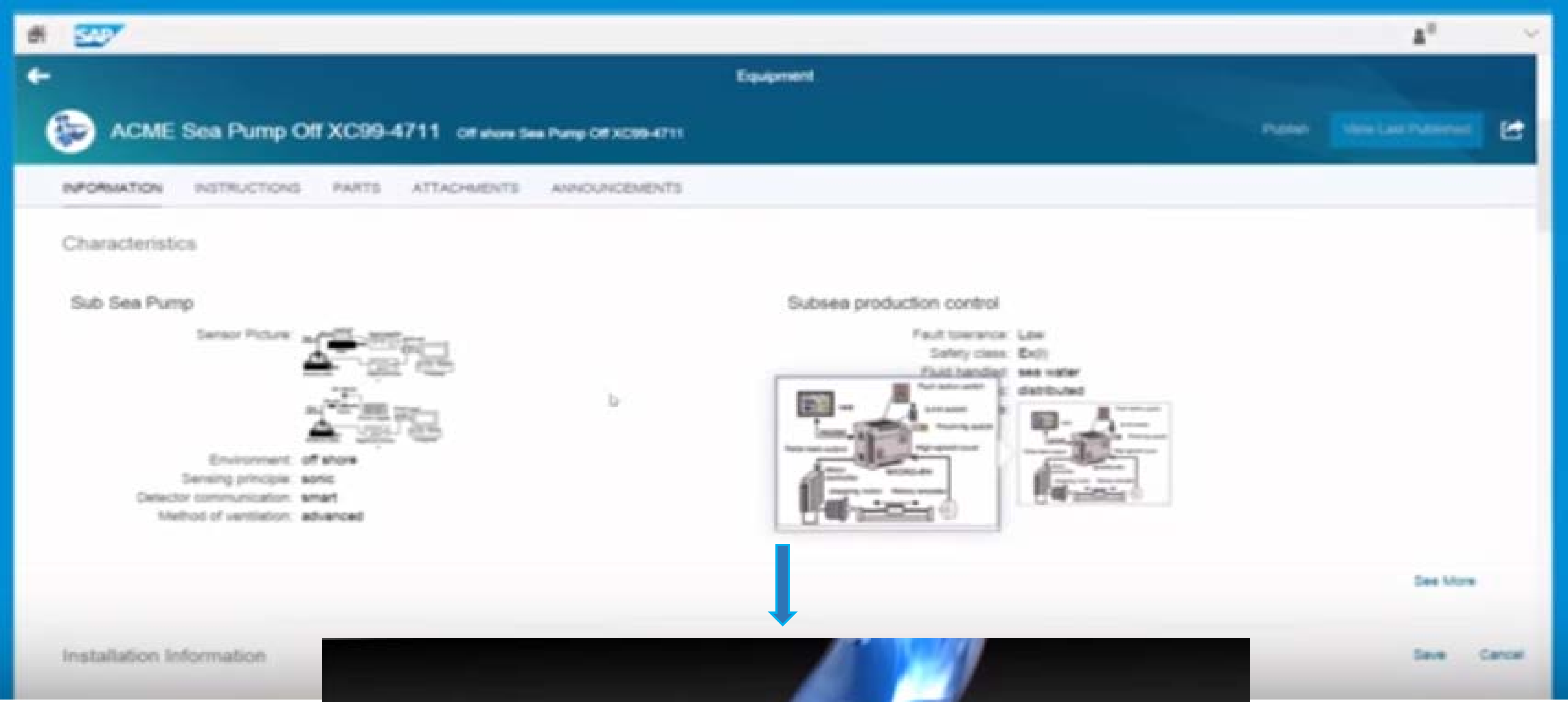
Physics of the Object

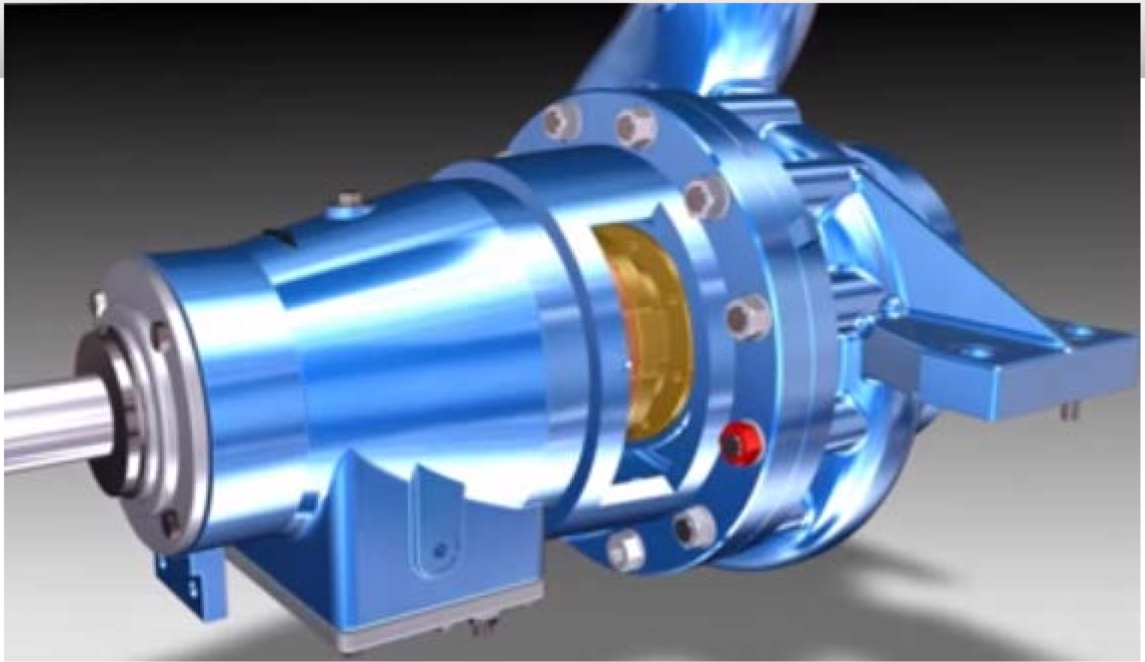
Equation of Operation

Populate Data for Variables

Compute & Analyze Outcome

Fleishmann, R.D. *et al.* Whole-genome random sequencing and assembly of *Haemophilus influenzae* Rd. *Science* **269**, 496-512 (7/28/95)

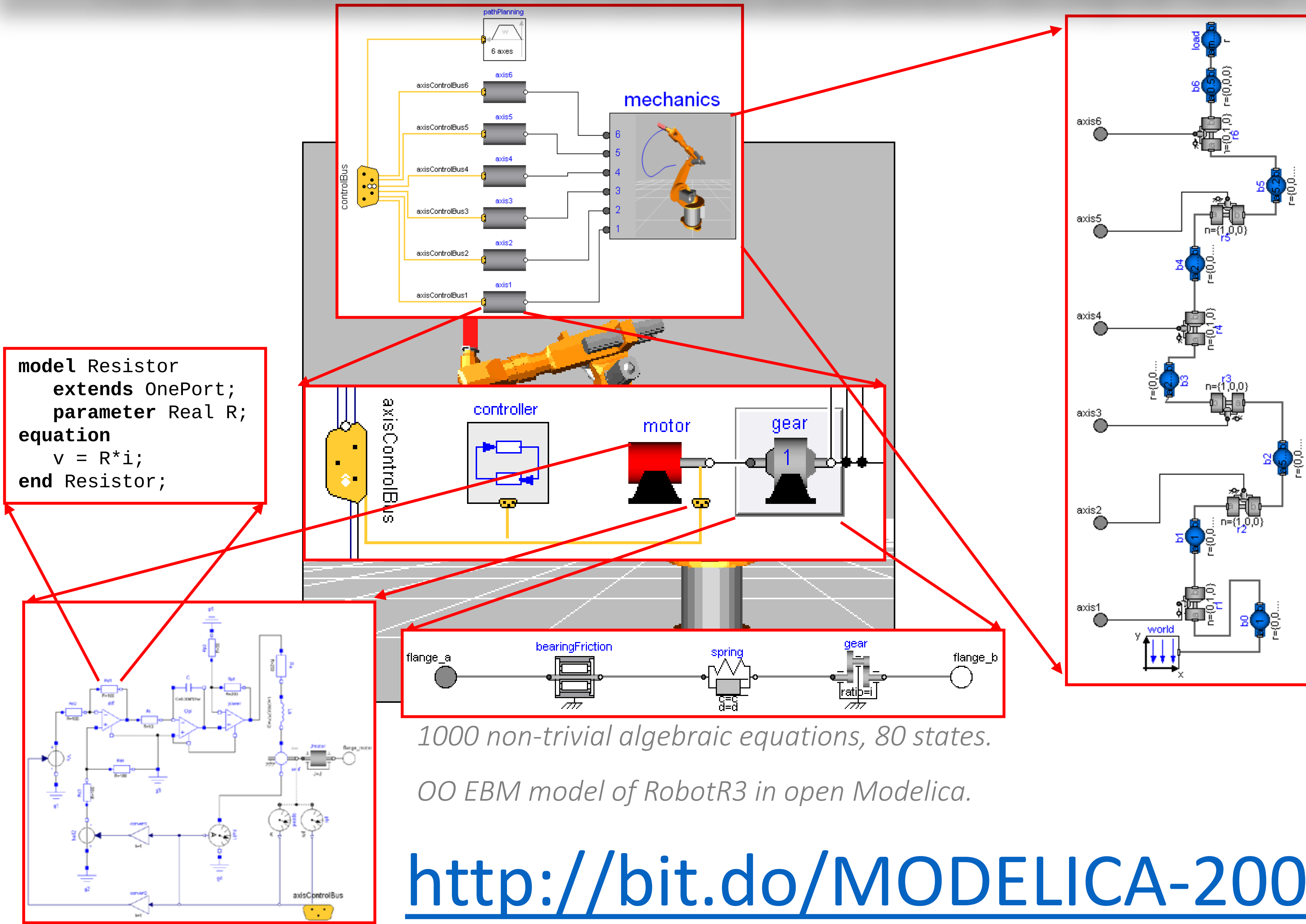




http://bit.do/SAP-AIN

Equation based tools pioneered by Modelica and others since 1996
FSM are insufficient but foundational and catalytic for Digital Twins

```
model Resistor
   extends OnePort;
   parameter Real R;
equation
   v = R*i;
end Resistor;
```

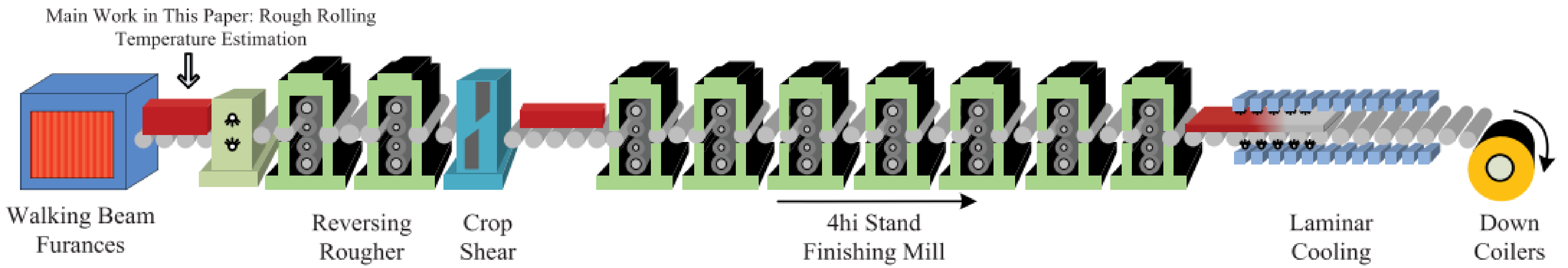


1000 non-trivial algebraic equations, 80 states.

OO EBM model of RobotR3 in open Modelica.

http://bit.do/MODELICA-2000

Integrate (WSN) Data from Industrial CPS with Digital Twins



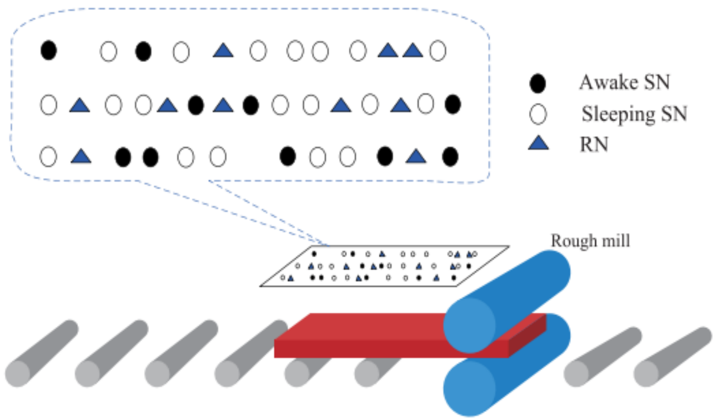


FIGURE 4. **Schematic illustration of the WSNs deployed at the entrance of the roughing mill.**

DOI 10.1109/TETC.2014.2386615

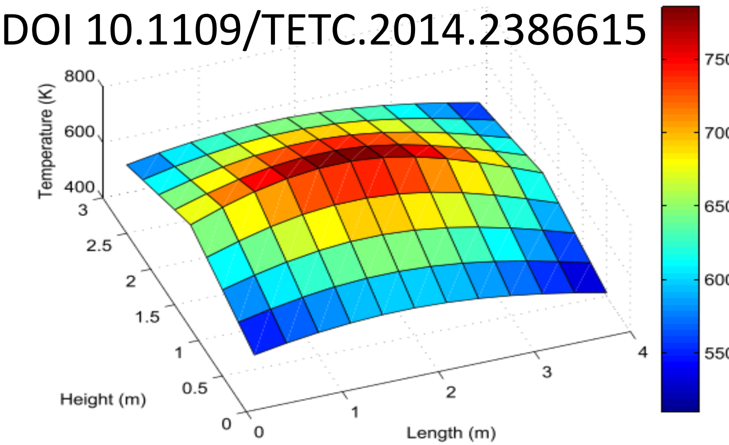


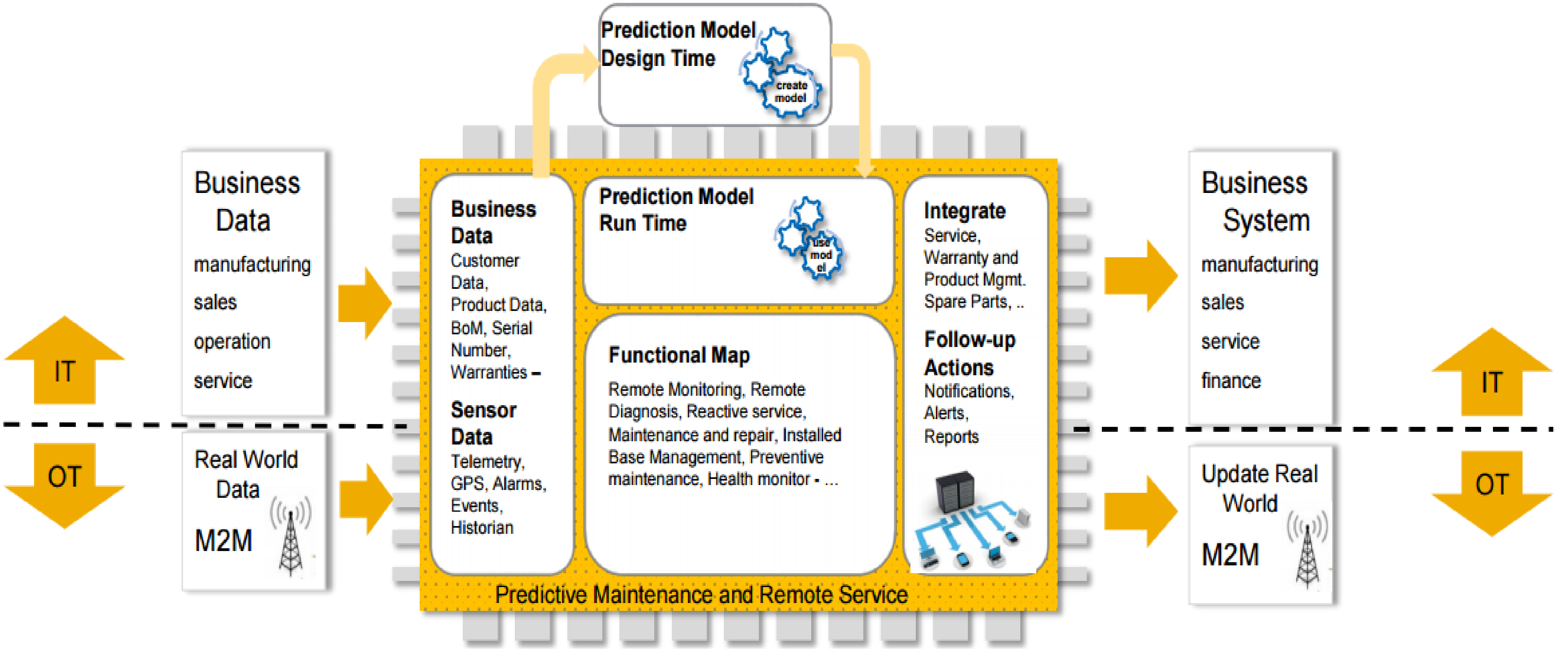
FIGURE 6. **Temperature distribution of slab in the direction of thickness.**

Ubiquitous Monitoring for Industrial Cyber-Physical Systems Over Relay-Assisted Wireless Sensor Networks

CAILIAN CHEN[1,2], (Member, IEEE), JING YAN[3], NING LU[4], (Student Member, IEEE), YIYIN WANG[1,2], (Member, IEEE), XIAN YANG[3], AND XINPING GUAN[1,2], (Senior Member, IEEE)

CAILIAN CHEN (S'03–M'06) received the B.Eng. and M.Eng. degrees in automatic control from Yanshan University, Qinhuangdao, China, in 2000 and 2002, respectively, and the Ph.D. degree in control and systems from the City University of Hong Kong, Hong Kong, in 2006. She joined the Department of Automation, Shanghai Jiao Tong University, Shanghai, China, in 2008, as an Associate Professor, where she is currently a Full Professor.

IT / OT Divide is Discouraging for Digital Twins

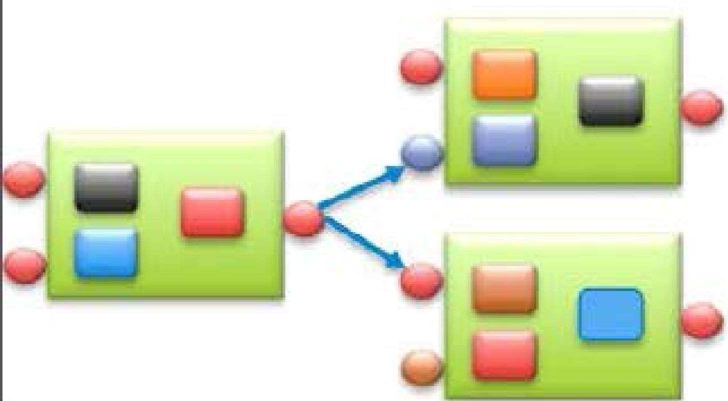


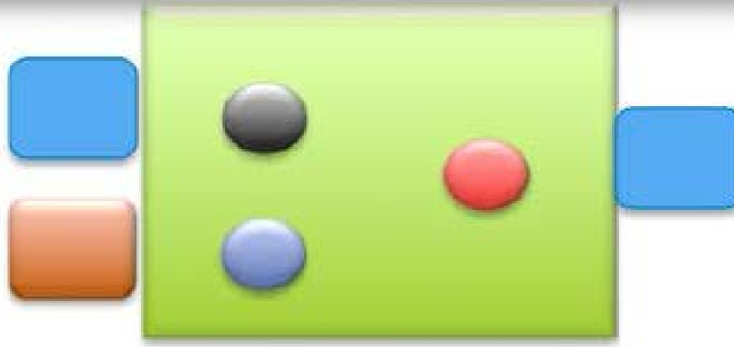
https://www.itu.int/en/ITU-T/Workshops-and-Seminars/ccsg/expdial/Documents/45-SAP.pdf

Digital Twins better served by Data Centricity rather than OO

Object Oriented

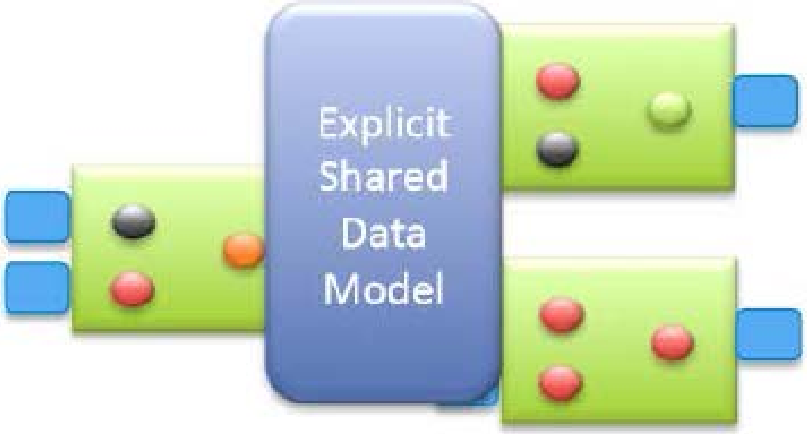
- Encapsulate data
- Expose methods



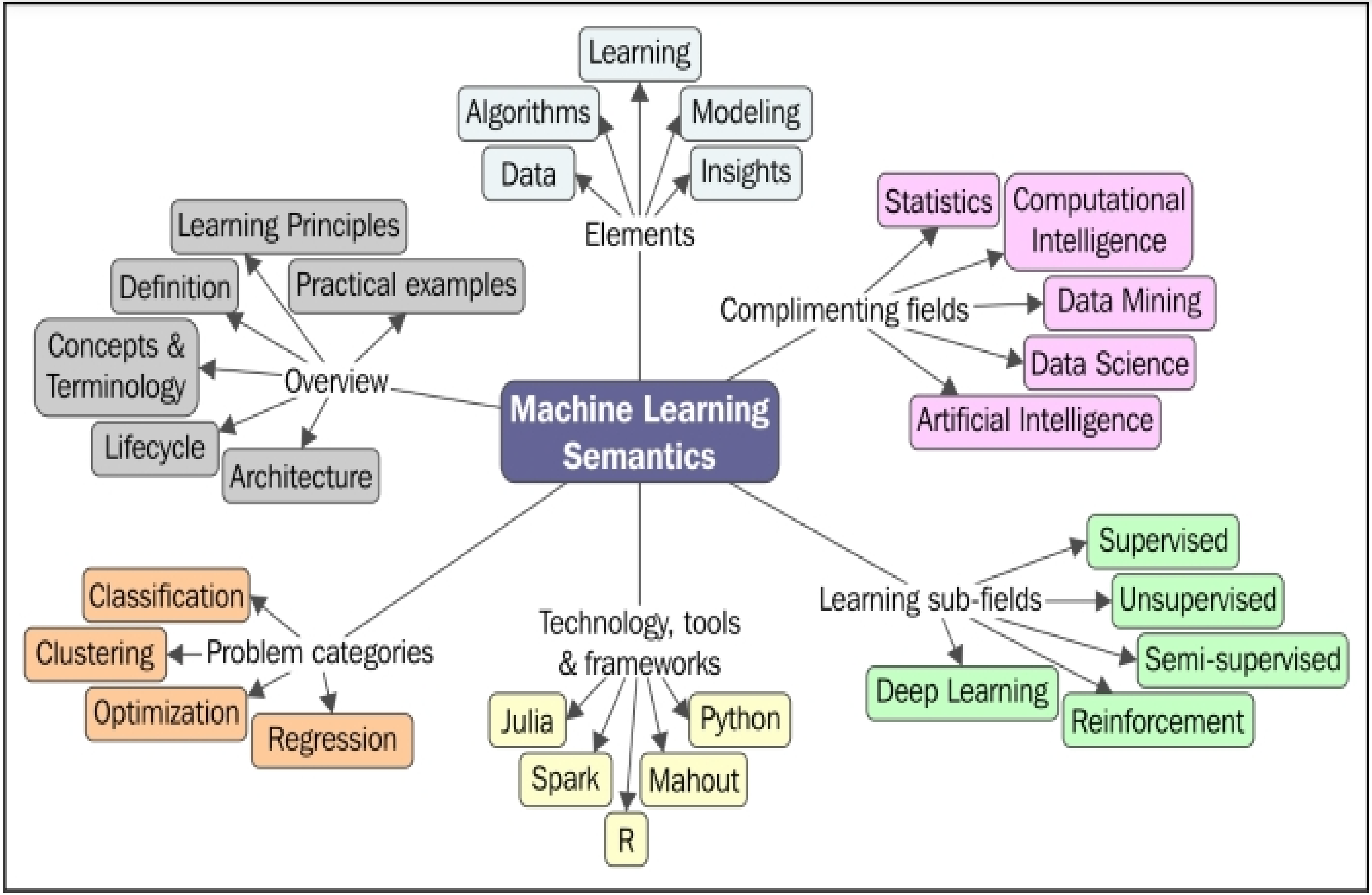


Data Centric

- Encapsulate methods
- Expose *data*



Digital Twins will die a premature death without semantic interoperability for ML tools

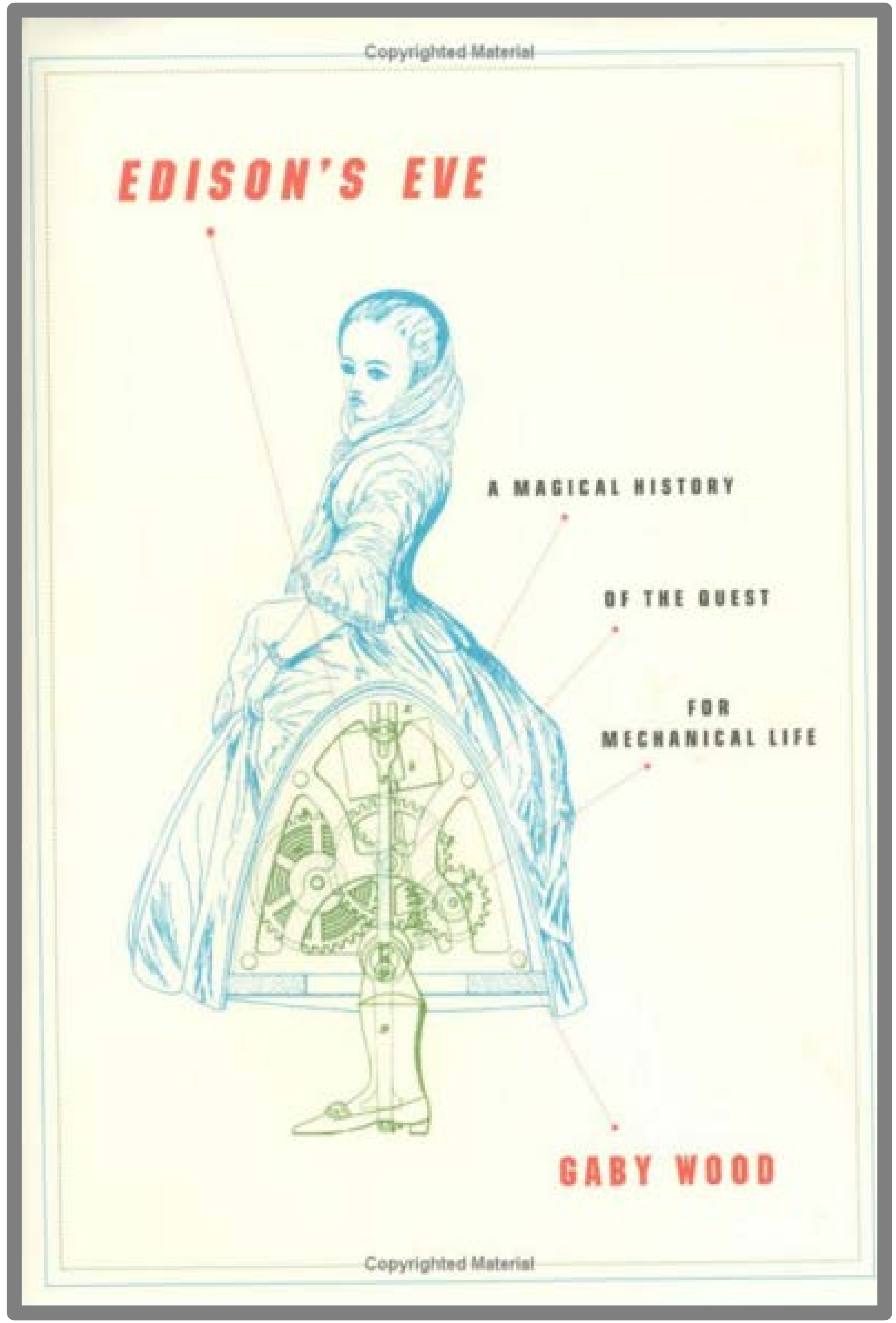


Most Existing Tools are EBM

Digital Twins may flourish when we migrate from EBM to ABM design

Agent based approaches may parallel evolution of digital by design

Digital Twin Today ?



April 14, 1956. Ampex's Charles Anderson described the scene when the VRX-1000 unveiling ceremony was played back to the audience moments after the event: "There was a deafening silence. Then came a roar. People started to swarm back around the machine."

www.wipo.int/wipo_magazine/en/2006/06/article_0003.html

Ampex released the world's first magnetic tape video recorder in April 1956. But with a price tag of US$50,000 (~$325,000 today), expensive rotating heads that had to be changed every few hundred hours and the need for highly skilled operators, it was far from a mass-use consumer item.

Masaru Ibuka, co-founder of Sony and Yuma Shiraishi at JVC, issued directives for their respective engineers to produce an unit that would cost $500, a mere 1% of Ampex's price. In the 1980's, video recorder sales went from $17 million to $2 billion at Sony, $2 million to $2 billion at JVC, $6 million to $3 billion at Matsushita and $296 million to $480 million at Ampex. Failure to adapt eclipsed Ampex.

Tellis & Golder, 1996 ▪ MIT Sloan Management Review

Sony chairman Akio Morita believed the Walkman would be a smash hit.

www.sony.net/SonyInfo/CorporateInfo/History/SonyHistory/index.html

Sony employees were shocked in the spring of 1979 when Morita instructed them to manufacture 30,000 Walkman units. This was before the public had even heard of the product. At the time, the company's best tape recorder was selling only 15,000 units a month. Morita was so sure the 30,000 units would sell, he said he would resign as company chairman if they did not. Since then, more than 200 million Walkman units have been sold. http://bit.do/SONY-VISION

The public does not know what is possible, but we do. So instead of doing a lot of market research, we refine our thinking on a product and its use and try to create a market by educating and communicating with the public. . . . I do not believe that any amount of market research could have told us that the Sony Walkman would be successful.[2]

While Morita was excited, his marketing department was not.

http://ww.prnayak.org/sites/default/files/nayak-breakthroughs_0.pdf

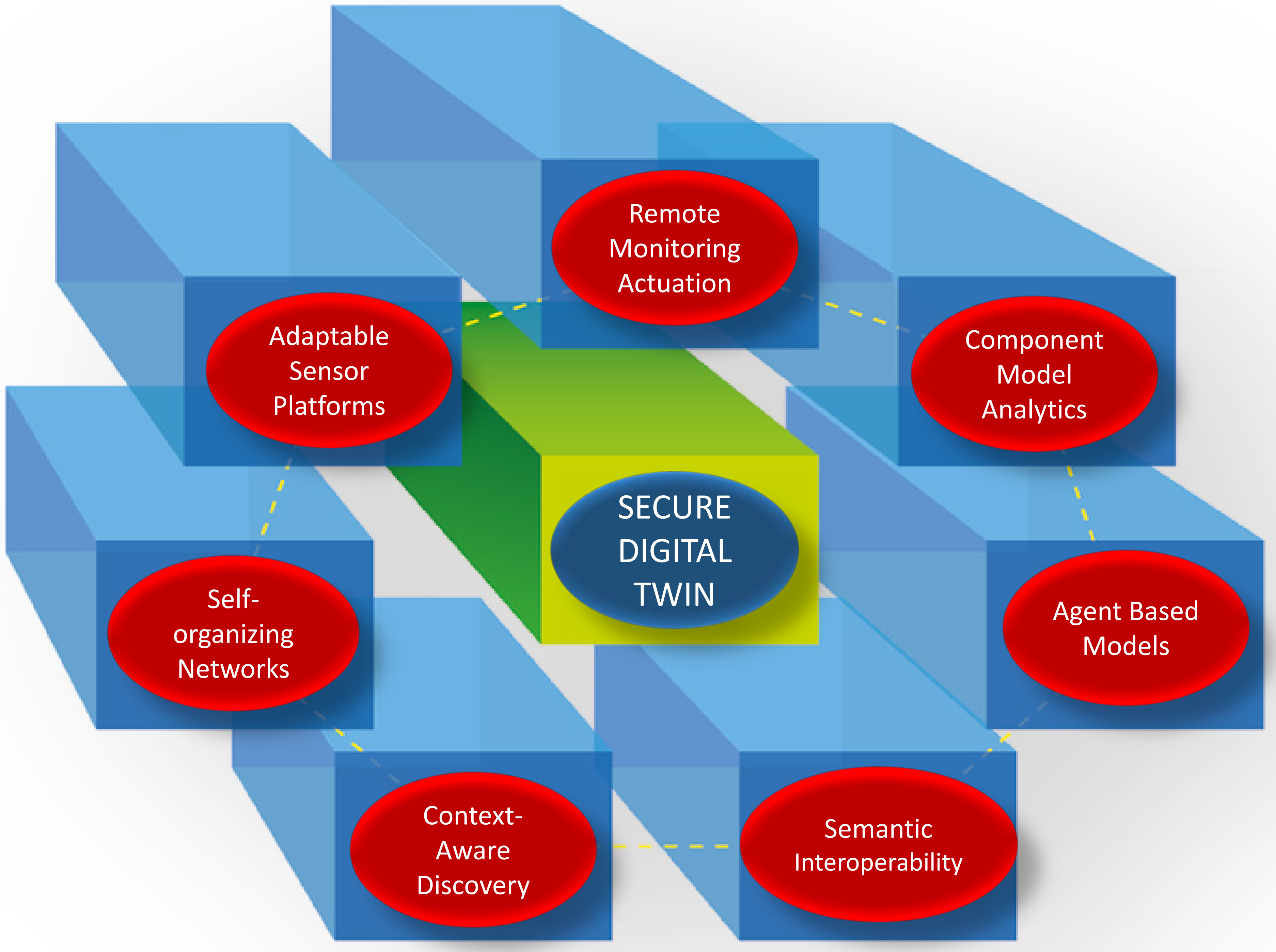
Generalized *ad hoc* Construction of Live Digital Twins

Digital Twin Direct

Digital Twin Dashboard

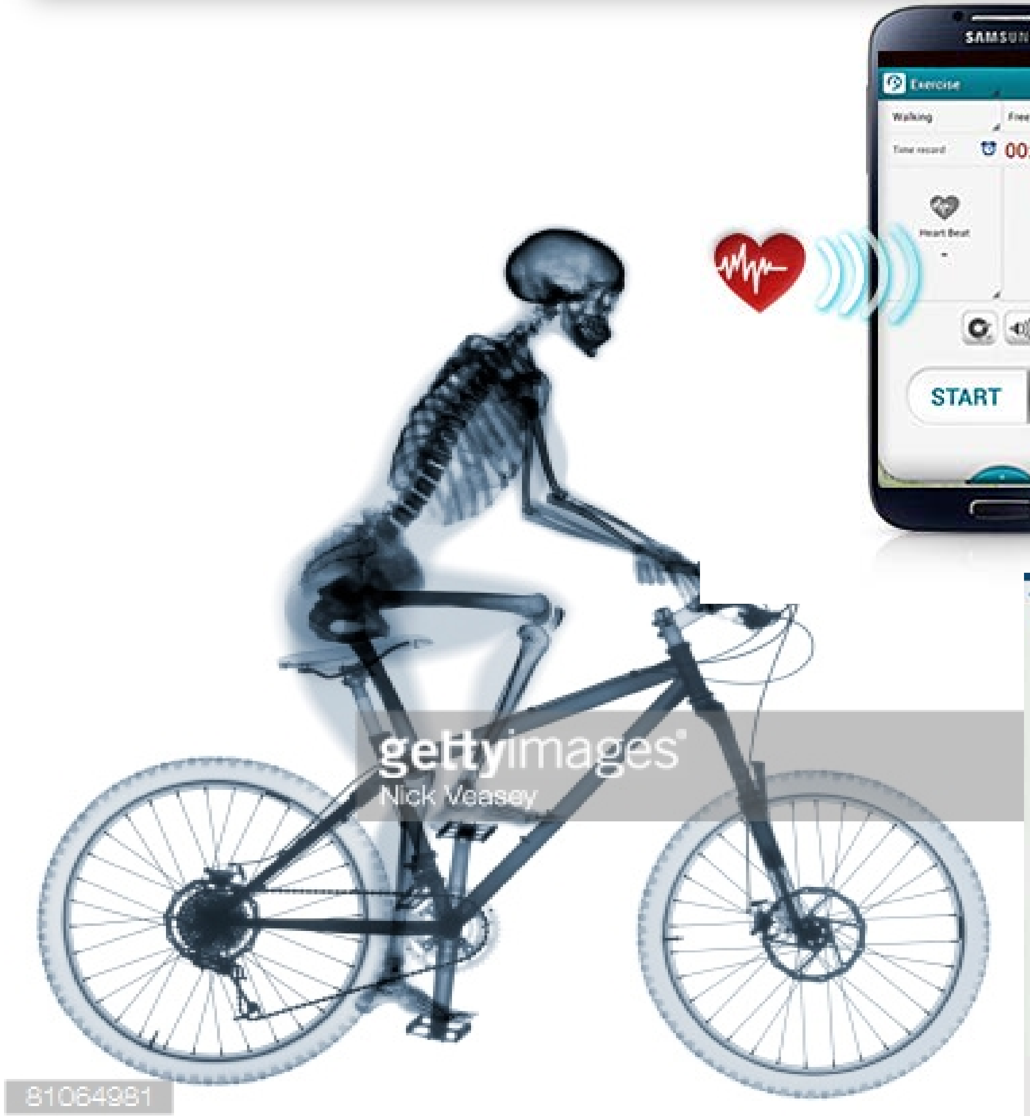
Digital Twin Drag & Drop

Digital Twin Plug and Play



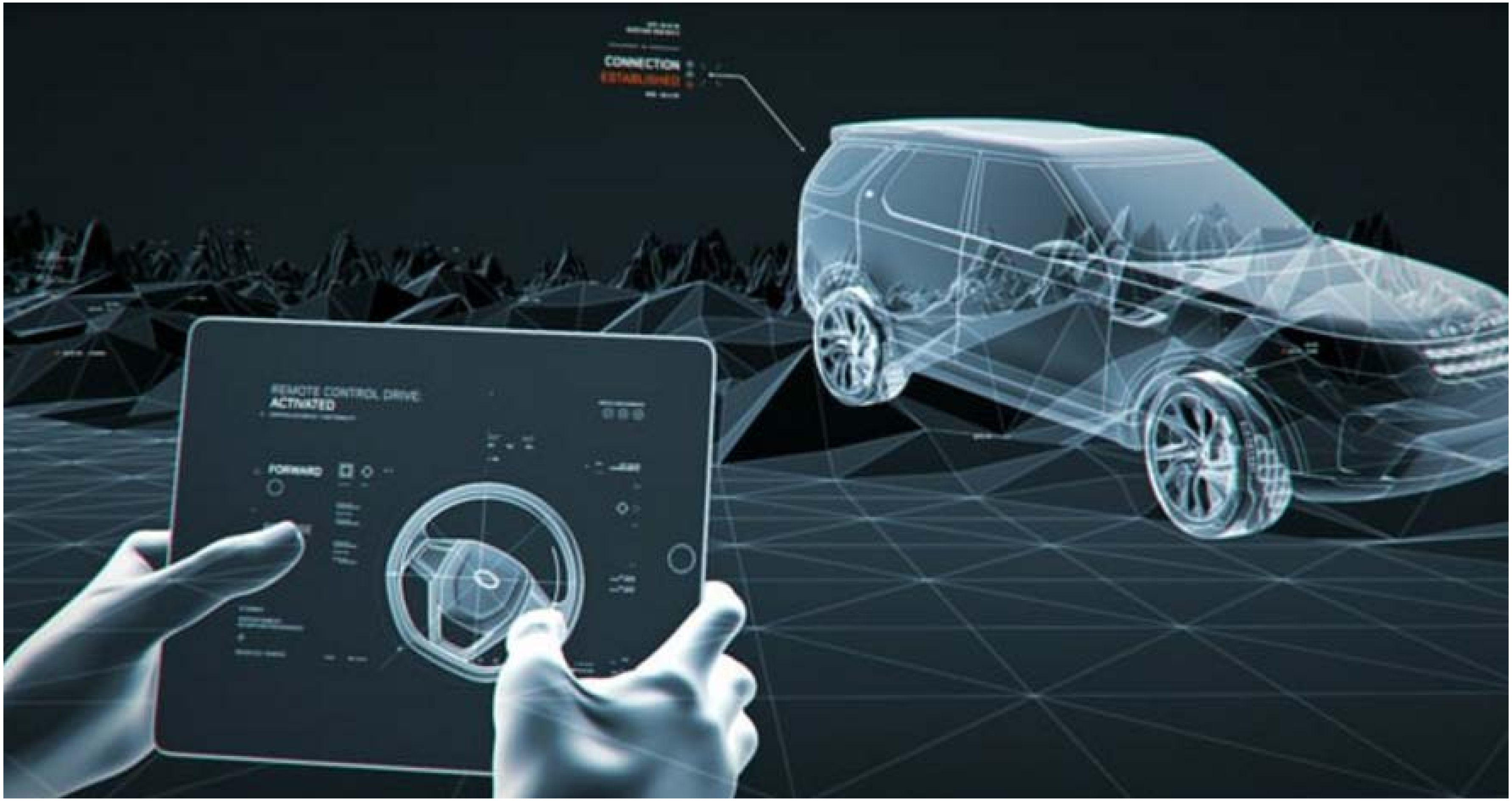
Remote Monitoring Actuation
Adaptable Sensor Platforms
Component Model Analytics
SECURE DIGITAL TWIN
Self-organizing Networks
Agent Based Models
Context-Aware Discovery
Semantic Interoperability

Digital Twin – SAM and SCHWINN



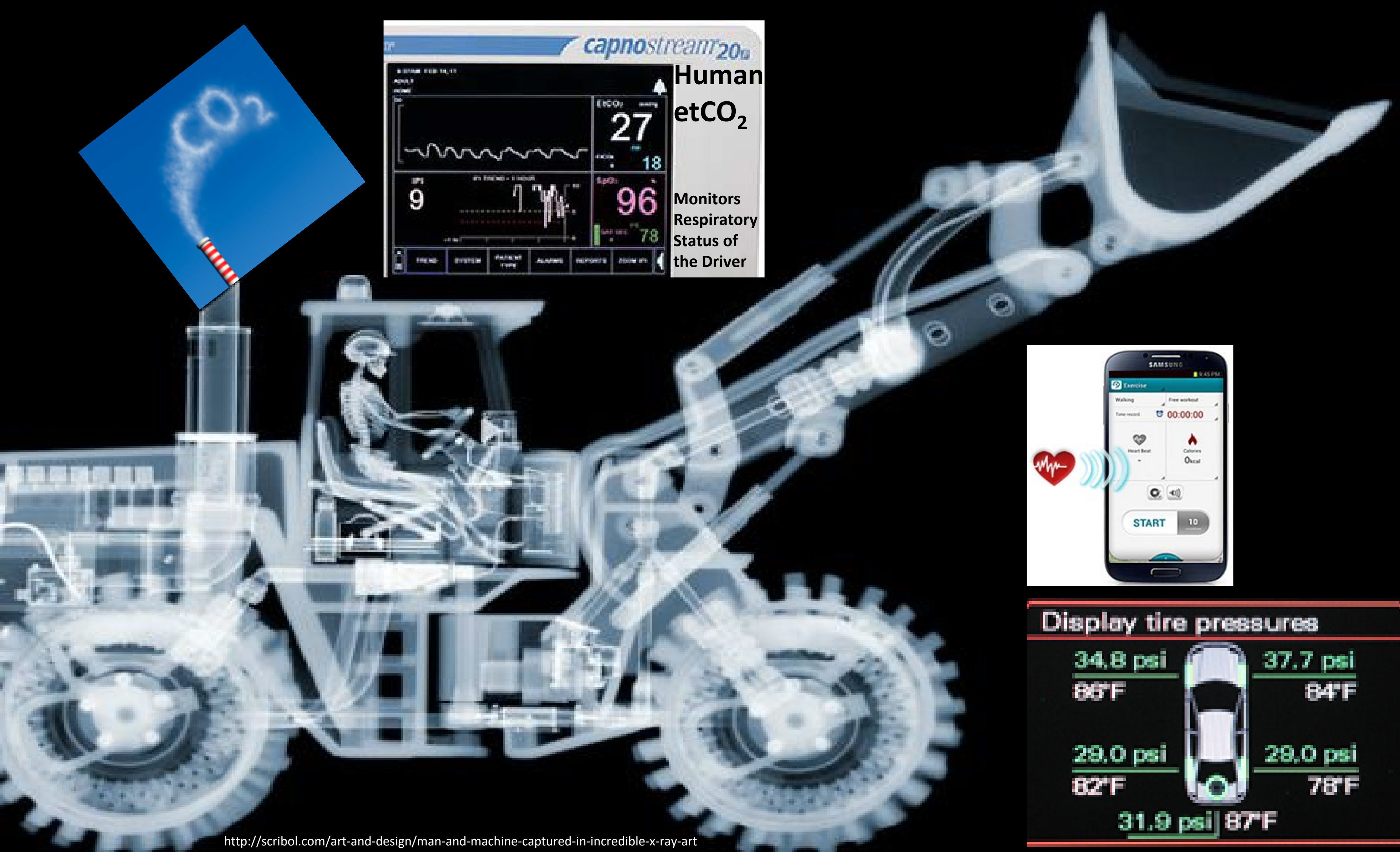
SCHWINN

More than diagnostics – Drive a truck from your home



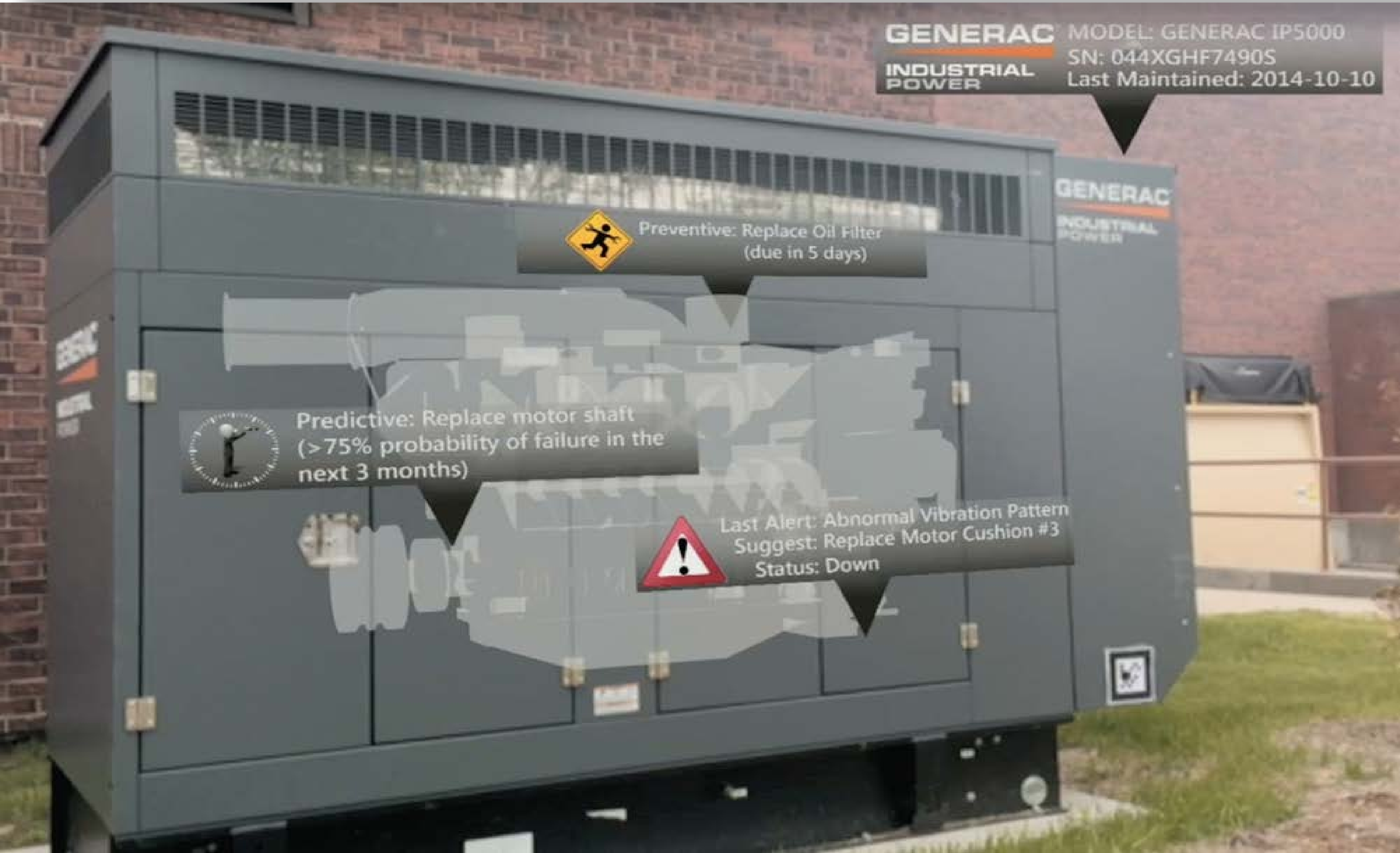
You can drive your daughter to her ballet class while you sip coffee at your neighborhood Starbucks store

Digital Twins – We measure, monitor and protect man, machine and environment



http://scribol.com/art-and-design/man-and-machine-captured-in-incredible-x-ray-art

Digital Twins – AIM for Asset Intelligence Management
Industrial Internet version of Product Lifecycle Management



Mass Market Diffusion of Digital Twins Direct Demands Democratization of Open Repository of Tools and Data Models for Digital Twin Creation

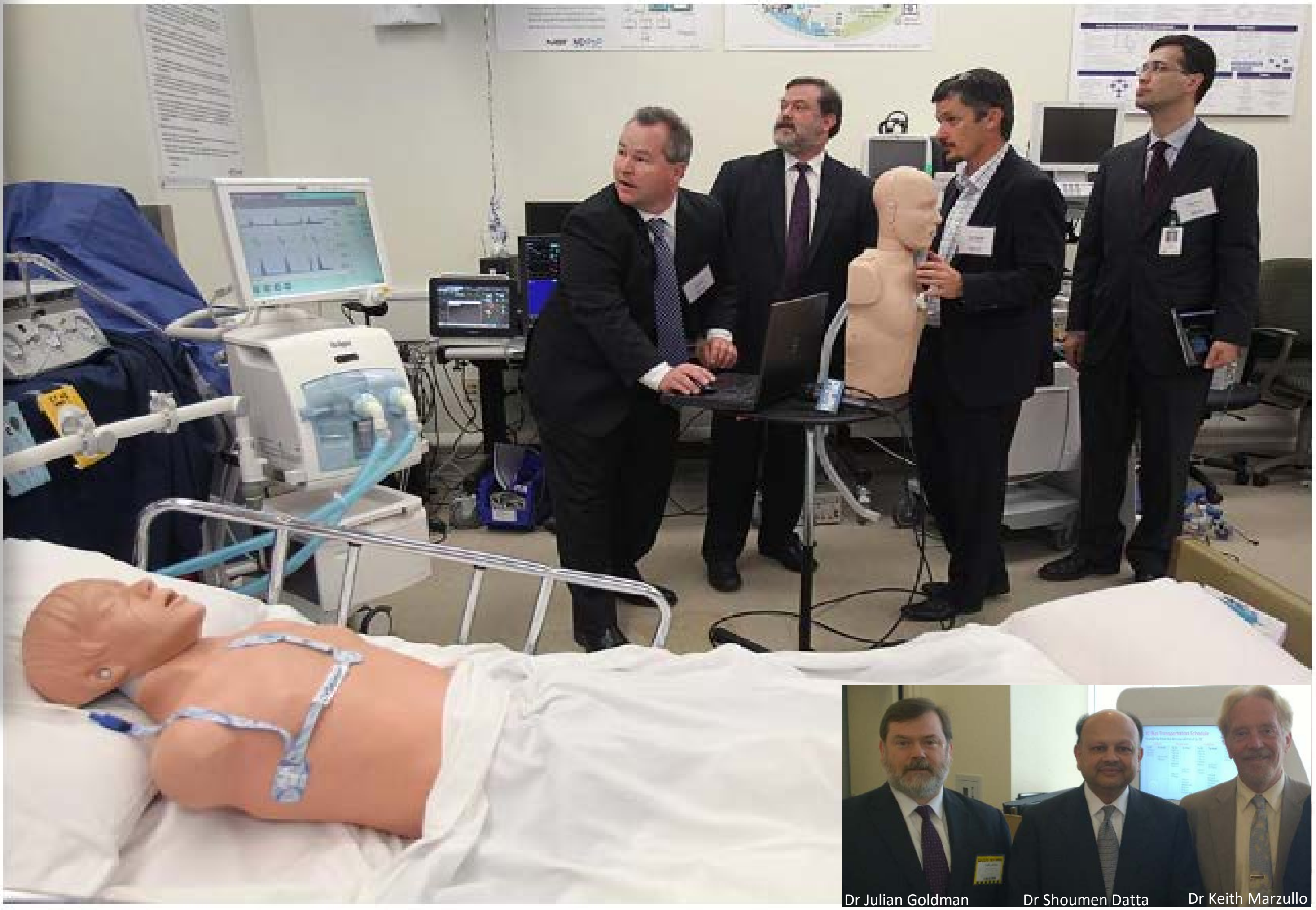
Monitor Ebola Patients via Digital Twins ?

Ebola spurs rethinking of devices at MGH

By Carolyn Y. Johnson | GLOBE STAFF NOVEMBER 07, 2014

WCVB TV ● http://bit.ly/MDPNP-MGH-EBOLA-ROBOTICS

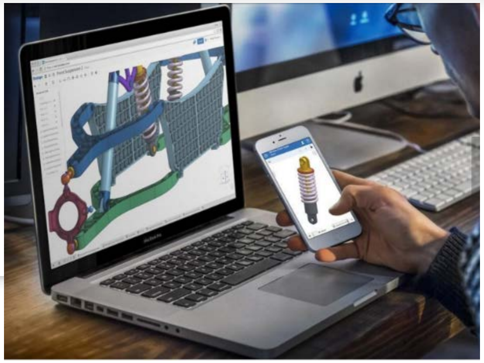
You cannot buy a TV without a remote. You cannot buy a medical device with a remote. Dr Julian M Goldman (MGH/HMS) MD PnP

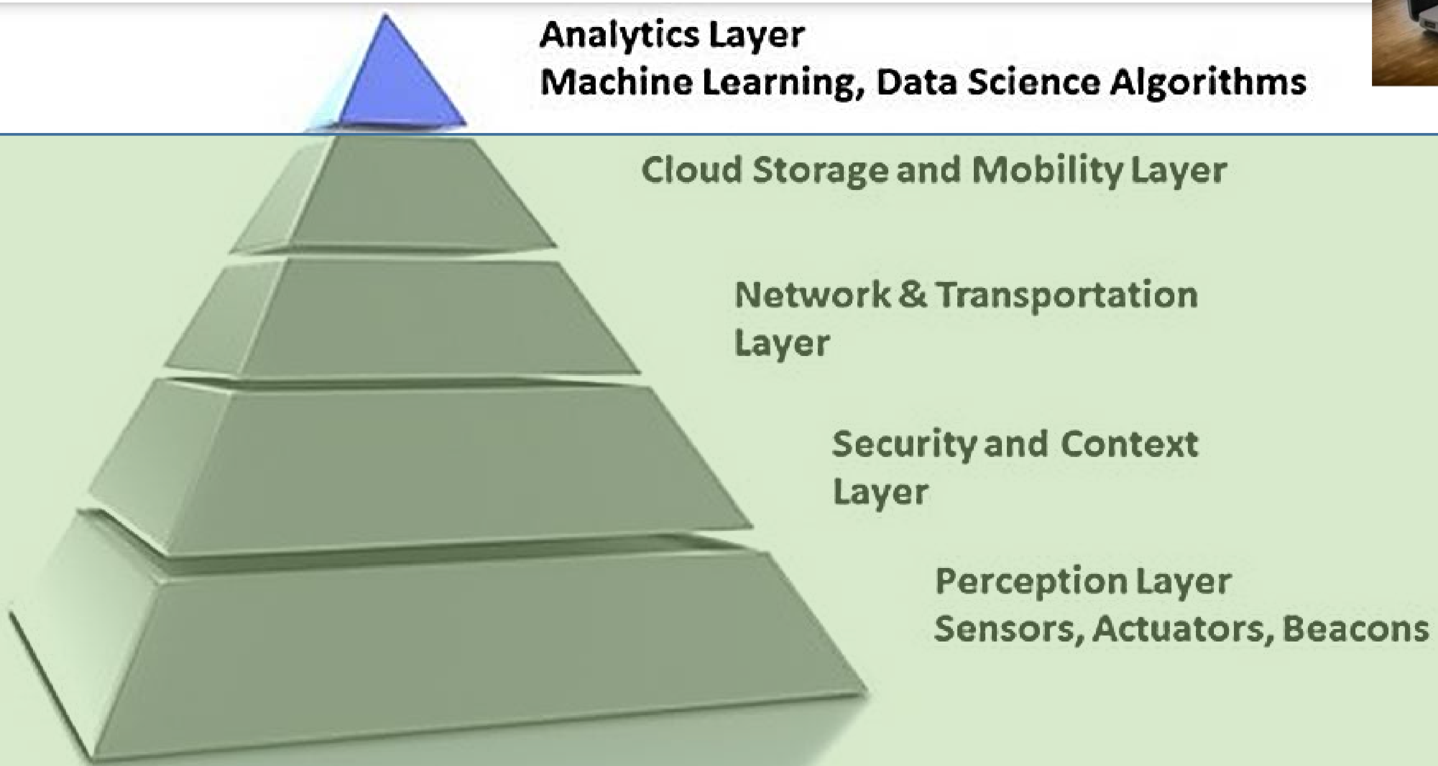


SUZANNE KREITER/GLOBE STAFF

Health officials demonstrated treating an Ebola patient remotely in a mock ICU. Pictured, left to right: Eric Lynn, Julian M. Goldman, Brian Russell, and Dave Arney.

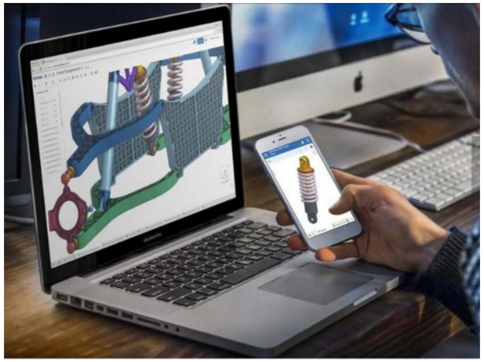
But customers may only pay if intelligent *services* at the point of transaction offers *value*

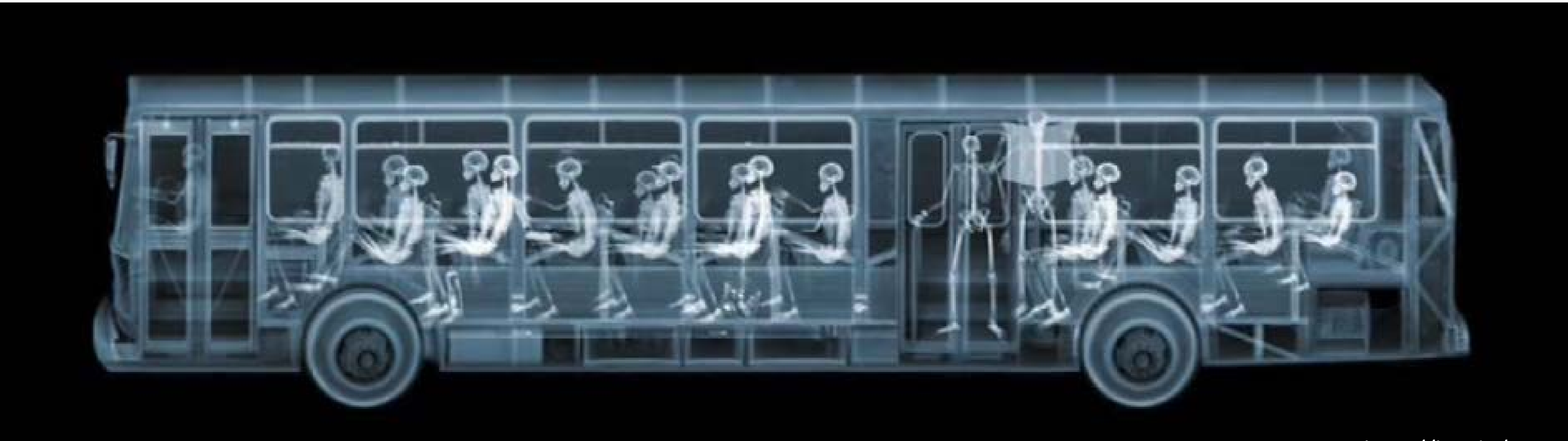




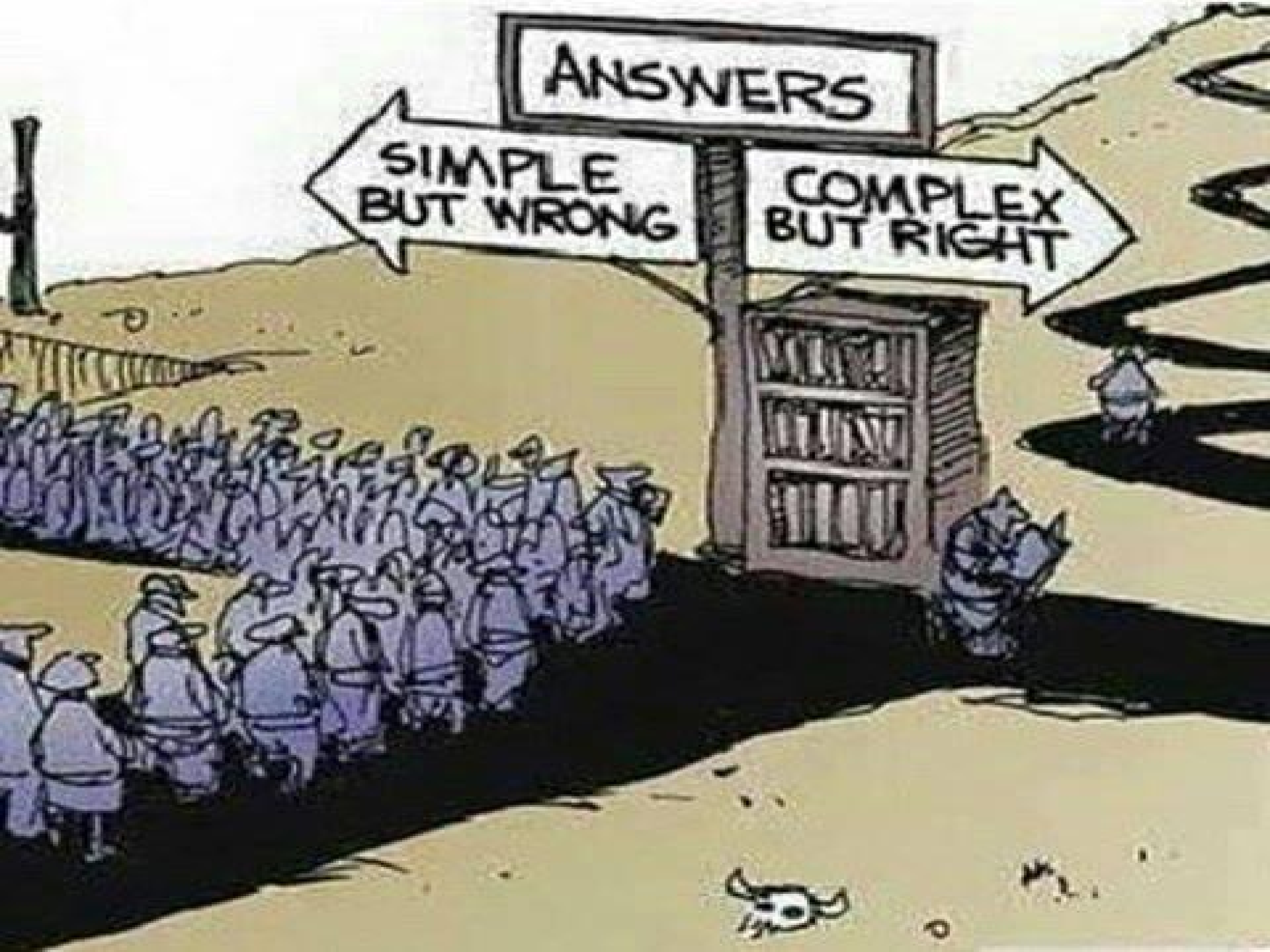
Connectivity – Design Metaphor for Digital Twins?

How do we inculcate connectivity across systems?





http://bit.do/XRAY

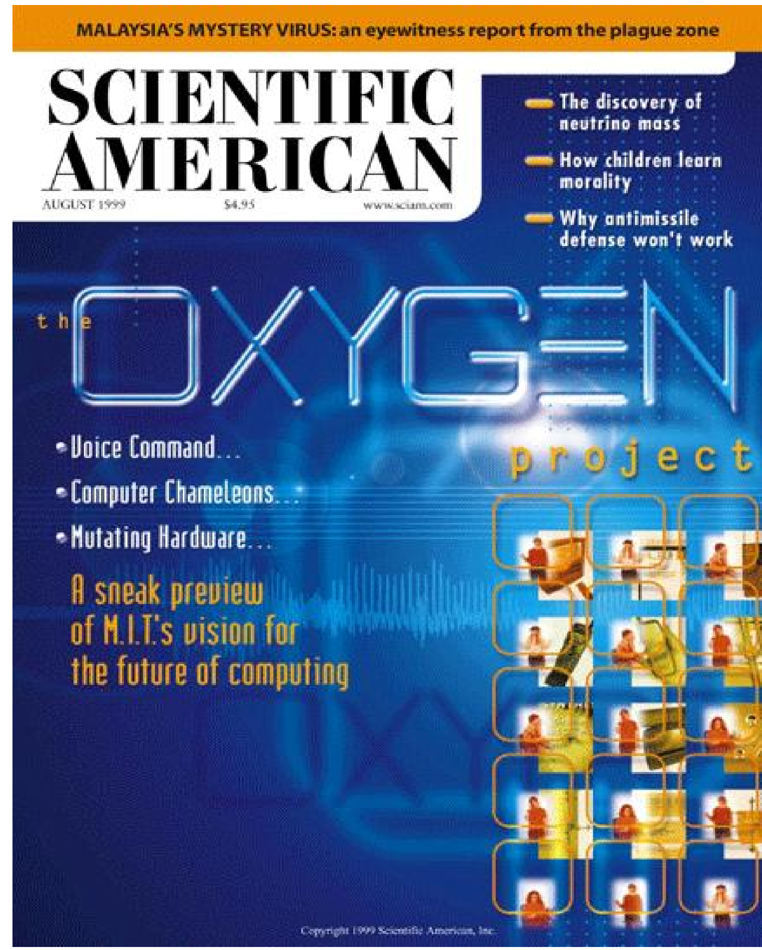

ANSWERS
SIMPLE BUT WRONG
COMPLEX BUT RIGHT

The Target – Outcome seeking Customers

- Component repository
- Configure
- Go Live

The Target – another accomplishment

- Component repository
- Configure
- Go Live



http://bit.do/OXYGEN-1999 ● MIT CSAIL Project Oxygen ● http://bit.do/Randall-Davis-06012002 *ten or even five years before, it would have failed. So it is with every new thing. Progress happens when all factors that make for it are ready and then it is inevitable. (Henry Ford)*

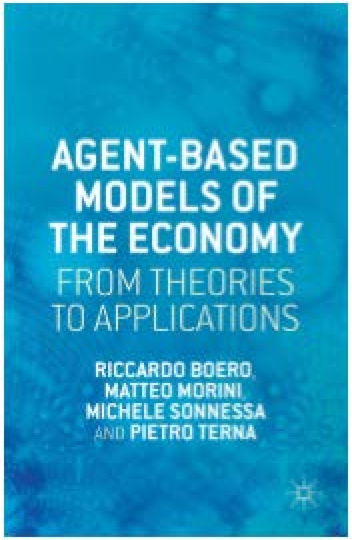
Target for IoT – digital by design services

- **Components (characteristics) in the online repository**
  - Each part (data / metric / state machine) can be an Agent model
    [1] based knowledge representation (semantic framework, OWL)
    [2] embedded with physics/chemistry/biology of the part/material
    [3] equation, logic, constraints (deterministic model) of operation
    [4] data kernel interface (API) to populate/refresh/transmit
    [5] analytics kernel (local or remote/cloud, fog, mist) to process object-specific, context-aware tools for data / applications
    [6] communications kernel (local, batch, remote, push-pull, publish-subscribe) capable of application driven networking (ADN) agnostic of network fabric (fixed, WiFi, SDN, NFV, LTE, 5G, SDR, CR)
    [7] Interoperability, discovery services, ecosystem standards (RDF)
    [8] software defined upgrade, var reconfig, modularity, reusability
    [9] cybersecurity (risk, intruder detection, repulsion, containment)
    [0] convergence by design - IT, OT, telco with autonomy/algorithms

Do we need all attributes for each model? No. For example, 5G latency limit crucial for autonomous driving functions but over-kill for retail shelf replenishment to reduce OOS

Digress – Are Agents anything new? No.

- Used by GM in automated car body painting (Van Dyke Parunak, 1998)
- State Machine Agent Model (1999) ● http://bit.do/State-Machine-Agent
- Agents: Where Artificial Intelligence Meets Natural Stupidity (2002, S Datta) https://dspace.mit.edu/handle/1721.1/41914
- Eric Bonabeau (2002) www.pnas.org/cgi/doi/10.1073/pnas.082080899
- Agent based supply chain inventory planning with RFID (Auto ID Center)
- Agent based models of the economy (Nature, 2009) http://bit.ly/AGENTS-in-ECONOMY
- Agent-Based Models of the Economy (Book, 2015)



Agent-based model for parts / variables

- Previous examples – RETSINA (CMU), Haystack (MIT)
- Equation based model (EBM) of a variable – see EViews
- Time series econometrics – applications (ARCH, GARCH)

Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) ● Datta & Granger, 2005

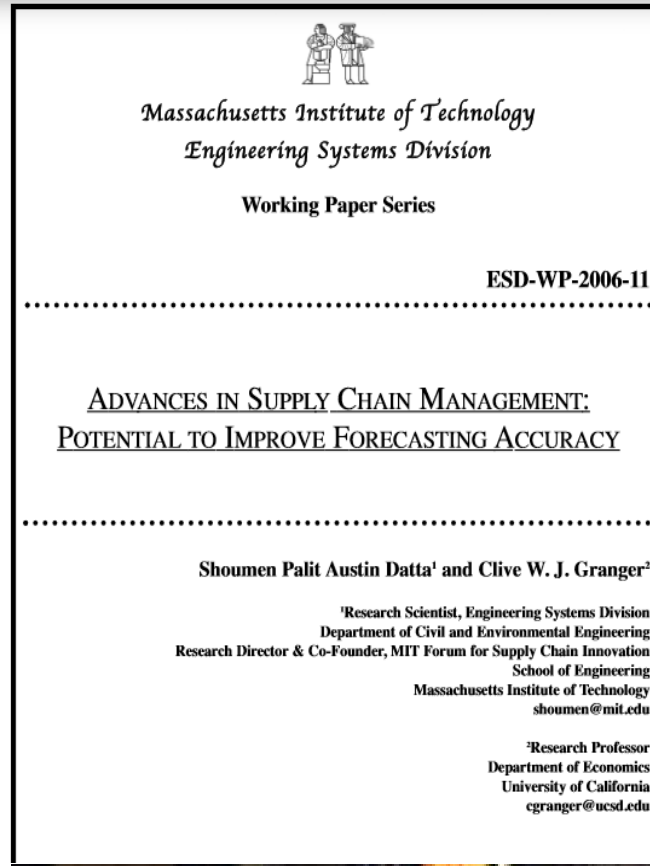
$$y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j y_{t-j} + \sum_{k=1}^{K} \sum_{i=1}^{N_{x_{kt}}} \alpha_{ki} x_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon^2_{t-1} + \theta_2 \varepsilon^2_{t-2} + \ldots + \theta_q \varepsilon^2_{t-q}$$

Variance of the random error term DEPENDS NOT ONLY on previous lagged errors (t-1, t-2, …., t-q) but also on LAGGED VALES OF THE VARIANCE (t-1, t-2, …, t-p)

$$y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j y_{t-j} + \sum_{k=1}^{K} \sum_{i=1}^{N_{x_{kt}}} \alpha_{ki} x_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \sum_{i=1}^{q} \theta_i \varepsilon^2_{t-i} + \sum_{j=1}^{p} \tau_j \sigma^2_{t-j}$$


Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2006-11

ADVANCES IN SUPPLY CHAIN MANAGEMENT: POTENTIAL TO IMPROVE FORECASTING ACCURACY

Shoumen Palit Austin Datta[1] and Clive W. J. Granger[2]

[1]Research Scientist, Engineering Systems Division
Department of Civil and Environmental Engineering
Research Director & Co-Founder, MIT Forum for Supply Chain Innovation
School of Engineering
Massachusetts Institute of Technology
shoumen@mit.edu

[2]Research Professor
Department of Economics
University of California
cgranger@ucsd.edu

Dr Shoumen Datta, MIT
Eml shoumen@mit.edu

This is also about big data – before big data hype.

Transformation of Equations to Agents? Using classical AI approaches (eg ANN)

EBM - Explanatory Variables

Example of X:
[1] Inventory
[2] Price
[K] Expiration

S A L E S

$$y_t = \beta_0 + \boxed{\beta_1 x_{1t}} + \boxed{\beta_2 x_{2t}} + \ldots + \boxed{\beta_K x_{Kt}} + \varepsilon_t$$

Inventory Agent

Price Agent

Expiration Agent

ABM – Agents in Decision Support

Dr Shoumen Datta, MIT <shoumen@mit.edu>

Decoupling Static EBM to form ABM

1. $$y_t = \beta_0 + \underbrace{\boxed{\beta_1 x_{1t}}}_{\text{Inventory}} + \underbrace{\boxed{\beta_2 x_{2t}}}_{\text{Price}} + \ldots + \underbrace{\boxed{\beta_K x_{Kt}}}_{\text{Expiration}} + \varepsilon_t$$

2. $$y_t = \beta_0 + \boxed{\beta_1 x_{1t}} + \blacksquare + \ldots + \boxed{\beta_K x_{Kt}} + \varepsilon_t$$

3. $$y_t = \beta_0 + \boxed{\beta_1 x_{1t}} + \boxed{a_2 z_{2t}} + \ldots + \boxed{\beta_K x_{Kt}} + \varepsilon_t$$

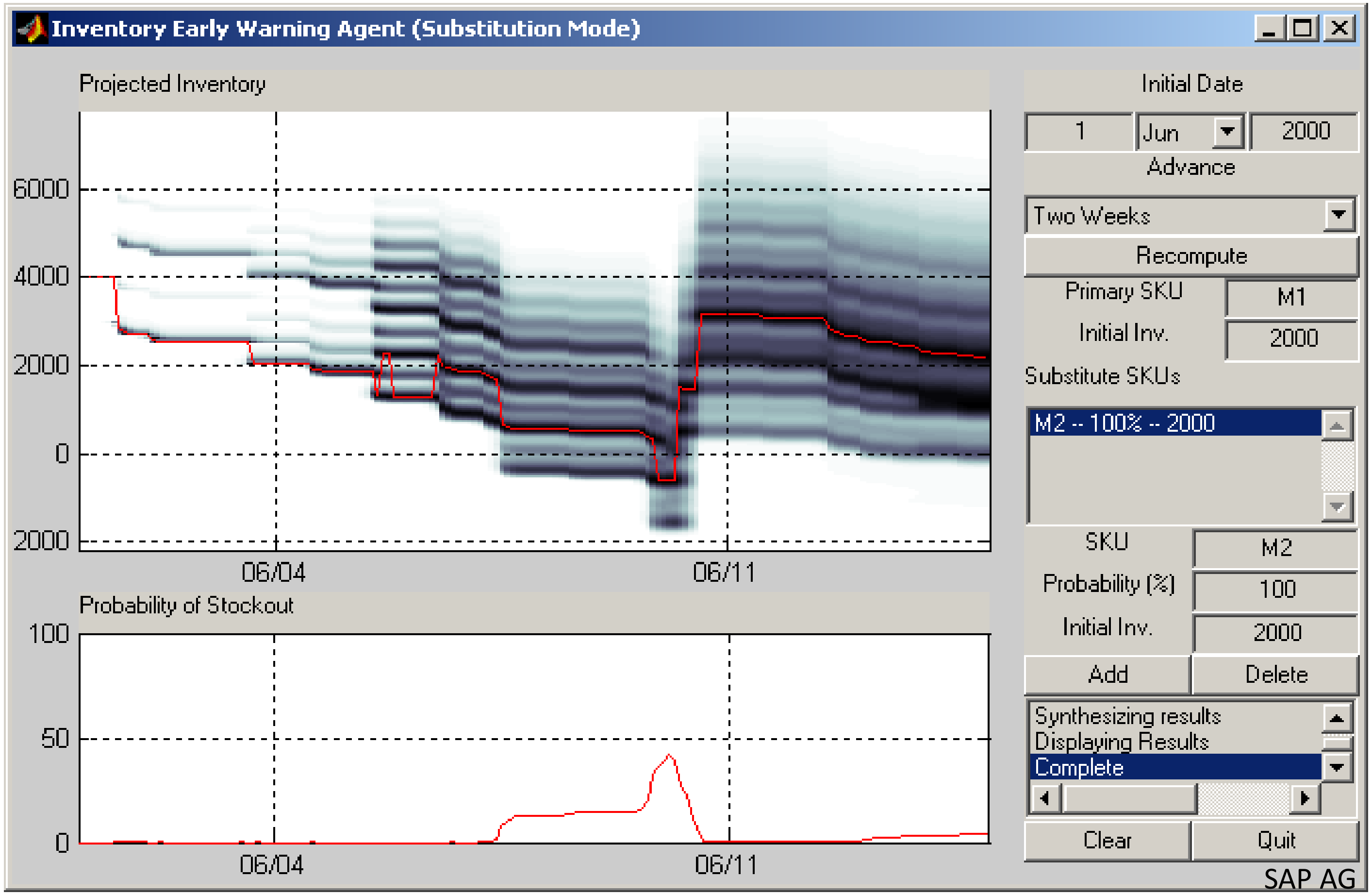
CONTEXT RELEVANT VARIABLE AGENT SURGERY

Dr Shoumen Datta, MIT <shoumen@mit.edu>

June 2000 ● RFID in Supply Chain Management ● Auto ID Center, MIT

Operation of a Multi-Agent System (ABM) to Reduce Out of Stock (Inventory Planning)

Data Agents collect ► Data
Monitoring Agent triggers ► Alert
Inventory Management Agent executes ► Substitution



M2 can be substituted for SKU M1

Inventory of M2 is 2000

OOS Danger

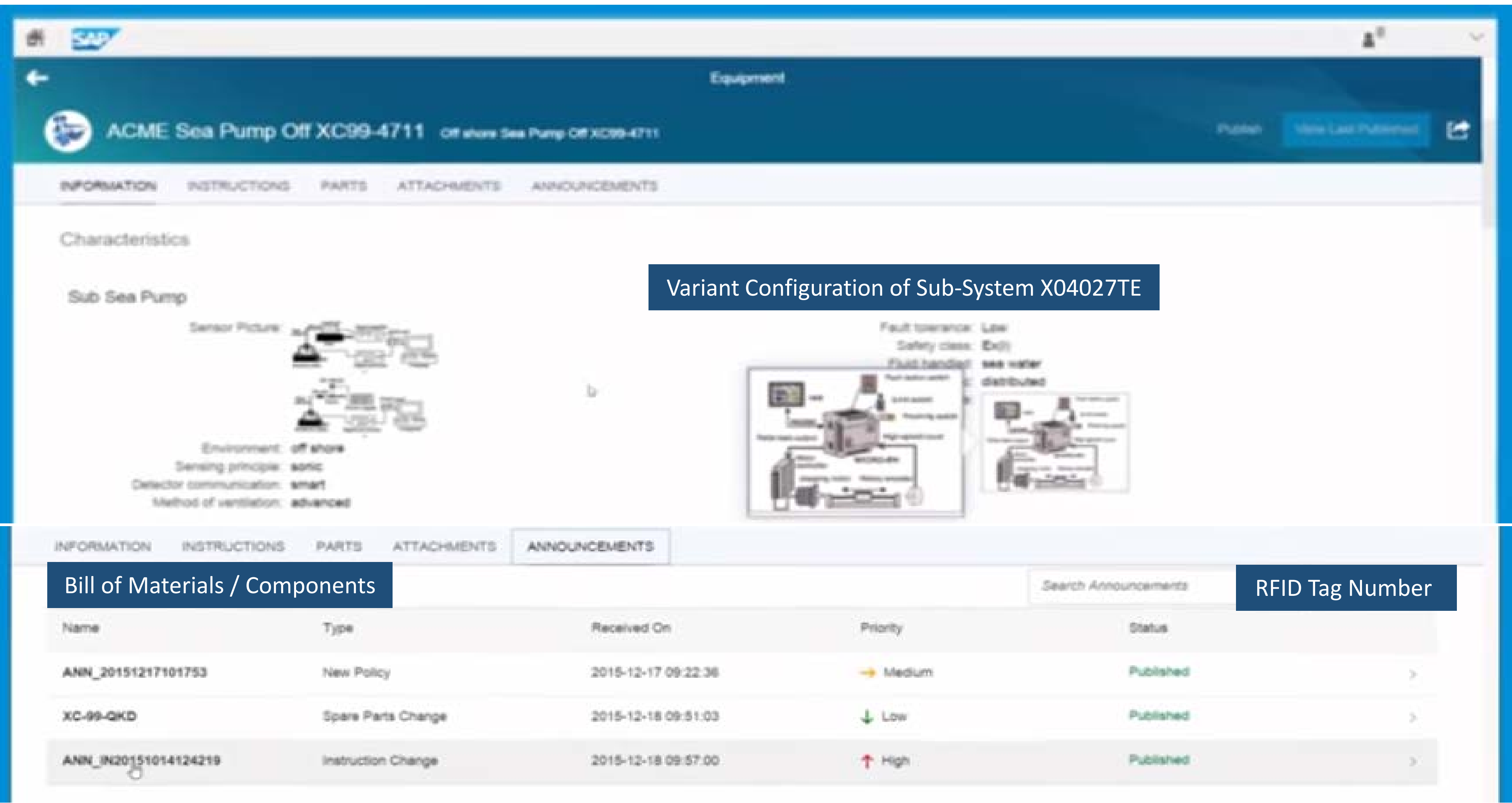
Less chance of a stock out with substitution via agent actions (M1 & M2)

So what's next in IoT era?

Connecting state machine agent models to configure complete systems and connect/transmit/analyze data

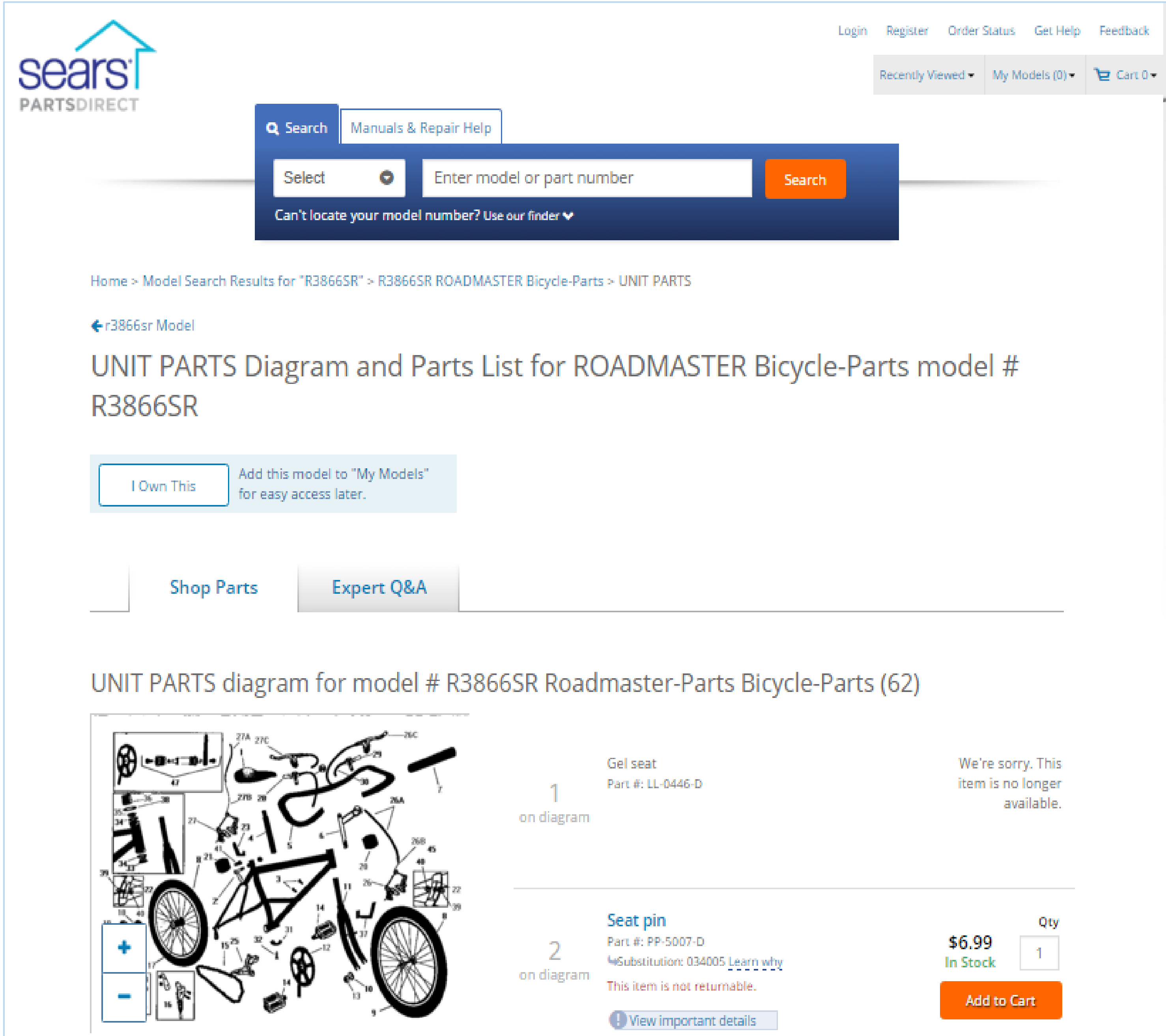
The Target – for IoT era service providers

- **Components (online) repository**
  - Visualization – how it may "look" for customers



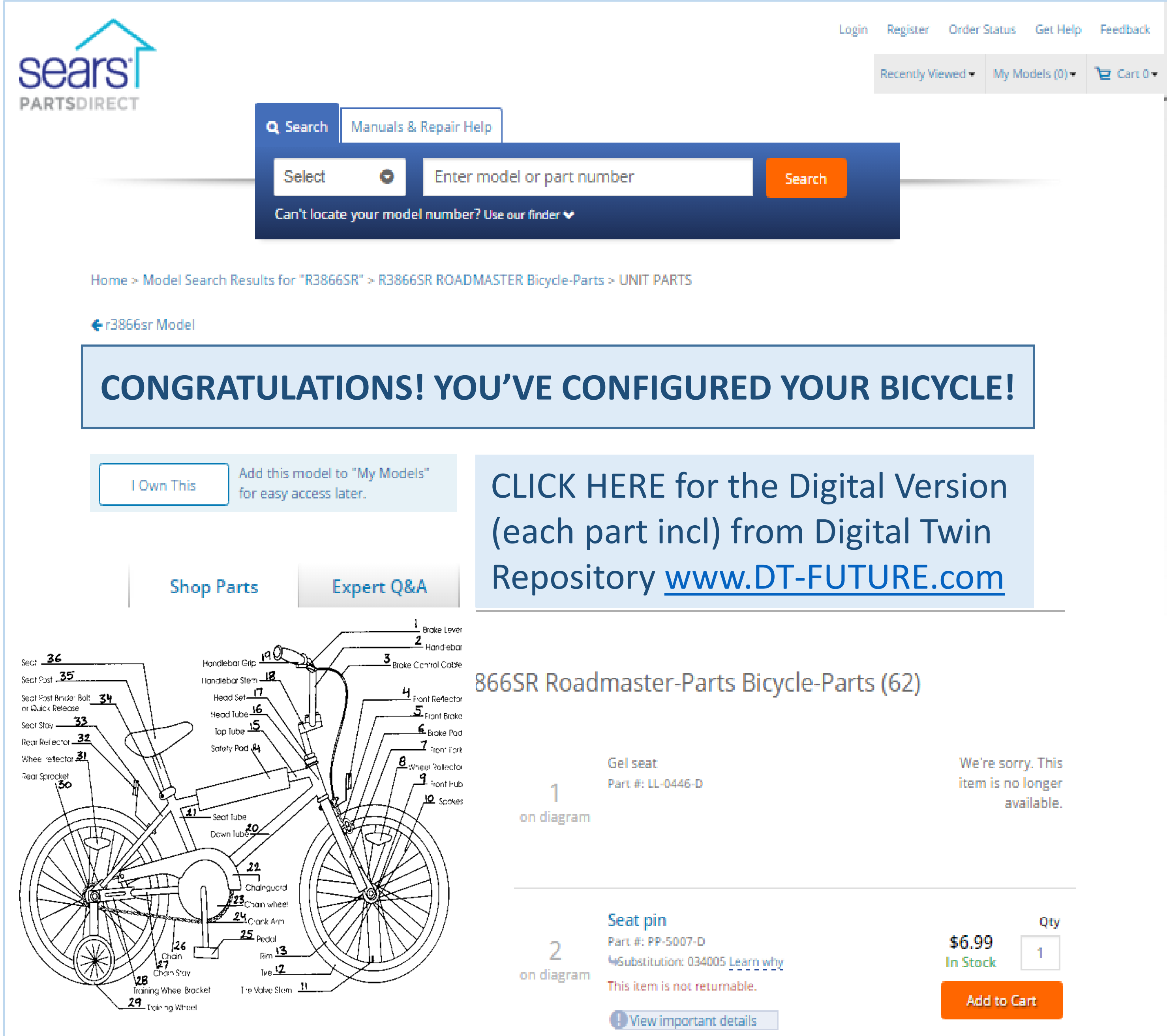
The Target – Outcome seeking Customers

- Component
- **Configure**
- Go Live



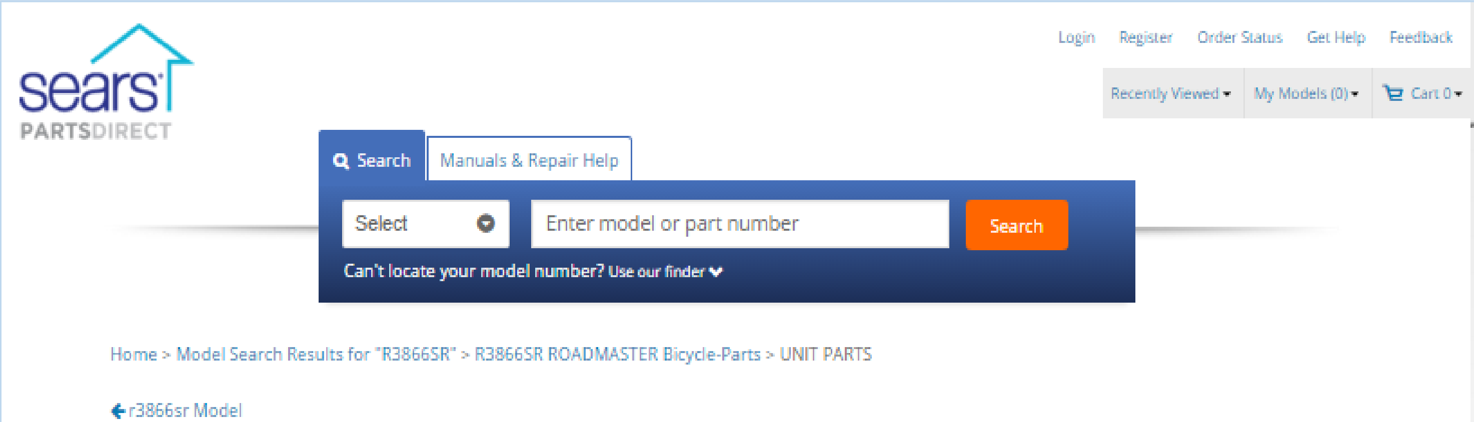
The Target – Outcome seeking Customers

- Component
- **Configure**
- Go Live



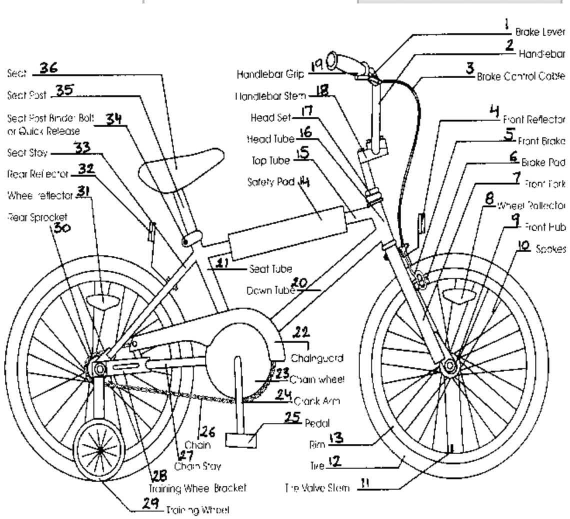
The Target – Outcome seeking Customers

- Component
- **Configure**
- Go Live



CONGRATULATIONS! YOU'VE CONFIGURED A DIGITAL TWIN

CLICK "GO LIVE" to activate your Digital Twin bike and transport it to any smartphone - click DT App



The Target – Outcome seeking Customers

- Component
- Configure
- **Go Live**

Go Live

Instructions

After you've configured the physical bicycle go to the Digital Twin site and authenticate the sensors to access your WiFi, BT, UWB gateway for mesh network to communicate between your bicycle and your devices (laptop, phone, tablets, wrist-watch). Allow auto-discovery mode to find context relevant data (weather)

sears PARTSDIRECT

Login Register Order Status Get Help Feedback

Recently Viewed My Models (0) Cart 0

Search | Manuals & Repair Help

Select | Enter model or part number | Search

Can't locate your model number? Use our finder

Home > Model Search Results for "R3866SR" > R3866SR ROADMASTER Bicycle-Parts > UNIT PARTS

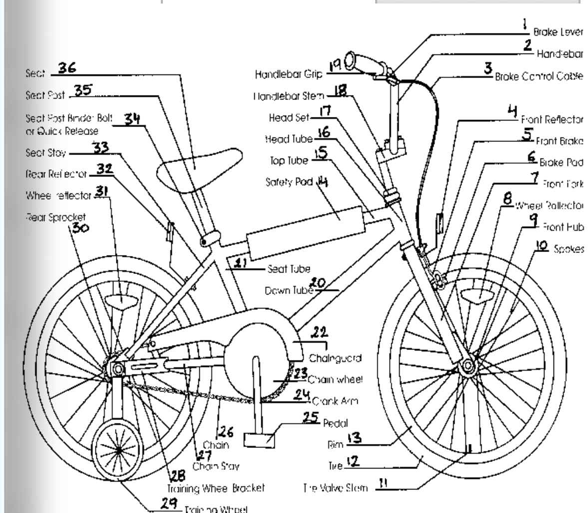
r3866sr Model

CONGRATULATIONS! YOU'VE CONFIGURED A DIGITAL TWIN

I Own This — Add this model to "My Models" for easy access later.

CLICK "GO LIVE" to activate your Digital Twin bike and transport it to any smartphone - click DT App

Shop Parts | Expert Q&A



The Target – Outcome seeking Customers

- Component
- Configure
- **Go Live**

Go Live

Instructions

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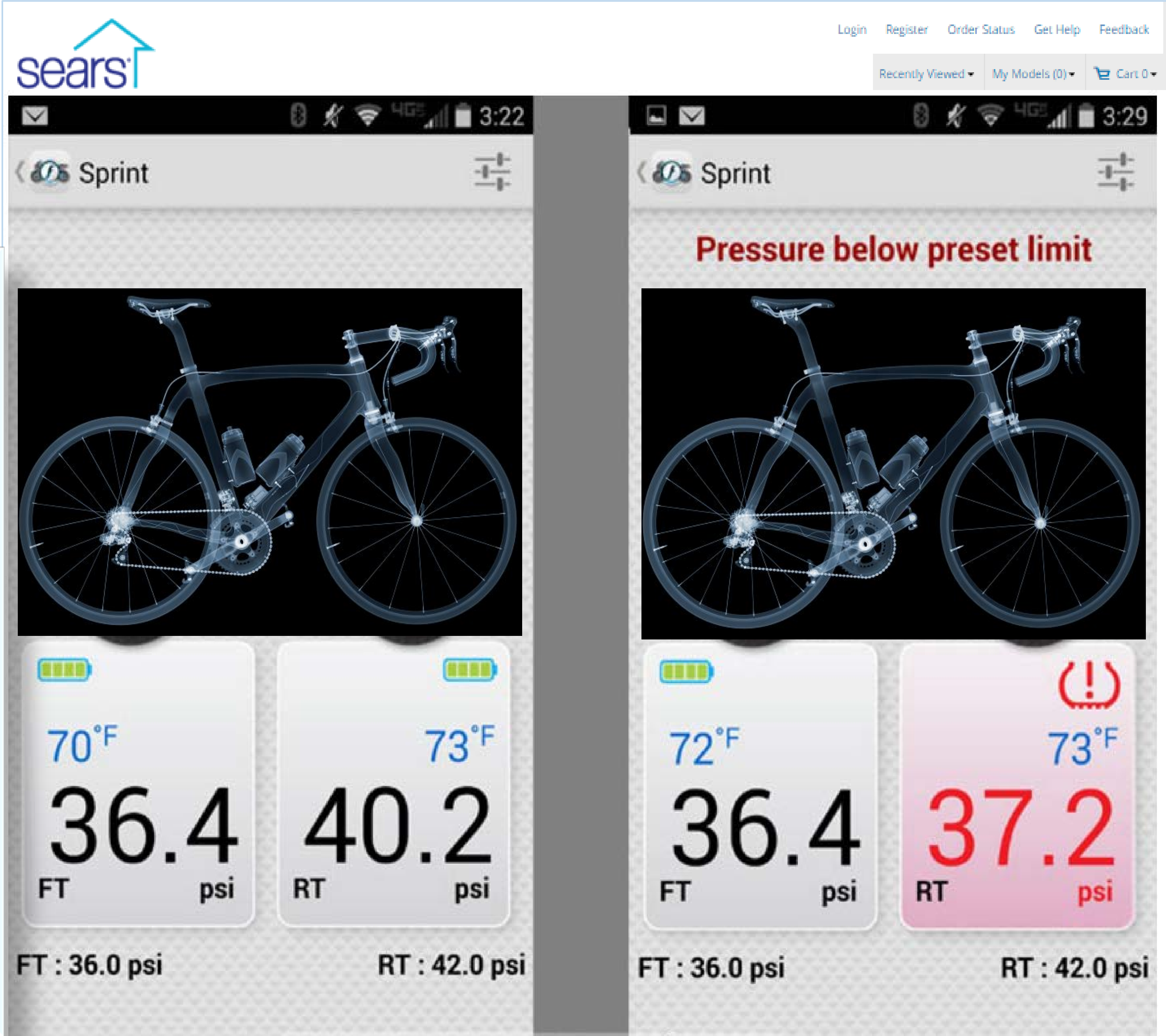
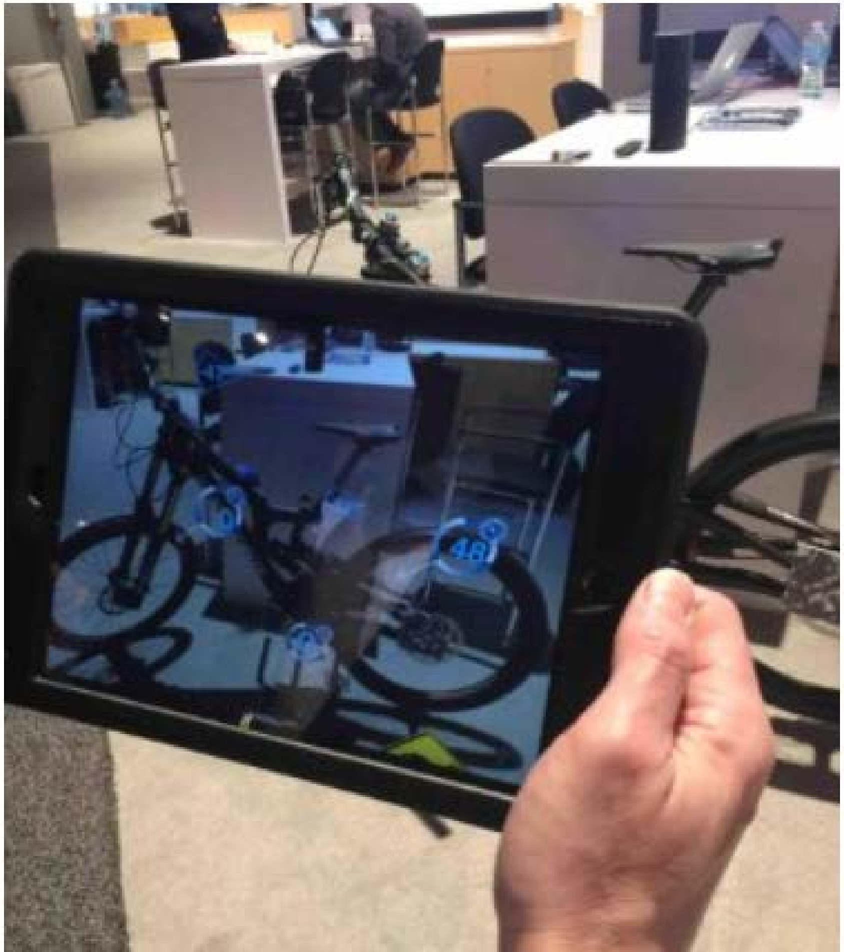


The Target – Outcome?

@Sapphirenow with Paul Clark at booth PS612 demonstrating our connected bike #IoT demo for @HPE_IOT. Follow me on Twitter @JRFuller321

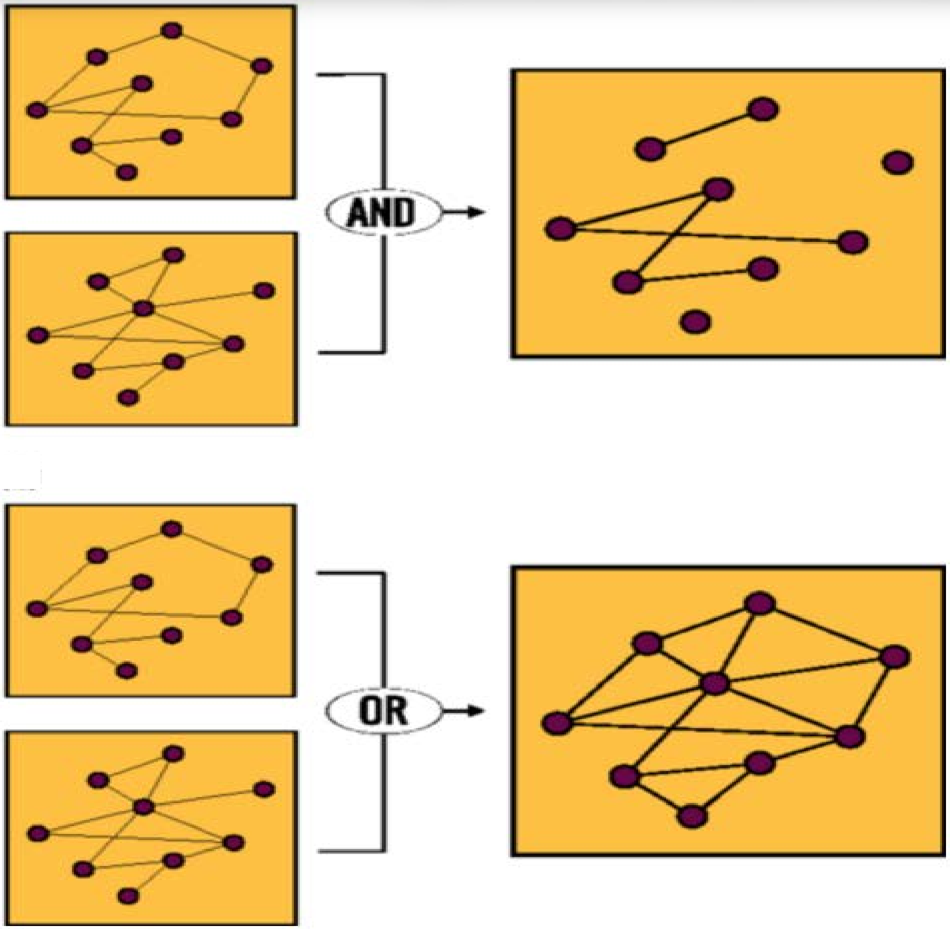


The Target – Outcome?

Real World Volatility

PARTS, SENSORS, NATURAL LAWS, AUTONOMY, ANALYTICS

In industrial environments, networks and connections may configure and re-configure with high or ultra-high velocity. Are Agents or Agencies better suited for dynamic transition states?



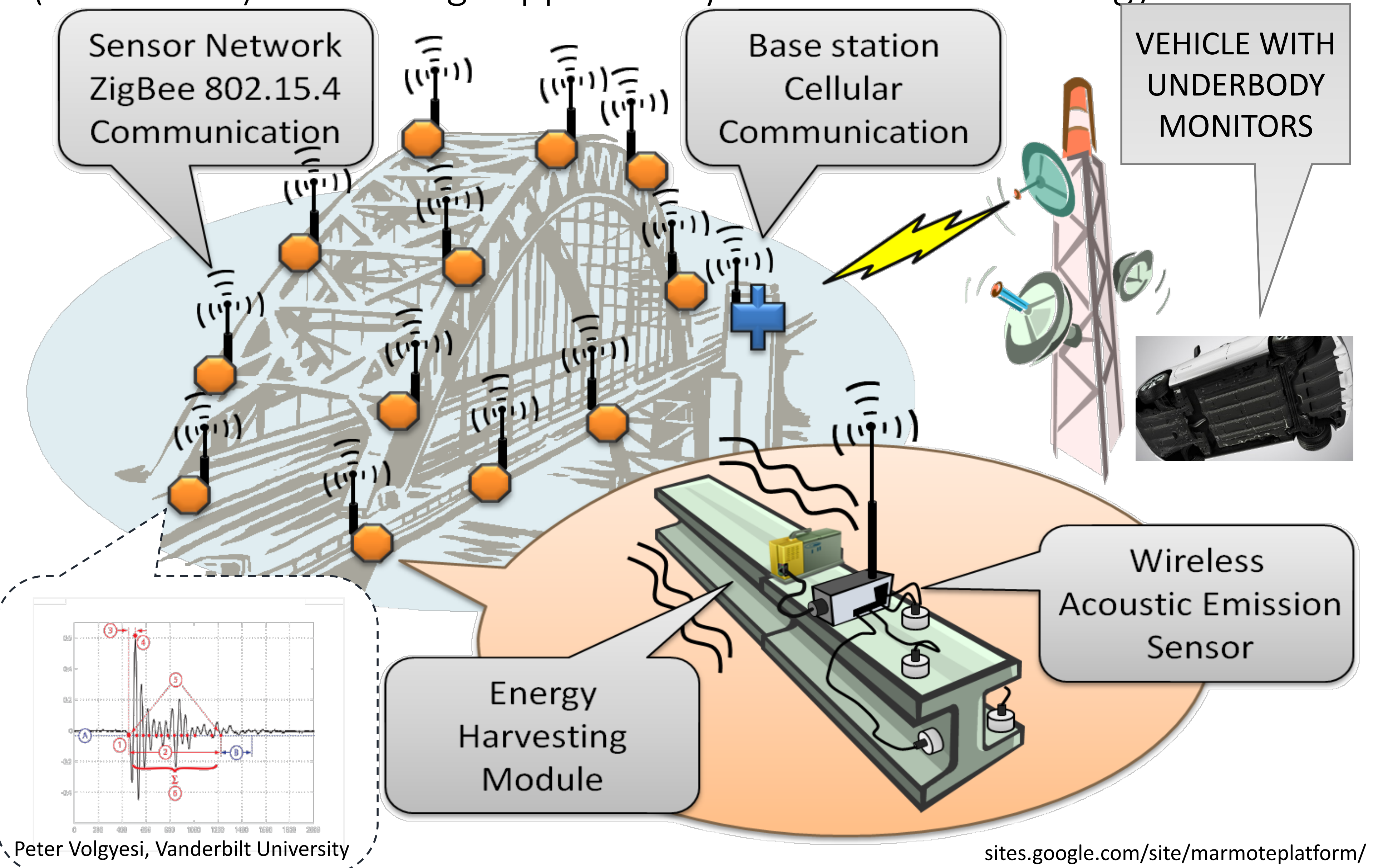
PHYSICAL REVIEW X **6,** 011036 (2016)
http://journals.aps.org/prx/pdf/10.1103/PhysRevX.6.011036

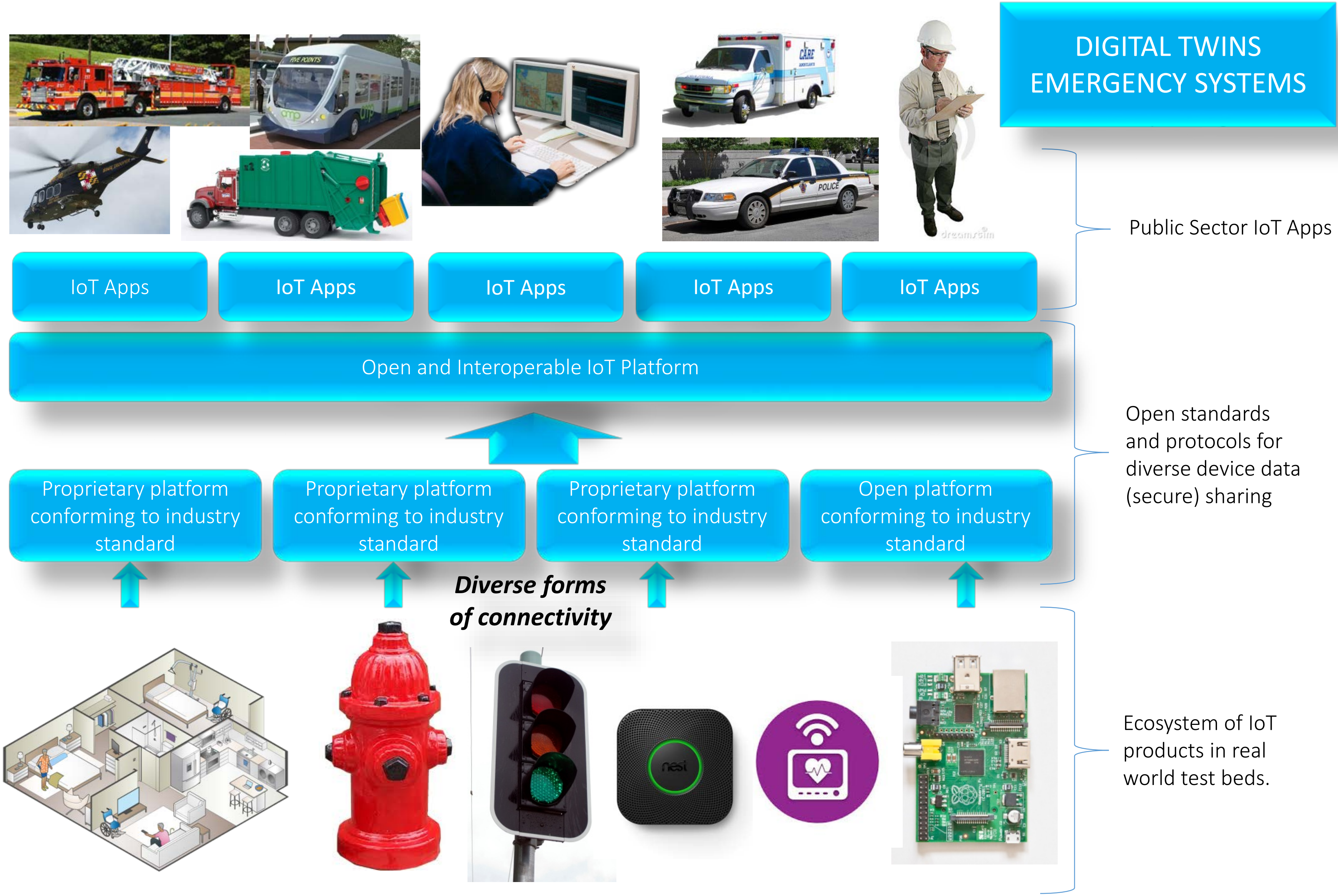
Multilayer Stochastic Block Models Reveal the Multilayer Structure of Complex Networks

Toni Vallès-Català,[1] Francesco A. Massucci,[1] Roger Guimerà,[2,1,*] and Marta Sales-Pardo[1,†]
[1]*Departament d'Enginyeria Química, Universitat Rovira i Virgili, 43007 Tarragona, Catalonia, Spain*
[2]*Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona 08010, Catalonia, Spain*
(Received 30 June 2015; revised manuscript received 23 December 2015; published 31 March 2016)

DIGITAL TWIN application - Critical Infrastructure Monitoring - Digital Twin System of Systems

Autonomous vibration (accel-erometers), stress (strain gauges) & cracks (AE sensors) monitoring supported by vibration-based energy harvester





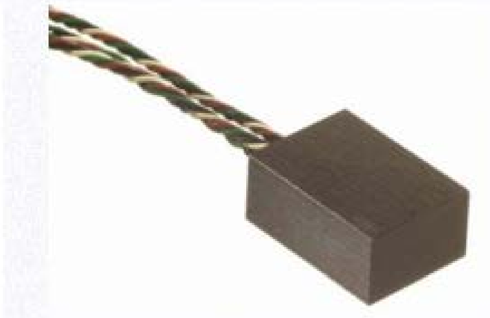
UC Irvine, MIT, IBM, Intel, AT&T, SigFox, Brivo Labs, Senseware, N5 Sensors, Responder, Del Ray Analytics, biobright, EIC Data, IoT DC, Captiva, Earth Networks, US DoD (TATRC), Victory Housing and Montgomery County, Maryland, USA.

Digital Twins ● Emergency Systems and Remote Response

Systemic foundational compass essential for smart anything

SENSORS

Thru hole, Triaxial



Miniature Triaxial

63 Accelerometer

High accuracy IS transmitter

Atex 4-20mA low cost

4-20mA for corrosive fluids

What does the data suggest about my health?

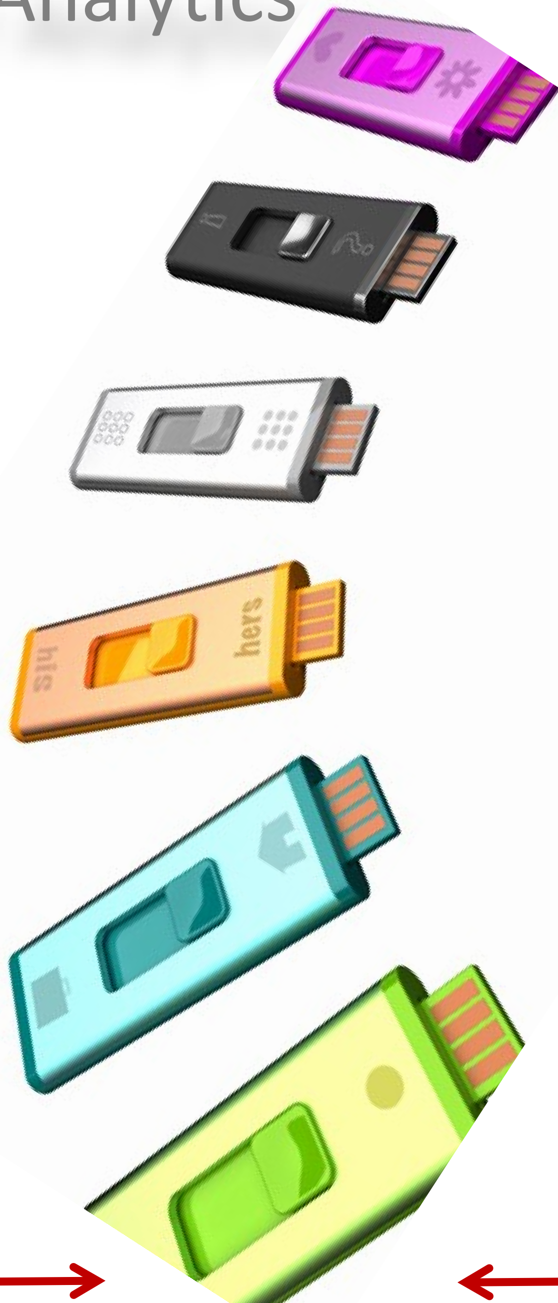
Pay 1c Per Analytics

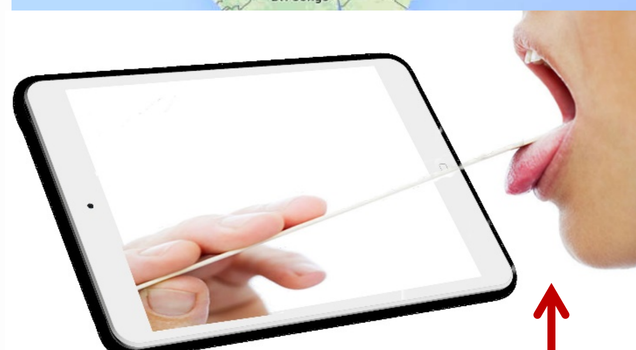
SENSORS

Glucose Sensor

Cholesterol Sensor

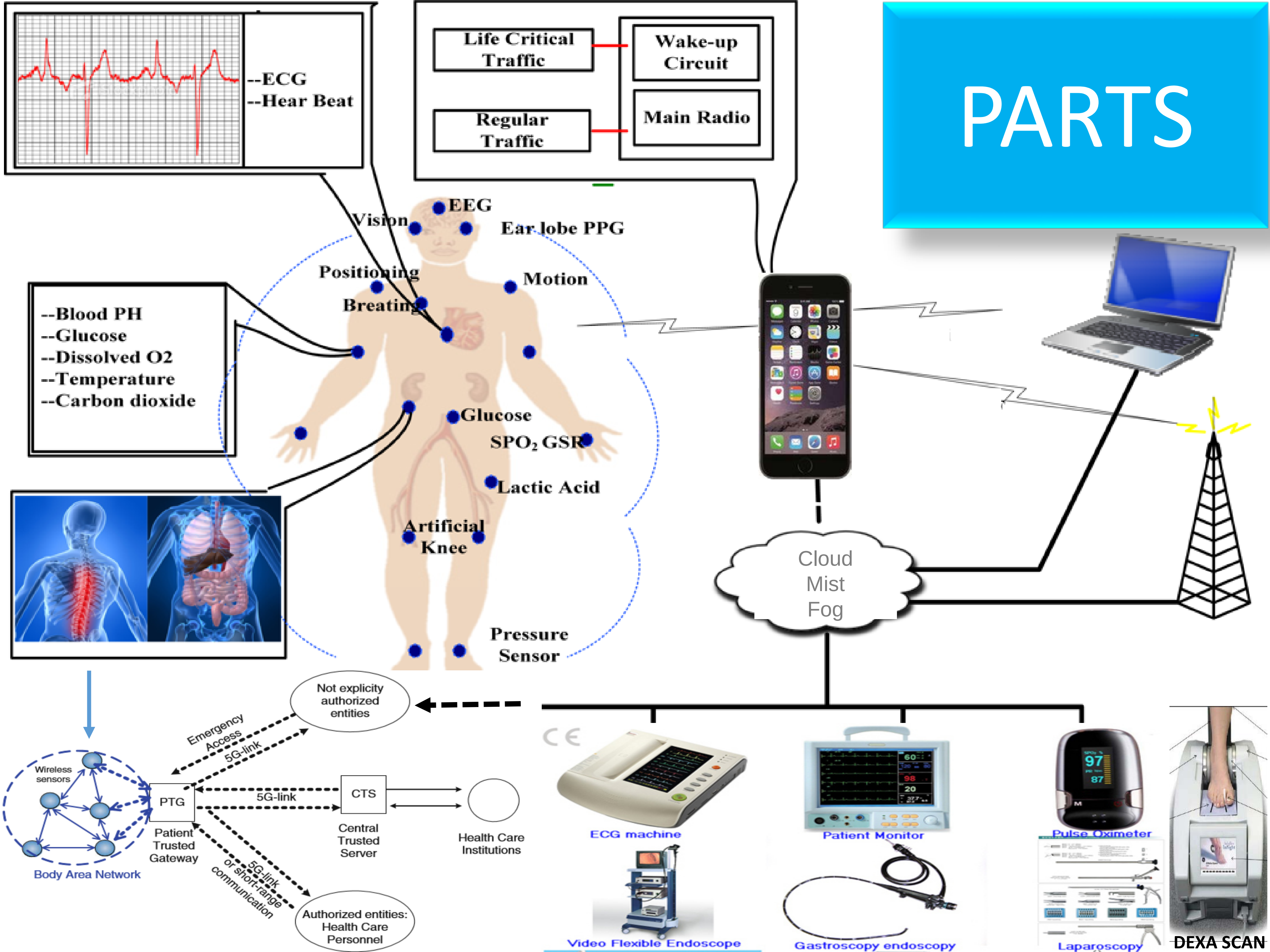
BNP Sensor





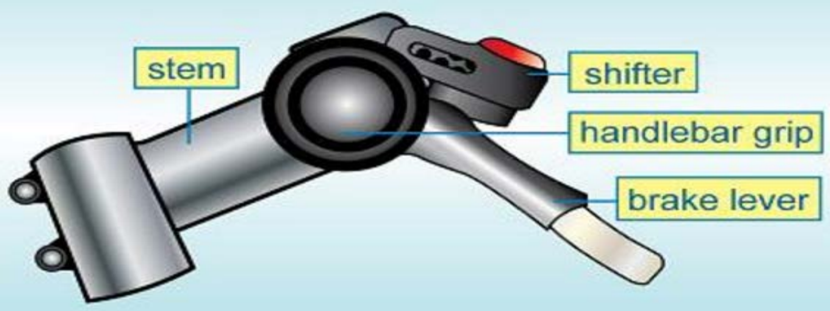
Hot swappable, modular, smart

NK Labs
ARA Prototype



PARTS
--ECG
--Hear Beat
Life Critical Traffic
Regular Traffic
Wake-up Circuit
Main Radio
EEG
Vision
Ear lobe PPG
Positioning
Motion
Breating
--Blood PH
--Glucose
--Dissolved O2
--Temperature
--Carbon dioxide
Glucose
SPO₂ GSR
Lactic Acid
Artificial Knee
Pressure Sensor
Cloud
Mist
Fog
Not explicity authorized entities
Emergency Access
5G-link
Wireless sensors
PTG
Patient Trusted Gateway
Body Area Network
5G-link
CTS
Central Trusted Server
Health Care Institutions
5G-link or short-range communication
Authorized entities: Health Care Personnel
ECG machine
Patient Monitor
Pulse Oximeter
Video Flexible Endoscope
Gastroscopy endoscopy
Laparoscopy
DEXA SCAN

PARTS



Nitto Technomic Road 1 Quill Stem 100mm 72 Degree 225mm

$33.15

Promax X4 Handlebar Bar Alloy Riser Stem 80mm 80

$15.57

Free Shipping

Sakae Stem & Handlebars Mountain Bike

$7.00

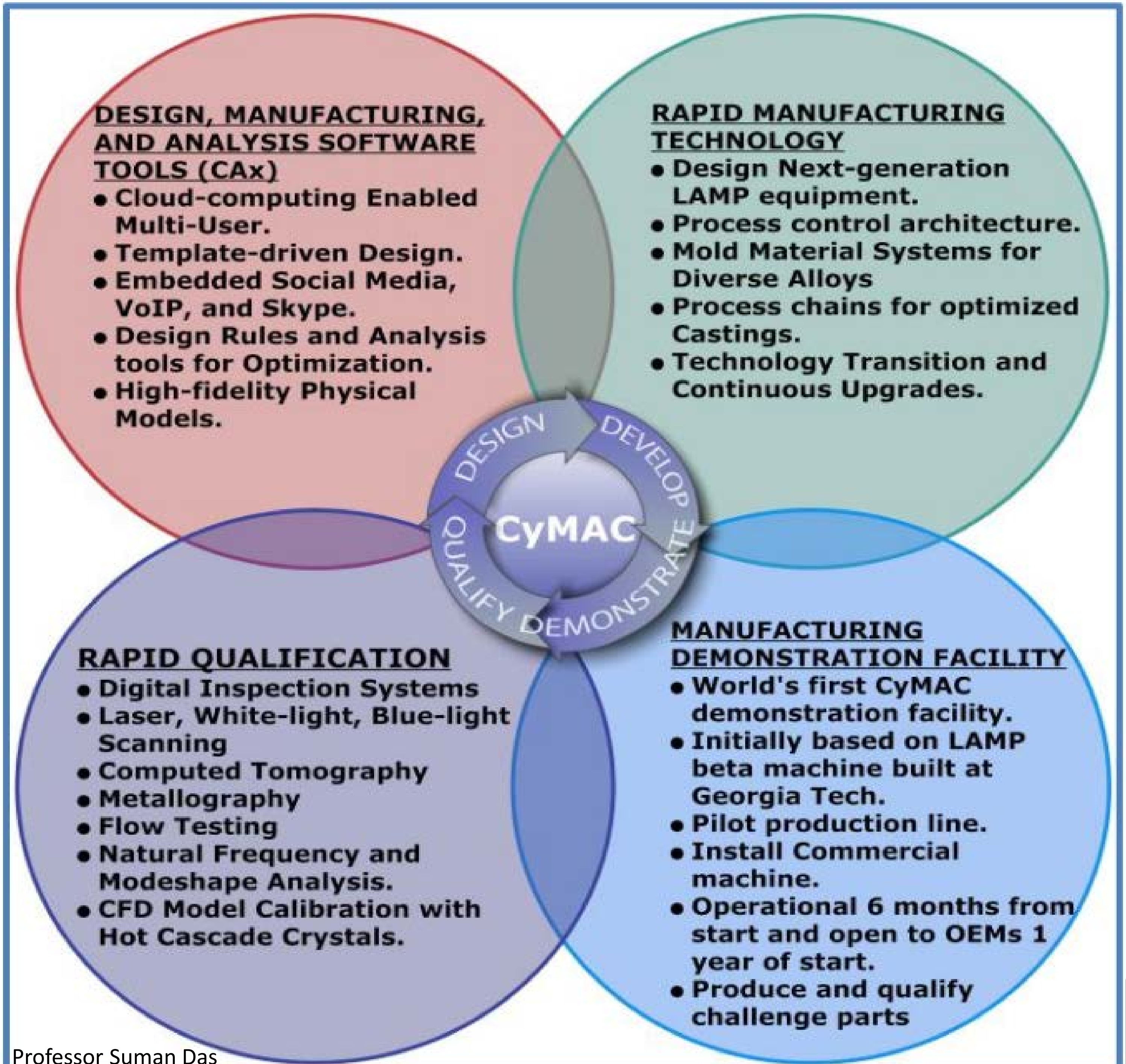
Thomson Elite X4 Mountain Bike Stem 70mm 31.8mm

$76.87

Free Shipping

3D Fuel Nozzle
GE Leap Engines

3D PARTS

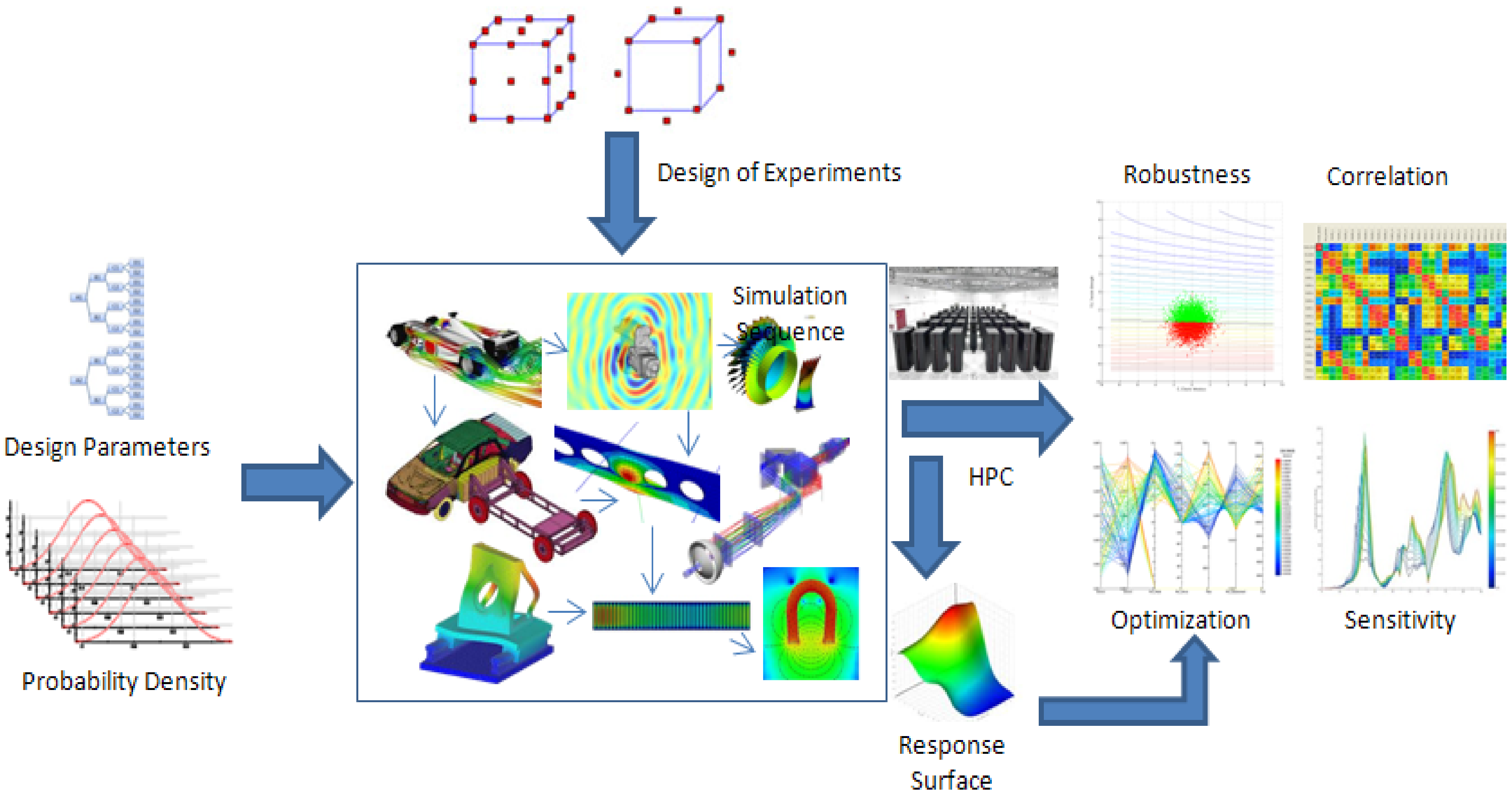


3D Fuel Nozzle
GE Leap Engines

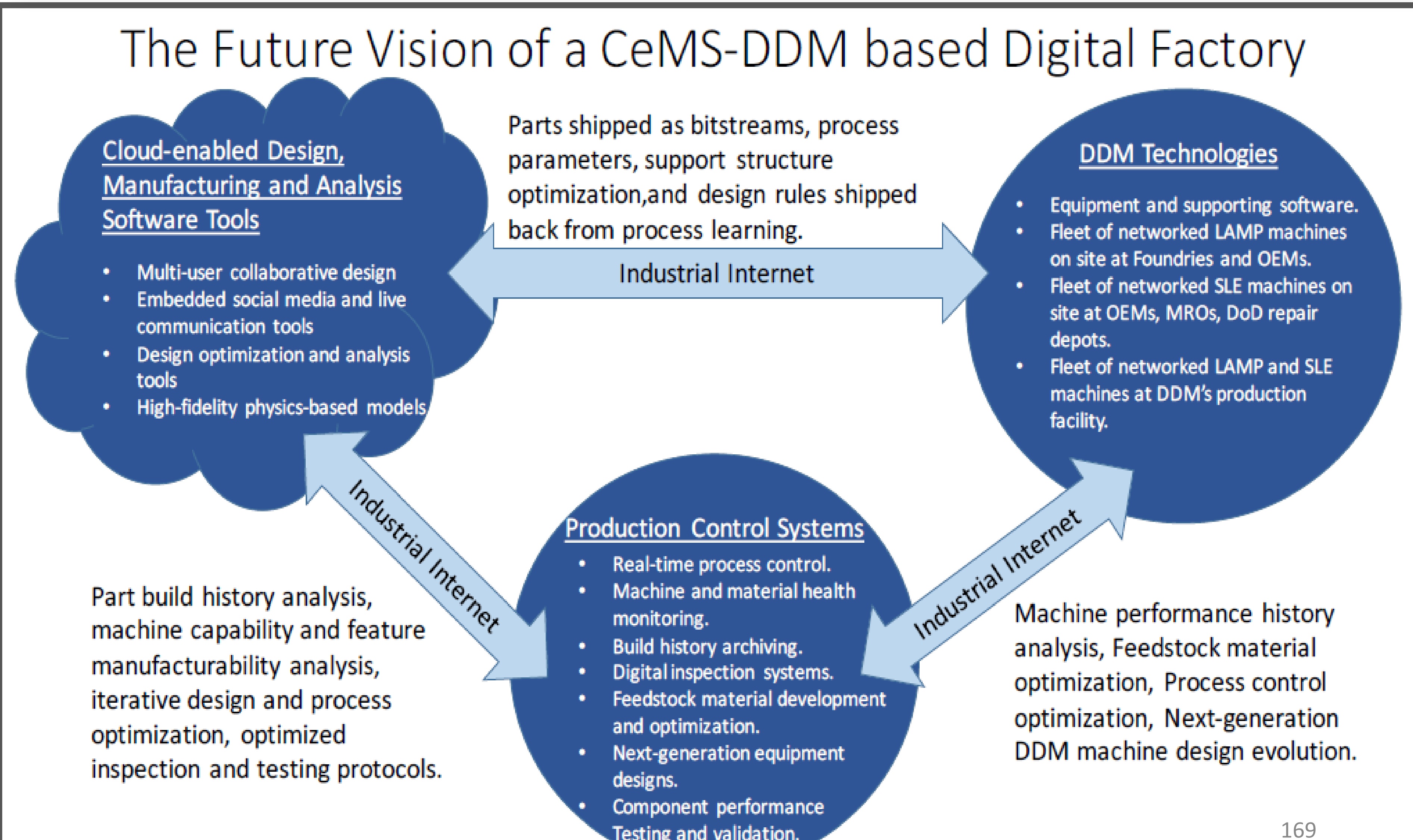
Is Inventory Necessary?

Digital Twins in an era of Cyber-Manufacturing

Simulated Design Environment and Integration with 3D Printing, Metrology, Re-configuration



Next Generation of Digital Twins evolves with 3D/4D Printed Parts and Material Science Design, Re-Engineering, Manufacturing, Data Analytics, Maintenance and Supply Chain



Professor Suman Das

Immelt: GE will use 100-year legacy to bridge physical and digital, create $15 billion software company

In 2015, GE inaugurated a new, Multi-Modal manufacturing facility in Chakan, India. If the company's ambitions for the space are realized, it could drive a massive change in global manufacturing.

It is hard to imagine, with its iconography of billowing smoke and raging furnaces, that a factory would ever be called "brilliant" or "flexible." But, global behemoth General Electric wants to change the way you think about those far away, smoke-belching buildings and introduce you to a new era—maybe even a revolution—in manufacturing.

In 2015, GE unveiled its first ever US $200 million "Multi-Modal" facility in Chakan, located in the Indian state of Maharashtra, which it thinks will be the agent of this change. It was inaugurated by Narendra Modi, the Indian Prime Minister who is confronted by the huge challenge of delivering jobs to hundreds of millions of youth who lack measurable skills. The factory won't be solving that gargantuan problem since it staffs a mere 1,500 technicians and engineers, but it's not meant to, at least not in a direct way. Instead, the factory promises to create an enormous, positive ripple effect both inside and outside India that will impact employment and supply chains, as well as promote radical new designs and industrial innovation like never before.

www.techrepublic.com

Are independent variables similar in principle to components (ABM) in Digital Twins?

The ability to design independent variables as ABM is one principle from GARCH which may drive the creation of ABM repositories of components (from machines, sensors or devices). To drag and drop (plug and play) modular components, ABM may abstract away the EBM related to the physics of the components (in terms of its material and operation). It may enables non-experts (managers) to create/configure the digital twin of their machines and sensors without requiring engineers with expertise in the physics of the part and the differential equations representing its operations. Transforming this idea into reality may enable the democratization of digital twins and catalyze their widespread diffusion as well as adoption in very diverse verticals (machines in manufacturing, devices connected to patients in hospitals, plants in nuclear energy facilities, adjusting security levels on-demand, coordinating objects in an emergency or crash to care scenario). These complex and volatile system of systems may be amenable for digital twin representation if semantic interoperability between component model standards can navigate between multi-lingual repositories and IT/OT can converge with telco in a manner that digital twin creation auto-triggers *ad hoc* self-organization of network/gateway to ***discover*** and feed context-aware data to the virtual clone using (one or more or all available) network function which is application-driven and protocol agnostic (cellular, WiFi, BT, UWB, 3G, LTE, 5G, NFV).

Who will create and maintain the repository of parts, sensors, sub-systems?

PAY-PER-USE MICRO-REVENUE

Digital Twin Design as a Service?

ADAPTABLE ?
SOFTWARE DEFINED?

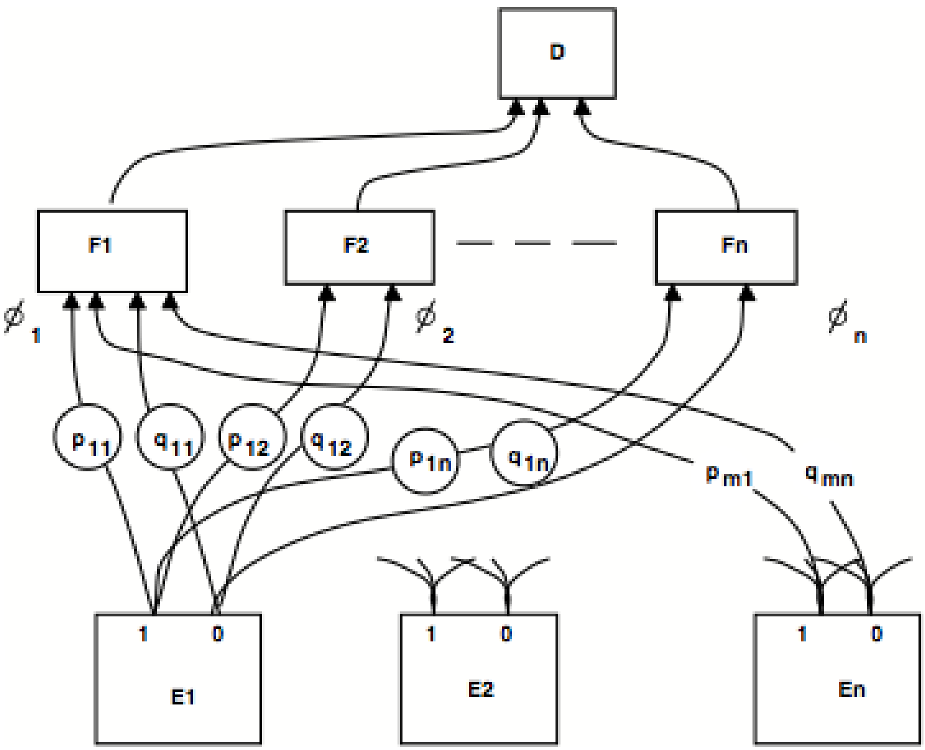
SENSORS

Suggestions from 2001

(is in progress)

Why not upgrade with software?

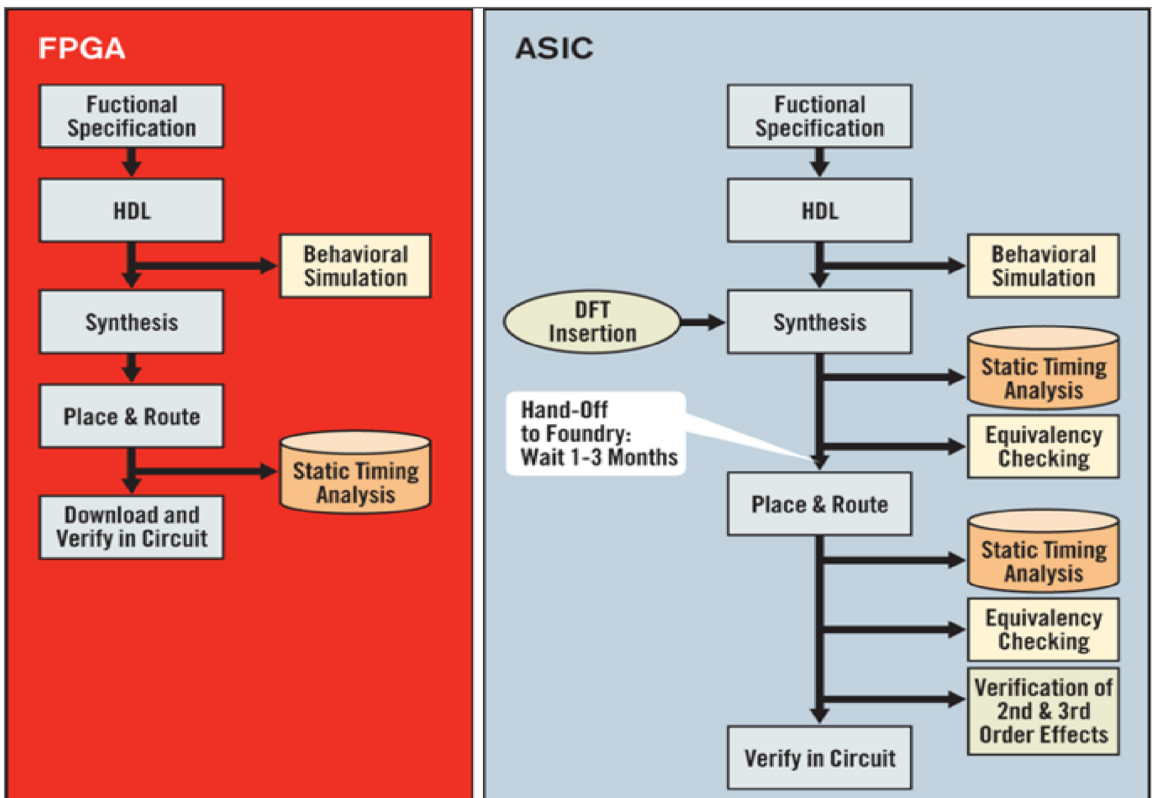
Marvin Lee Minsky (9 Aug 1927 - 24 Jan 2016) mentions one part of Bayesian classification 'can be made by a simple network device' and shares (1998, MIT) how obsolete it may be in this era of software.



http://bit.do/MINSKY-CHOMSKY

This information. Anything new? Not at all.

While working for Zilog, Ross Freeman (co-founder, Xilinx, 1984) wanted to create chips that acted like a blank tape, allowing users to program the technology themselves. Hence, field programmable gate arrays (FPGA) would allow circuits to be tailored by/for individual market segments (Altera, Xilinx).



Chip designed to run in a digital voice recorder or a high-efficiency Bitcoin miner is an ASIC example.

Scenario 2010 (Management by Learning)

SONY TV

SONY PlayStation

SONY VAIO

SONY Mobile

Customer wants improved function! Customer gets instant satisfaction!!

On-line Upgrade with Software

Printed logic inorganic transistors

Code-morphing software-silicon chips

Solution
software
CONTENT
TRACKING

SONY

Generate Revenue:
CONTENT
Version Change
Upgrade
Licensing

SAPMarkets

www.wired.com/2015/10/tesla-self-driving-over-air-update-live/

WIRED

Tesla's Cars Now Drive Themselves, Kinda

BUSINESS | CULTURE | DESIGN | GEAR | SCIENCE

1 / 7 Technically, it's advised to keep hands resting on the wheel---but you can go hands-free. MOLLY MCHUGH/WIRED

SoC

Software Defined Vehicle

TONIGHT, TESLA MAKES its cars autonomous. Well, semi-autonomous. And it did it with an over-the-air update, effectively making tens of thousands of cars already sold to customers way better.

www.teslamotors.com/blog/your-autopilot-has-arrived

Tekes

Technology Review 196/2006
Helsinki 2006

Figure 26. Radical Insight?

POC ● 2009 ● http://bit.do/Smooth-Operator

ADAPTABLE ? SOFTWARE DEFINED?

SENSORS

DARPA DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

EXPLORE BY TAG

ABOUT US / OUR RESEARCH / NEWS / EVENTS / WORK WITH US /

Defense Advanced Research Projects Agency › Program Information › ADAPTable Sensor System

ADAPTable Sensor System (ADAPT)

Dr. Craig Lawrence

Military sensor systems typically require between three and eight years to complete, resulting in sensor technology unable to keep pace with rapidly evolving mission needs. Commercial systems of similar complexity, forced by competitive pressures, are routinely developed in one to two years.

The ADAPT program seeks novel techniques and processes to rapidly develop low-cost ISR sensor systems by adapting commercial manufacturing approaches. The primary goal of the ADAPT program is to deliver common hardware and software that can be quickly configured to perform a variety of mission-specific ISR applications.

The elements of the ADAPT concept are divided into three areas: A reusable hardware core, reusable software, and sensor-specific applications. The reusable hardware core aims to leverage low-cost commercial components available at the time of manufacture, enabling it to be refreshed at the rate of commercial technologies. For example, commercial consumer electronic products are typically developed using Original Design Manufacturers (ODM) who promote fabless product development in factories that make a large number of variations on similar products. ADAPT seeks to use ODMs for design and production rather than the common practice of using contract manufacturers.

Reusable software efforts will addresses sensor management functions such as processing, storage, communications, navigation and orientation—all of which are common to a wide variety of sensor systems. These are also the same types of functions used in smart phone products which will allow leveraging of commercial technology for economies of scale. Consumer software can be developed quickly by using open-source software frameworks that include application development and distribution environments. These rich software tools and libraries create opportunities for nimble, third party application developers to rapidly create and refine software products. The ADAPT program will leverage similar commercial software development environments for smartphone products to enable new classes of sensor system application developers.

Sensors currently require production of common hardware and software for each sensor-specific application. Sensors created in the ADAPT program will benefit from not having to develop and produce common hardware and software. Military missions will define specific sensors, packaging and power systems to be used depending upong the mission performance requirements. Processing, storage, communication, navigation, orientation and sensor management functions will be handled by the reusable core hardware and software.

ADAPTABLE ? SOFTWARE DEFINED?

SENSORS

DARPA DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

SRI International

Adaptable Sensor System for Real-Time Data on the Front Line

DARPA taps SRI to deliver usable video and analytics to U.S. Armed Forces when and where they need it.

Defense Advanced Research Projects Agency › Program Information › ADAPTable Sensor System

ADAPTable Sensor System (ADAPT)

Dr. Craig Lawrence

Military sensor systems typically require between three and eight years to complete, resulting in sensor technology unable to keep pace with rapidly evolving mission needs. Commercial systems of similar complexity, forced by competitive pressures, are routinely developed in one to two years.

The ADAPT program seeks novel techniques and processes to rapidly develop low-cost ISR sensor systems by adapting commercial manufacturing approaches. The primary goal of the ADAPT program is to deliver common hardware and software that can be quickly configured to perform a variety of mission-specific ISR applications.

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SRI's video processor shares data from multiple sensors

1 2 3

Connecting Soft Hardware

The Networked Physical World

Published October 1, 2000. Distribution restricted to Sponsors until January 1, 2001.

AUTO-ID CENTER

WHITE PAPER

The Networked Physical World

Proposals for Engineering the Next Generation of Computing, Commerce & Automatic-Identification

Sanjay Sarma, David L. Brock & Kevin Ashton

MIT AUTO-ID CENTER MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 77 MASSACHUSETTS AVENUE, BUILDING 3-449G, CAMBRIDGE, MA 02139-4307

ABSTRACT

The Auto-ID Center at the Massachusetts Institute of Technology is a new industry sponsored lab charged with researching and developing automated identification technologies and applications. The Center is creating the infrastructure, recommending the standards, and identifying the automated identification applications for a networked physical world. All technologies and intellectual property developed at the Auto-ID Center are freely distributed. This white paper outlines the Auto-ID Center's key conclusions and research progress after its first year of research.


KALORIK
this toaster tweets
@mytoaster
POWERED BY
ioBridge
10:23 am
2
13
45c
00:13

"CAN I INTEREST YOU IN A FIREWALL FOR YOUR TOASTER?"

Published November 1, 2002. Distribution restricted to Sponsors until February 1, 2003.

AUTO-ID CENTER

WHITE PAPER

RFID Systems, Security & Privacy Implications

Sanjay E. Sarma, Stephen A. Weis, Daniel W. Engels

AUTO-ID CENTER MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 77 MASSACHUSETTS AVENUE, BLDG 3-449, CAMBRIDGE, MA 02139-4307, USA

ABSTRACT

The Auto-ID Center is developing low-cost radio frequency identification (RFID) based systems with the initial application as next generation bar-codes. We describe RFID technology, summarize our approach and our research, and most importantly, describe the research opportunities in RFID for experts in cryptography and information security. The common theme in low-cost RFID systems is that computation resources are very limited, and all aspects of the RFID system are connected to each other. Understanding these connections and the resulting design trade-offs is an important prerequisite to effectively answering the challenges of security and privacy in low-cost RFID systems.

It doesn’t matter if you can potentially

“CONNECT”

50 BILLION THINGS WILL BE CONNECTED BY 2020

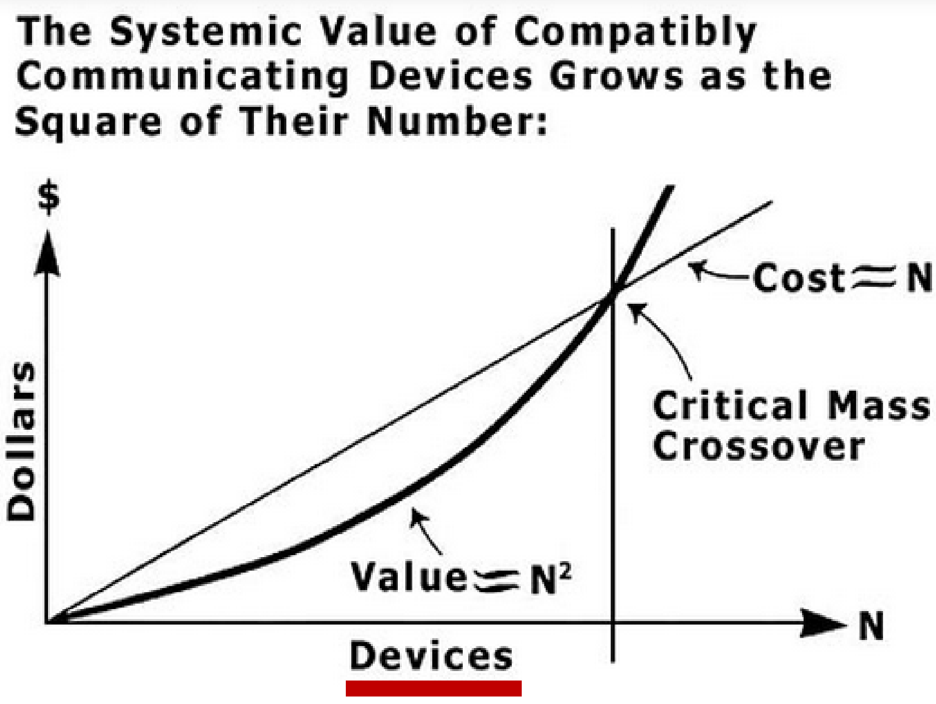
SENSATIONAL but INCORRECT
connectivity impotent unless
DISCOVERED and SECURED

Who knows you are connected?

DISCOVERY OF CONNECTED OBJECTS
IN CONTEXT-AWARE ECOSYSTEMS

http://bit.ly/BOB-METCALFE-LAW

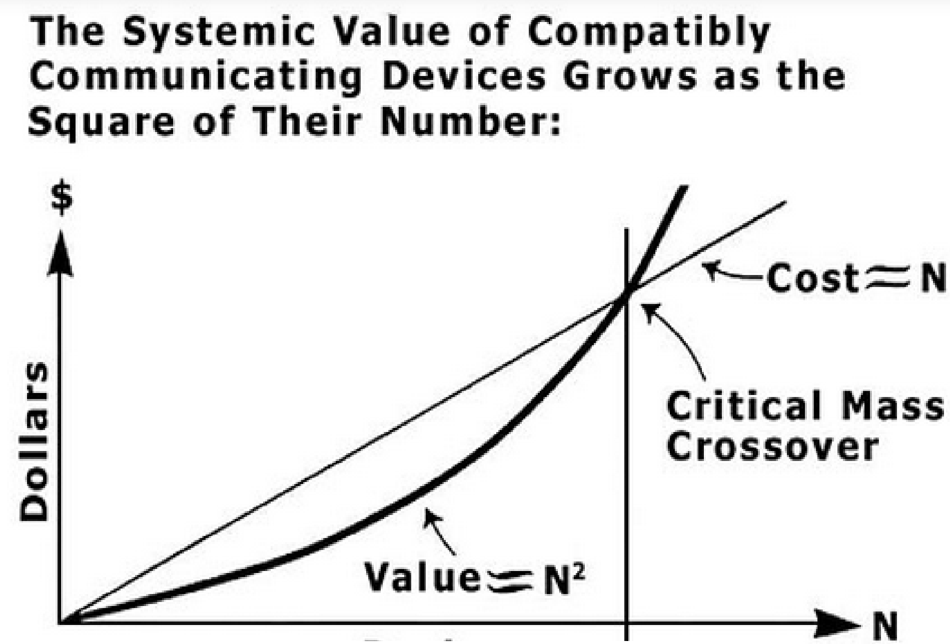
http://bit.ly/BOB-METCALFE-LAW



WRONG

Robert Melancton 'Bob' Metcalfe (Apr 7, 1946) co-invented the Ethernet, founded 3Com and formulated the Metcalfe's Law

http://bit.ly/BOB-METCALFE-LAW



Local Area Networks

The unit of measurement along the X-axis is "compatibly communicating devices", not users. The credit for the "users" formulation goes to George Gilder who wrote about Metcalfe's Law in Forbes ASAP on September 13, 1993. However, Gilder's article talks about machines and not users. Anyway, both the "users" and "machines" formulations miss the subtlety imposed by the "compatibly communicating" qualifier, which is the key to understanding the concept.

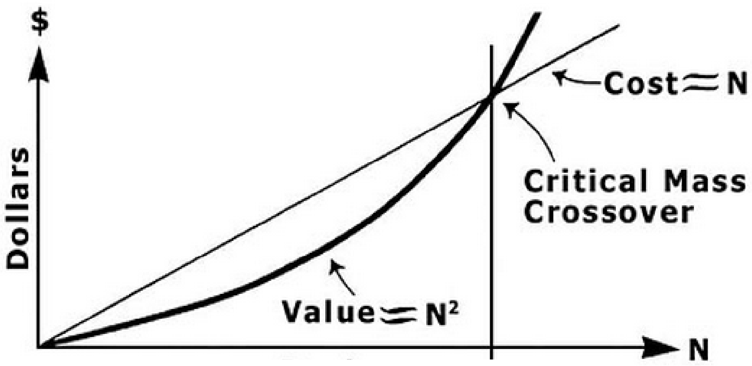
Bob, who invented Ethernet, was addressing small LANs where machines are visible to one another and share services such as discovery, email, etc. He recalls that his goal was to have companies install networks with at least three nodes. Now, that's a far cry from the Internet, which is huge, where most machines cannot see one another and/or have nothing to communicate about... So, if you're talking about a smallish network where indeed nodes are "compatibly communicating", I'd argue that the original suggestion holds pretty well.

The authors of the IEEE article take the "users" formulation and suggest that the value of a network should grow on the order of $O(n\log n)$ as opposed to $O(n^2)$. Are they correct? It depends. Is their proposal a meaningful improvement on the original idea? No.

NETWORKS

Robert Melancton 'Bob' Metcalfe (Apr 7, 1946) co-invented the Ethernet, founded 3Com and formulated the Metcalfe's Law

The Systemic Value of Compatibly Communicating Devices Grows as the Square of Their Number:



Local Area Networks

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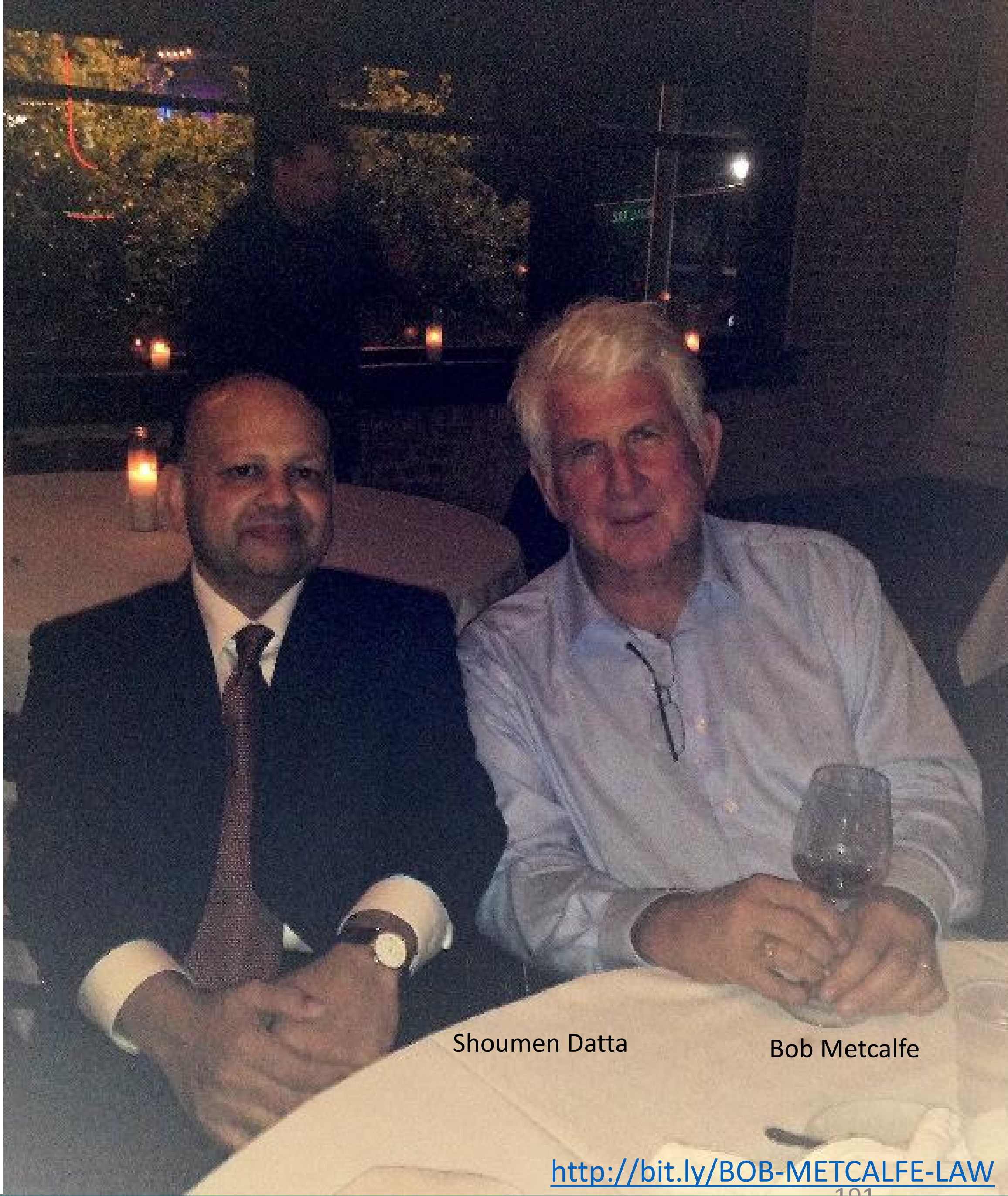
The authors of the IEEE article take the "users" formulation and suggest that the value of a network should grow on the order of O(nlogn) as opposed to O(n²). Are they correct? It depends. Is their proposal a meaningful improvement on the original idea? No.



Shoumen Datta Bob Metcalfe

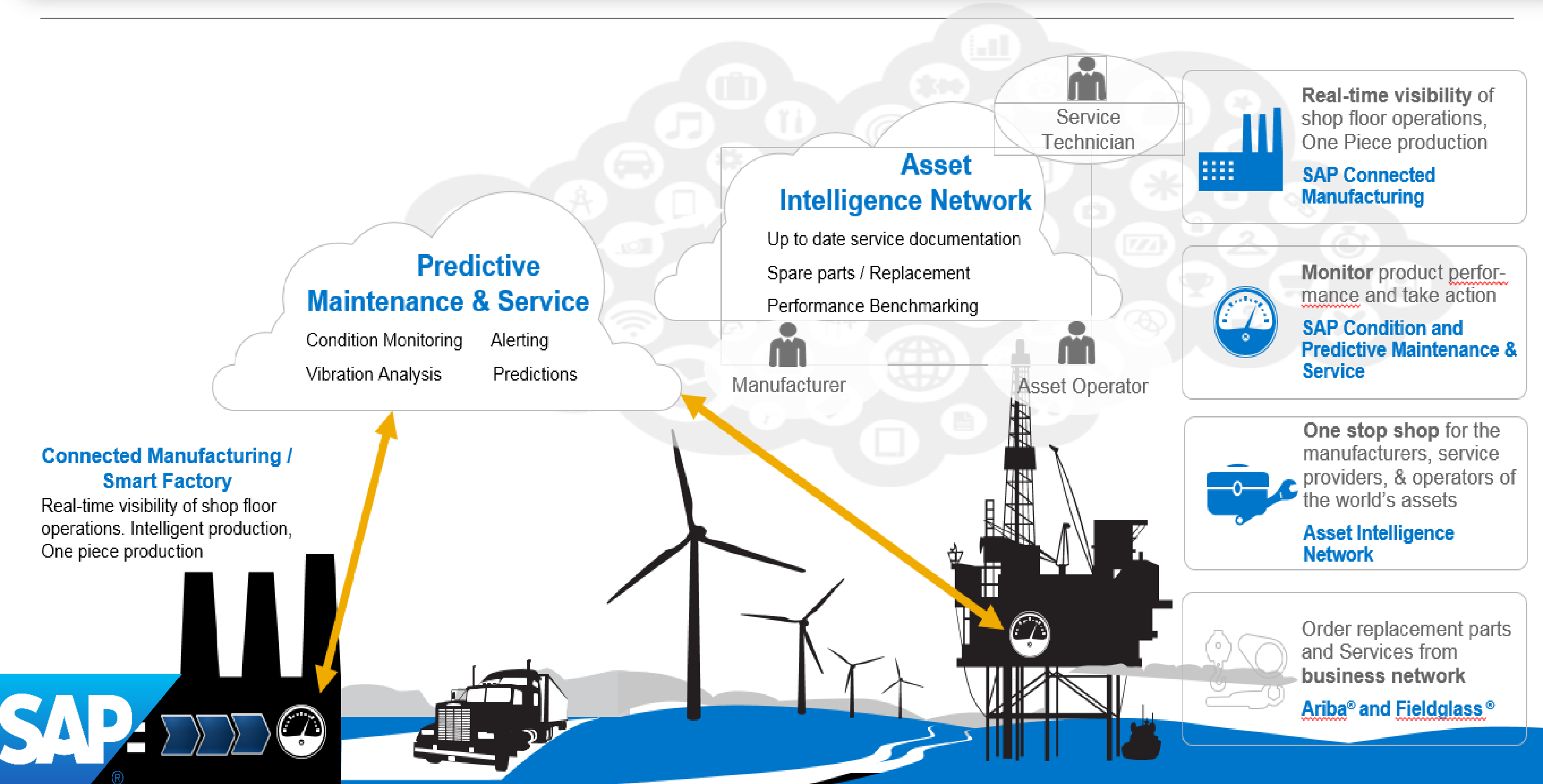
http://bit.ly/BOB-METCALFE-LAW

Robert Melancton 'Bob' Metcalfe (Apr 7, 1946) co-invented the Ethernet, founded 3Com and formulated the Metcalfe's Law

If the object in your system can discover the ecosystem or be discovered by the network

DEMANDS INTEROPERABILITY *BETWEEN* STANDARDS

Success or failure with respect to enabling the diffusion of connectivity necessary for the Industrial Internet of Things will depend on global collaboration and cooperation to drive interoperability between standards and diverse verticals in order to connect ecosystems. Transforming the vision to reality will require, amongst multiple other things, the essential convergence of IT, OT with TELCO.



IT and OT and TELCO

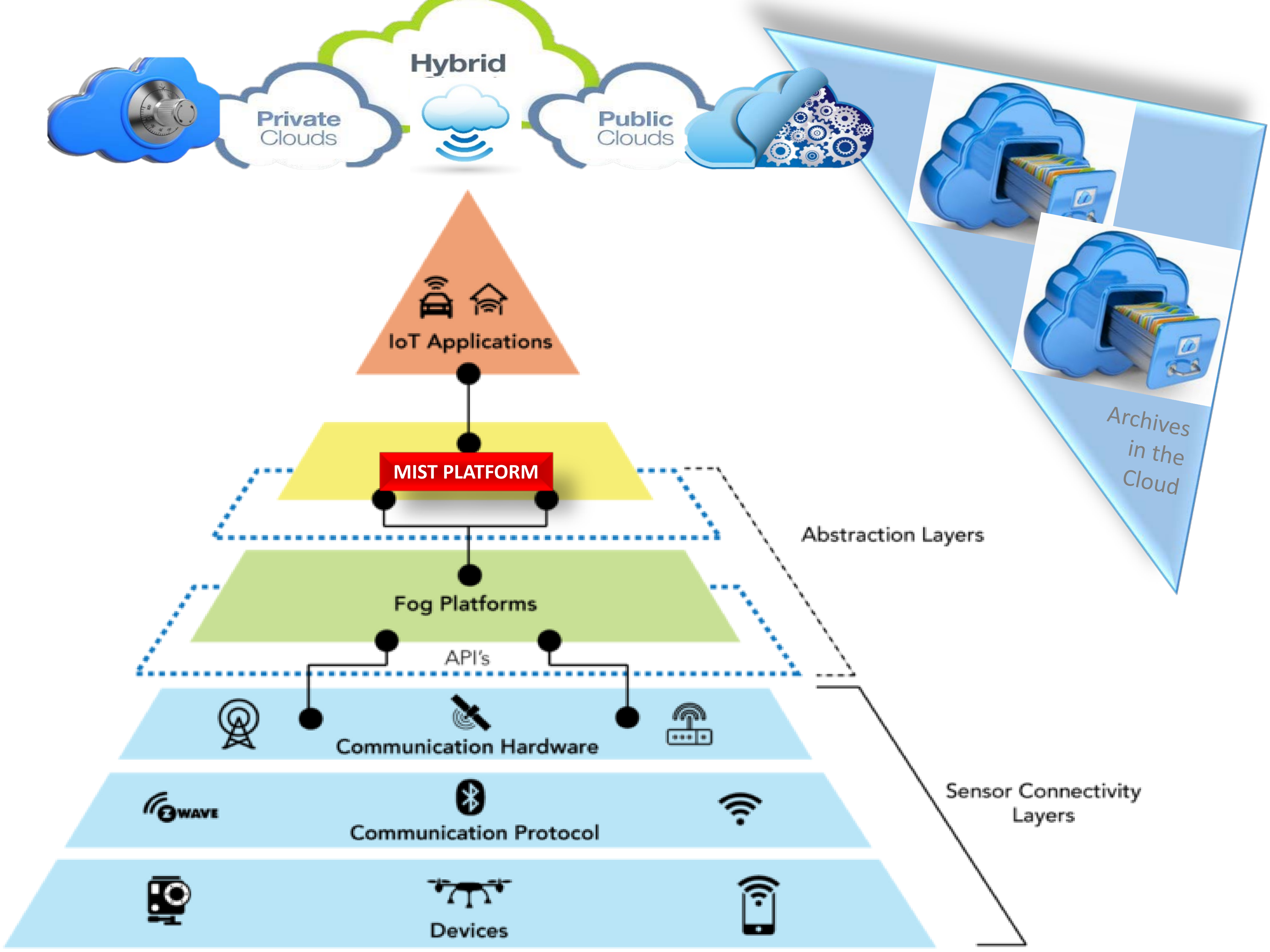
CONVERGENCE AND SECURITY BY DESIGN

Edge to Cloud – Latency?

Ground the CLOUD nearer to the edge

some telcos may suggest you wait for

5G



Hybrid
Private Clouds
Public Clouds
Archives in the Cloud
IoT Applications
MIST PLATFORM
Abstraction Layers
Fog Platforms
API's
Communication Hardware
ZWAVE
Communication Protocol
Devices
Sensor Connectivity Layers

DESIGN FLAW ?

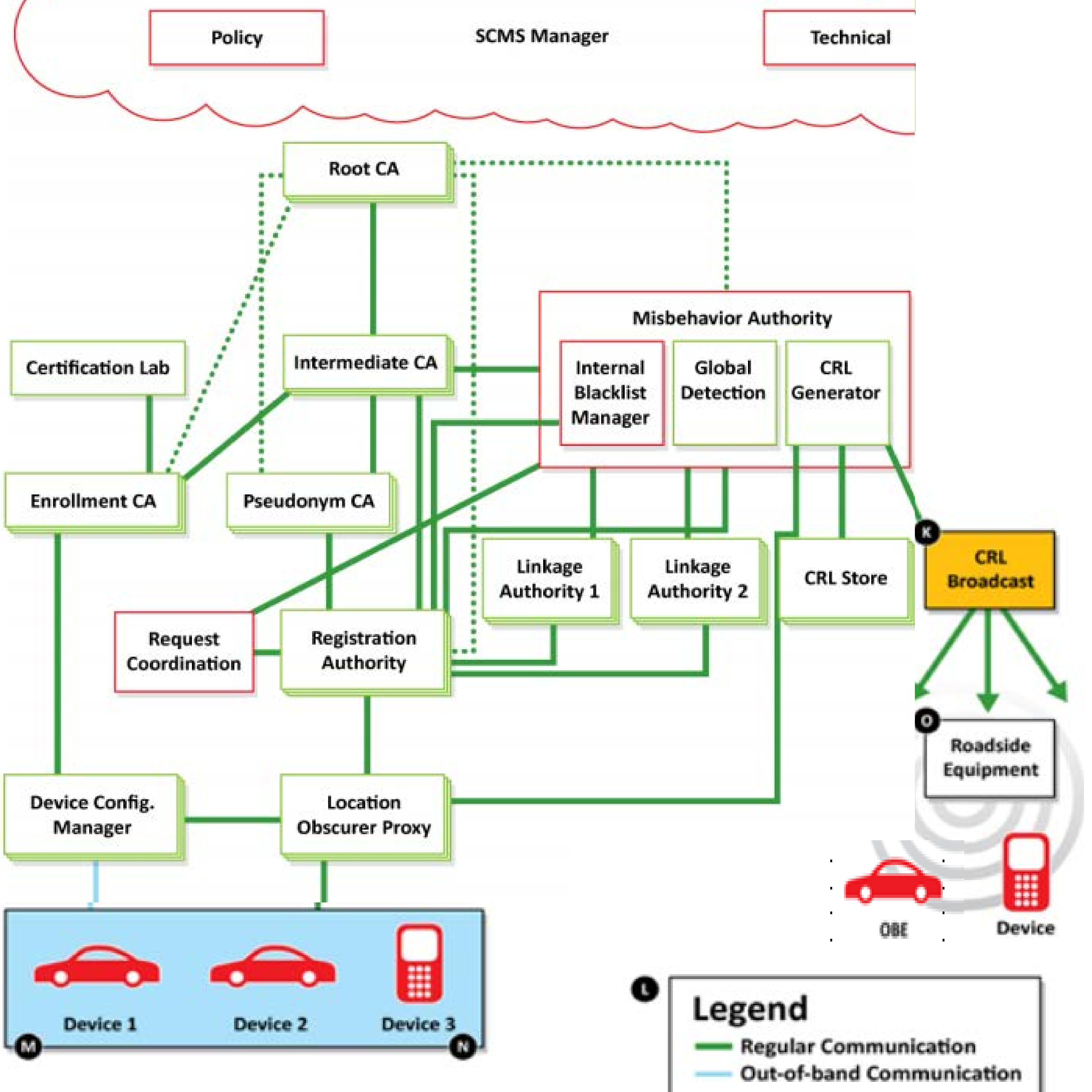
Time Synchronization?

Time Criticality, Time Guarantee, Deterministic Time Sensitive Networks

5G
Latency 2ms
Jitter ??

Semantics
of
Time

Edge
Intelligence
(CNN, RNN)



5G
Latency 2ms
Jitter ??

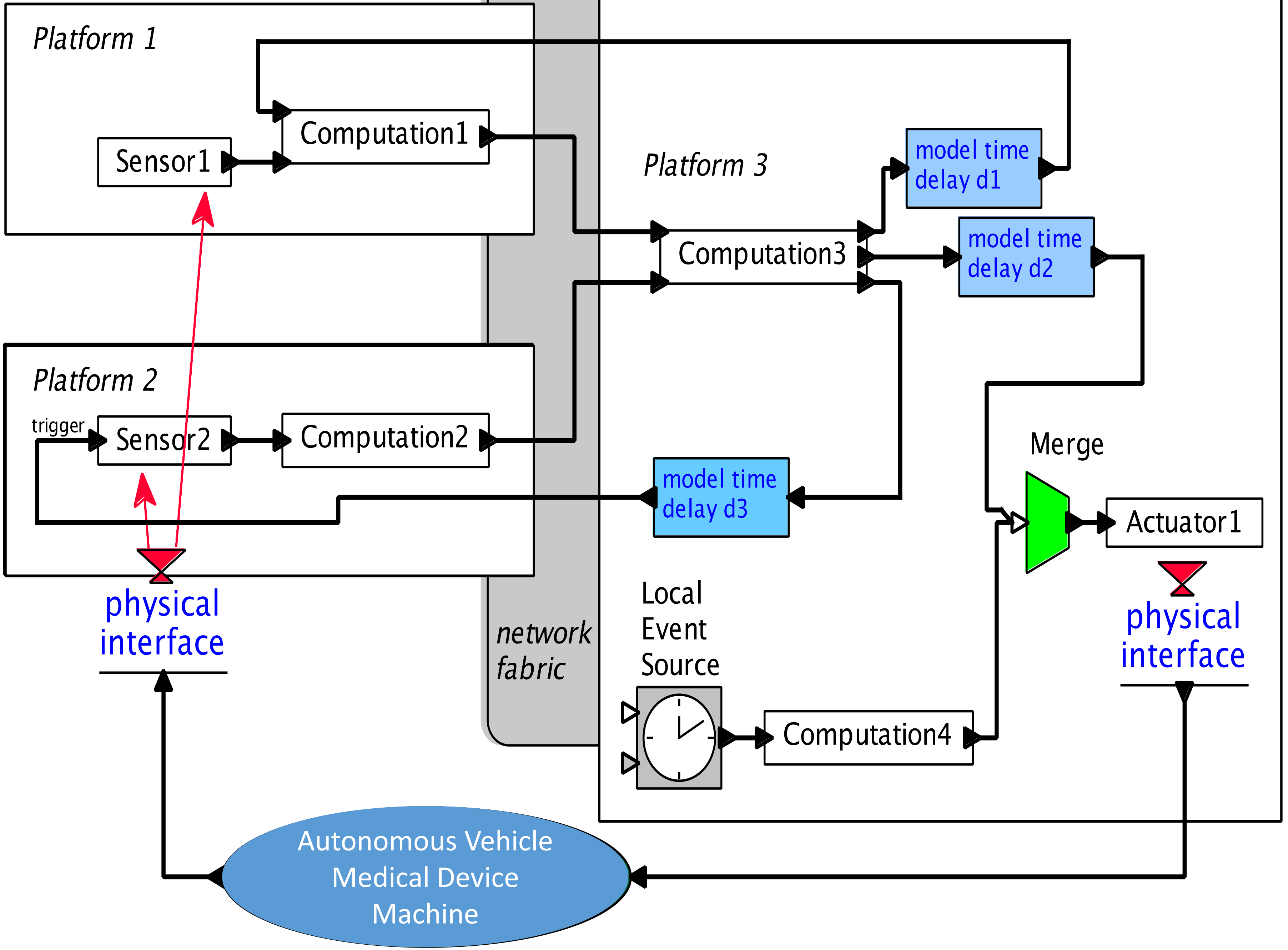
Semantics
of
Time

Edge
Intelligence
(CNN, RNN)

For real-time edge convergence

MIST COMPUTING is a MUST

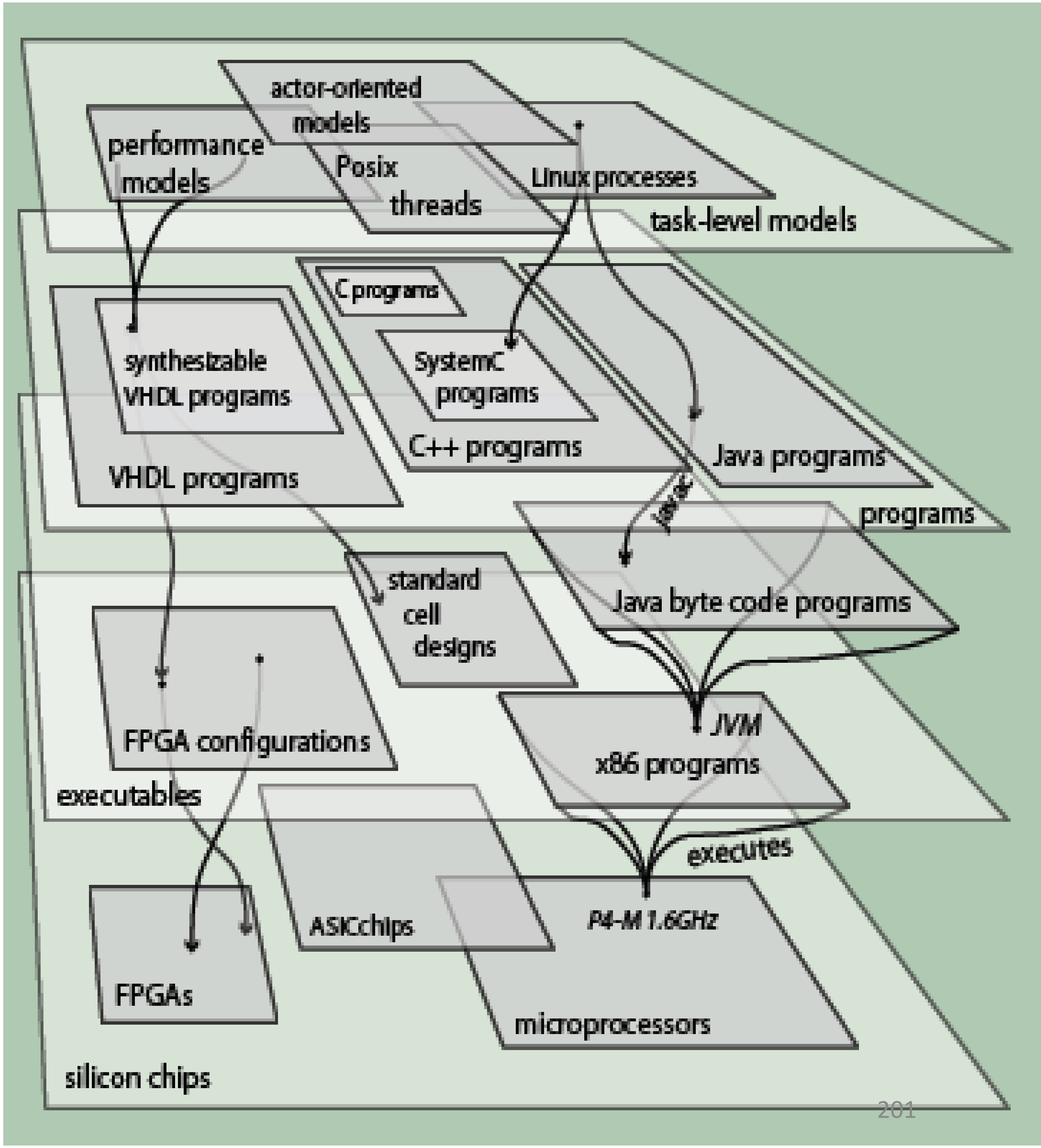
Archives
in the
Cloud



Platform 1
Computation1
Sensor1
Platform 3
model time delay d1
model time delay d2
Computation3
Platform 2
trigger
Sensor2
Computation2
model time delay d3
Merge
Actuator1
physical interface
network fabric
Local Event Source
Computation4
physical interface
Autonomous Vehicle
Medical Device
Machine

Failure of abstraction

Semantics of time absent from instruction set architecture (ISA)



PTIDES
Professor Edward Lee, UC Berkeley

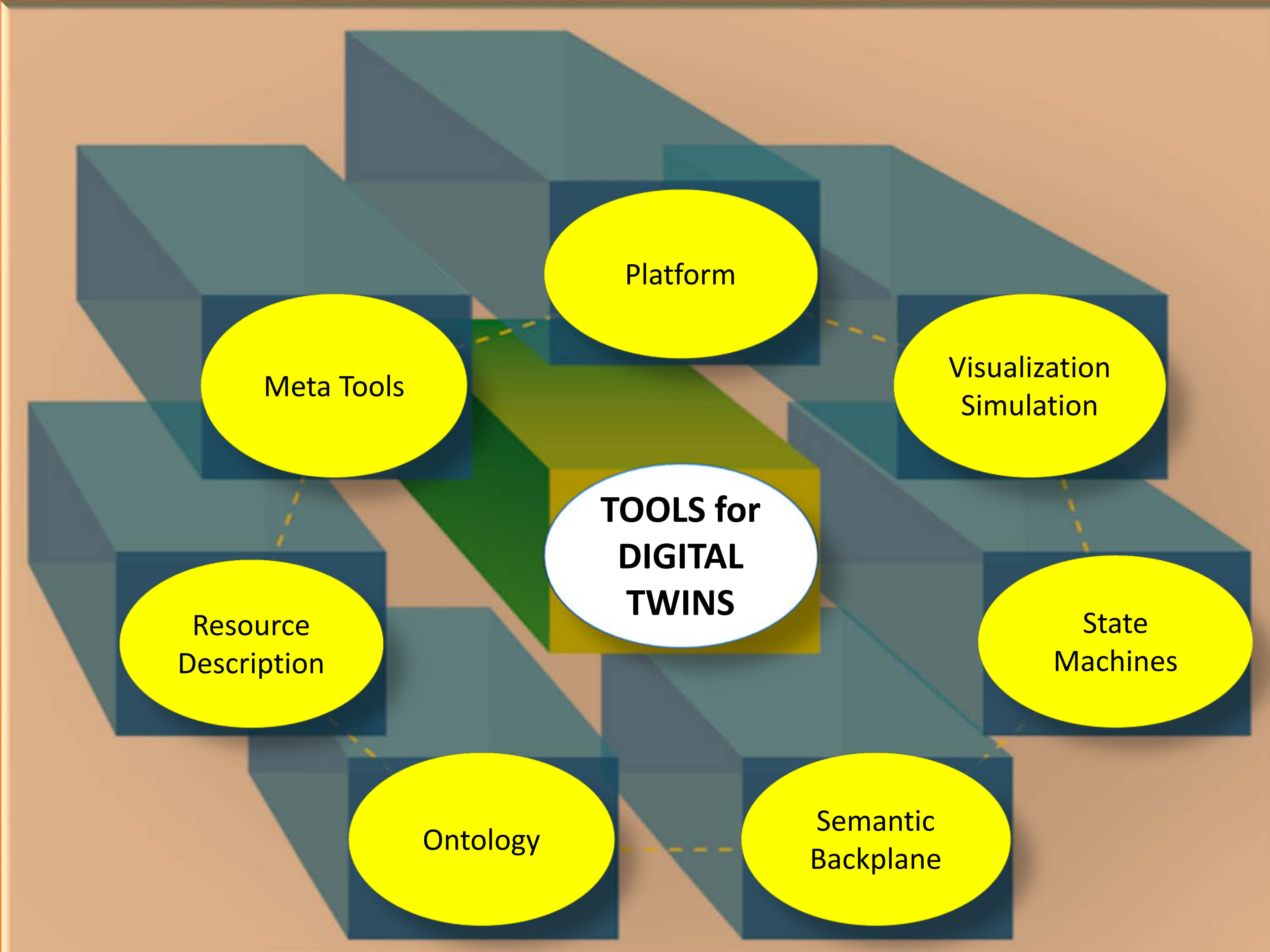
- Example: to execute an interrupt service routine
- The actual timing of this system is not specified
- Timing of this system emerges when program maps to a particular piece of hardware (for the software to execute) because it is dependent on the particular peripherals of the processor eg edge GPU such as Intel Edison, MIT Eyeriss, IBM NM (Boeing storage)
- Timing is actually not part of the semantics of the software
- Correct execution of a program (C, C++, C sharp, Java, Haskell, Ocaml) has nothing to do with how long it takes to do anything
- Timing emerges as an accident of the implementation
- Programmers need to specify temporal behavior (critical for CPS and certain industrial IoT applications)
- Programmers have to step outside the programming abstractions to specify timing behavior
- Programming models that make temporal behavior an intrinsic part at the specification
- Programming temporally integrated distributed embedded systems (PTIDES)

→ PTIDES is based on the semantics of discrete-event (DE) systems which provides a model of time and concurrency

→ In typical DE semantics, each actor processes input events in timestamp order but without constraints on the real time at which events are processed (t + Δt)

→ PTIDES extends DE by establishing correspondence between model time and real time at sensors, actuators and network interfaces (assumes each local platform contains a real-time clock synchronized with similar clocks in the other platforms).

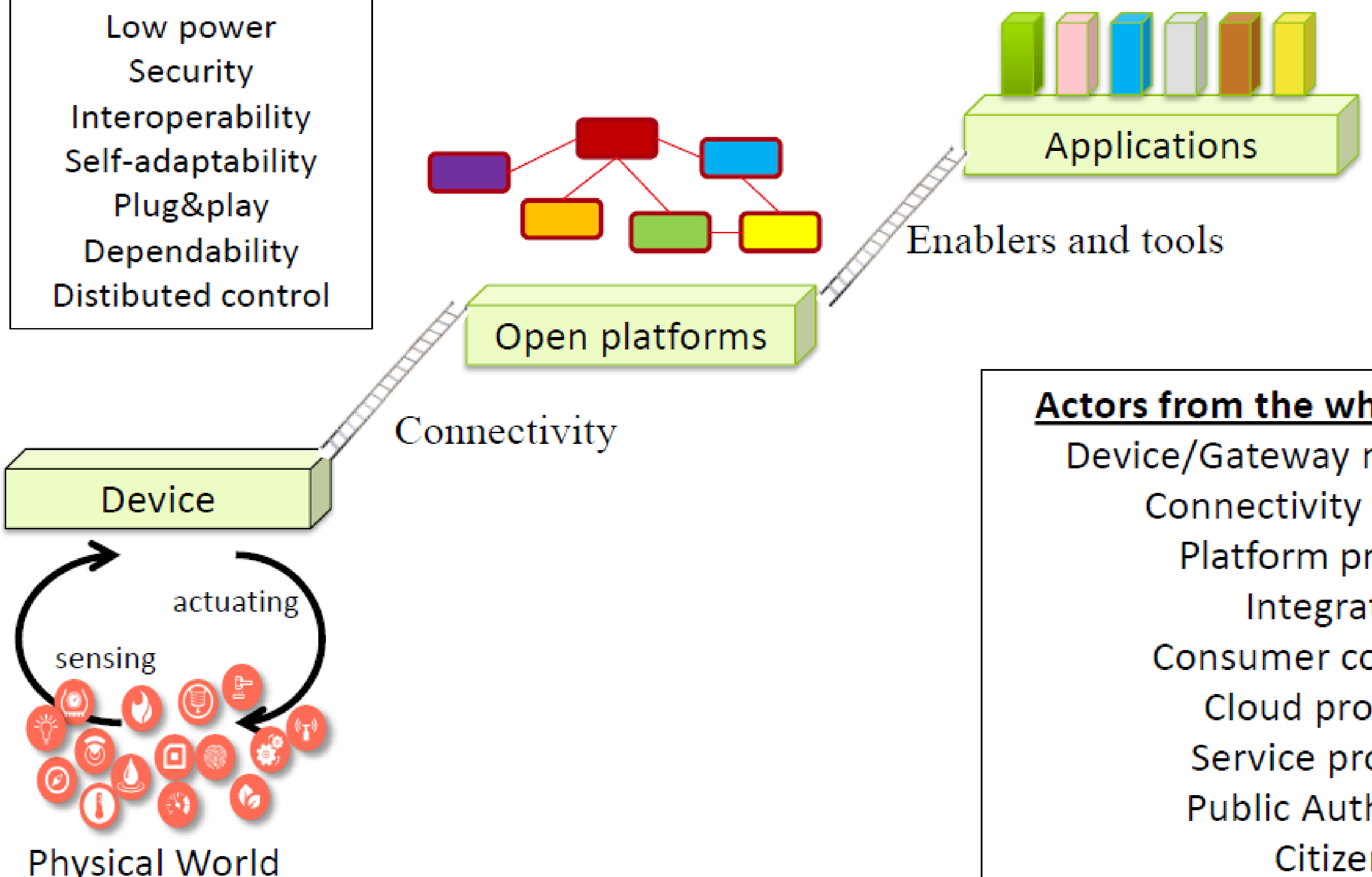
http://bit.do/PTIDES
http://bit.ly/TIME-SYNC
https://chess.eecs.berkeley.edu/ptides/
https://chess.eecs.berkeley.edu/pubs/857/PTIDES_Smart_Grid.pdf
http://www.uni-salzburg.at/fileadmin/multimedia/SRC/docs/publications/C085.pdf


Platform
Meta Tools
Visualization Simulation
TOOLS for DIGITAL TWINS
Resource Description
State Machines
Ontology
Semantic Backplane

General Abstraction ● Connectivity, Open Platforms & Broad Spectrum DT Applications

Technical challenges

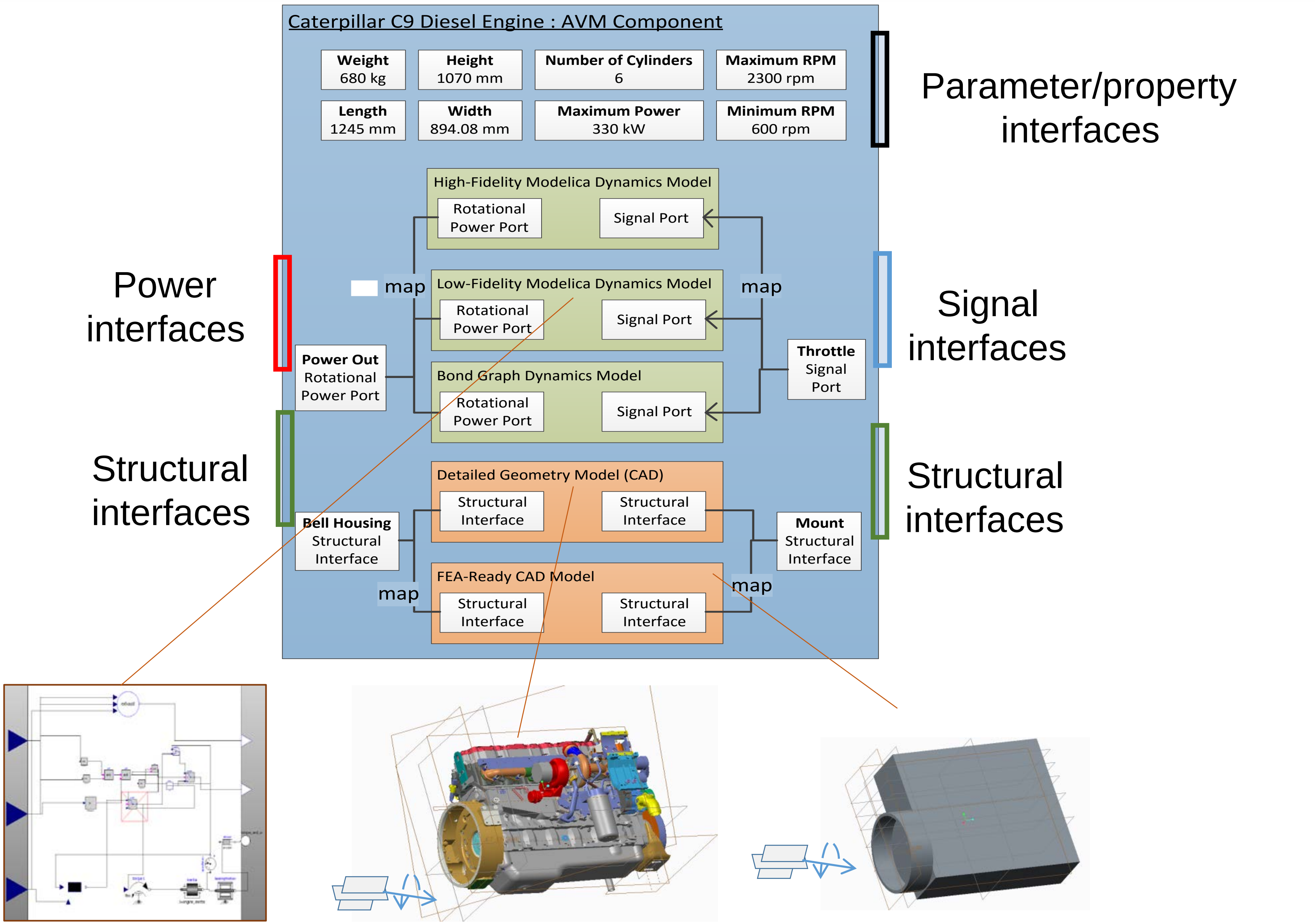
Heterogeneity
Integration
Low power
Security
Interoperability
Self-adaptability
Plug&play
Dependability
Distibuted control



Actors from the whole value chain

Device/Gateway manufacturers
Connectivity providers
Platform providers
Integrators
Consumer companies
Cloud providers
Service providers
Public Authorities
Citizens

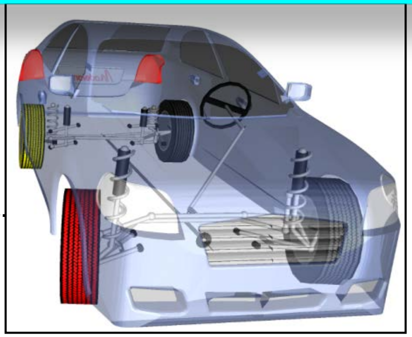
DARPA Adaptive Vehicle Make (AVM) Component Model



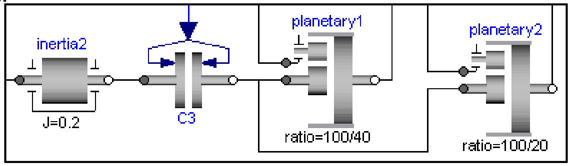
Low-Fidelity Dynamics *Detailed Geometry* *FEA Geometry*

Example of Vehicle Model from Modelon AB and Modelica

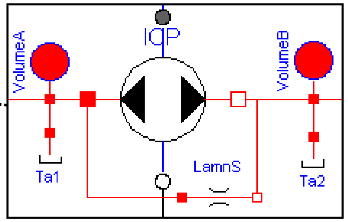
- **Vehicle dynamics** (3-dim. mechanics)



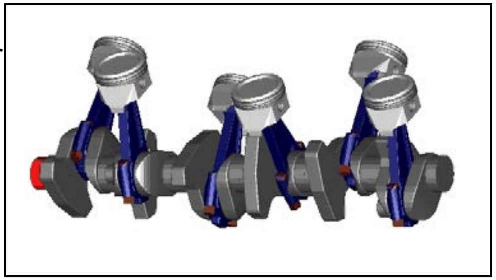
- **Drive trains** (1-dim. mechanics)



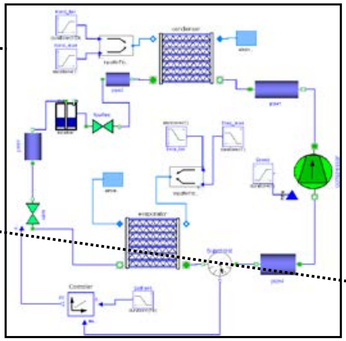
- **Hydraulics**



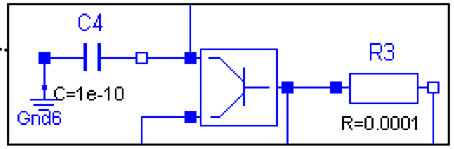
- **Combustion**



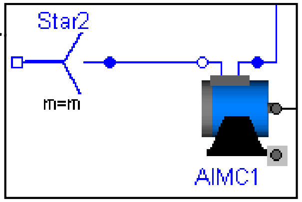
- **Air Conditioning** (Thermofluid systems)



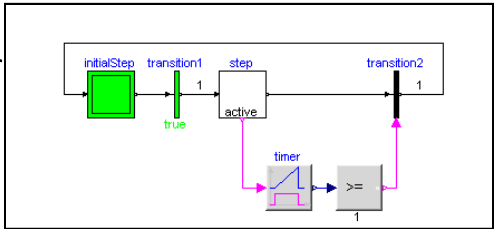
- **Electrical/electronic systems**



- **Electrical machines**

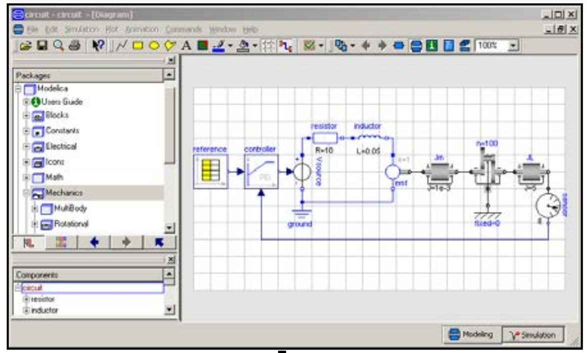


- **Hierarchical state machines**
- **Control** (Input/output blocks, ...)



Examples from Modelica Language and Simulation Environments

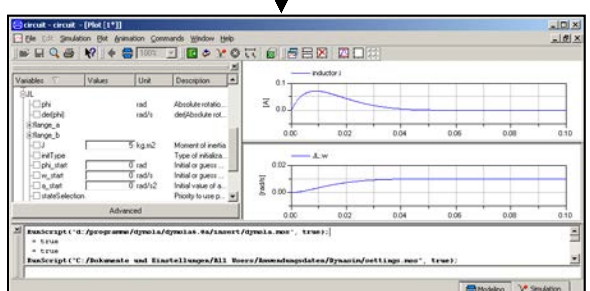
Graphical editor



Textual description
(equations, schematic, animation)

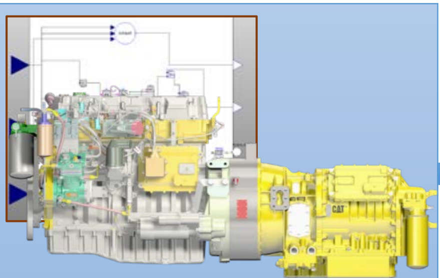
```
model circuit
  a;
  Modelica.Electrical.Analog.Basic.Resistor resistor(R=10) a;
  Modelica.Electrical.Analog.Basic.Inductor inductor(L=0.05) a;
  Modelica.Electrical.Analog.Basic.EMF emf(k=1) a;
  Modelica.Electrical.Analog.Sources.SignalVoltage Vsource a;
  Modelica.Electrical.Analog.Basic.Ground ground a;
  Modelica.Blocks.Continuous.LimPID controller a;
  Modelica.Mechanics.Rotational.Inertia Jm(J=1e-3) a;
  Modelica.Mechanics.Rotational.IdealGear n(ratio=100) a;
  Modelica.Mechanics.Rotational.Fixed fixed a;
  Modelica.Mechanics.Rotational.Inertia JL(J=5) a;
  Modelica.Mechanics.Rotational.Sensors.SpeedSensor sensor a;
  Modelica.Blocks.Sources.CombiTimeTable reference a;
```

Translation of Modelica models in C-Code, simulation and interactive scripting



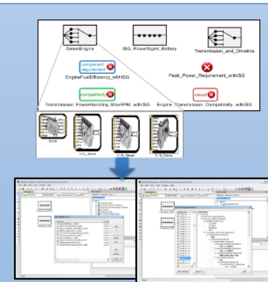
Design Automation Tools to Catalyze Digital Twin Mass Market?

Component Based Design



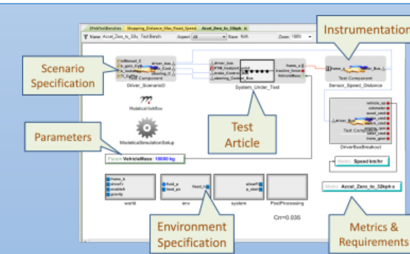
- Design Reuse, Distribute Workload
- Leverage cross-domain Component Libraries

Design Space Exploration

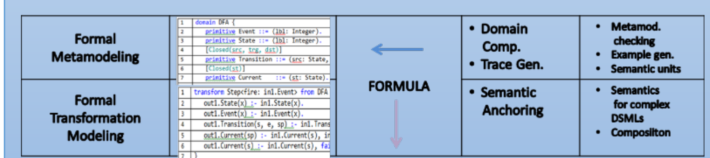


- Explore, Evaluate, Understand Tradeoffs
- Maintain Design Flexibility/Agility

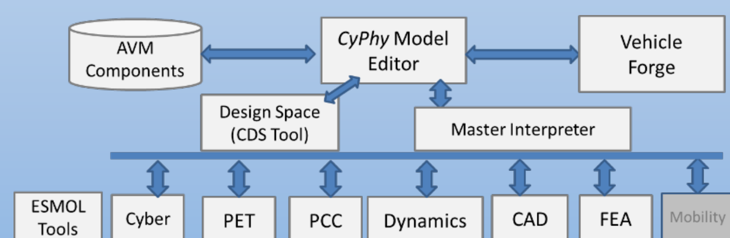
Executable Requirements



- Auto-compose models/invoke domain analysis tools
- Minimize repetitive engineering labor



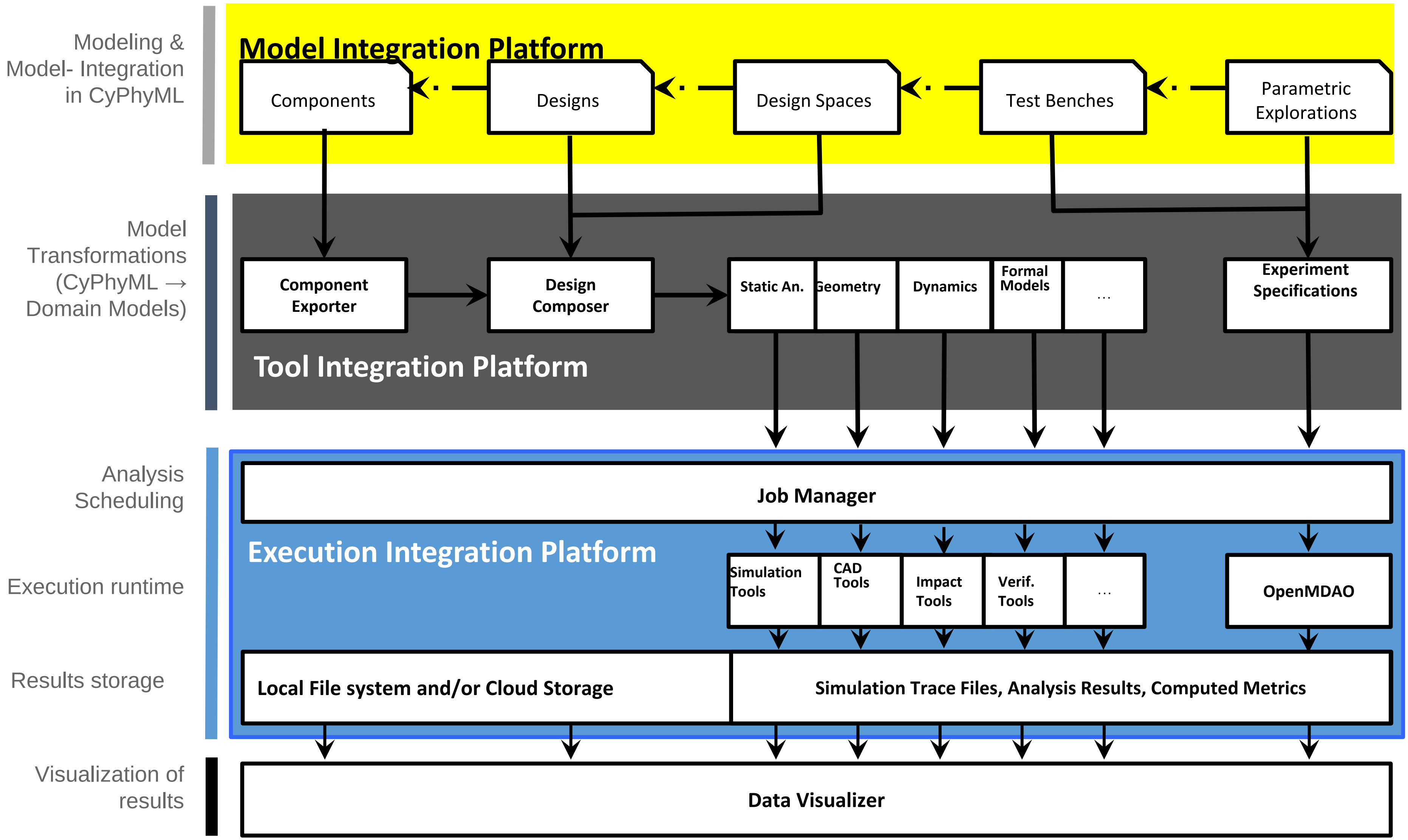
- Support integration of new tools and analysis
- Applicable across new domains and engineering processes



Meta Programmable Tools and Semantic Backplane

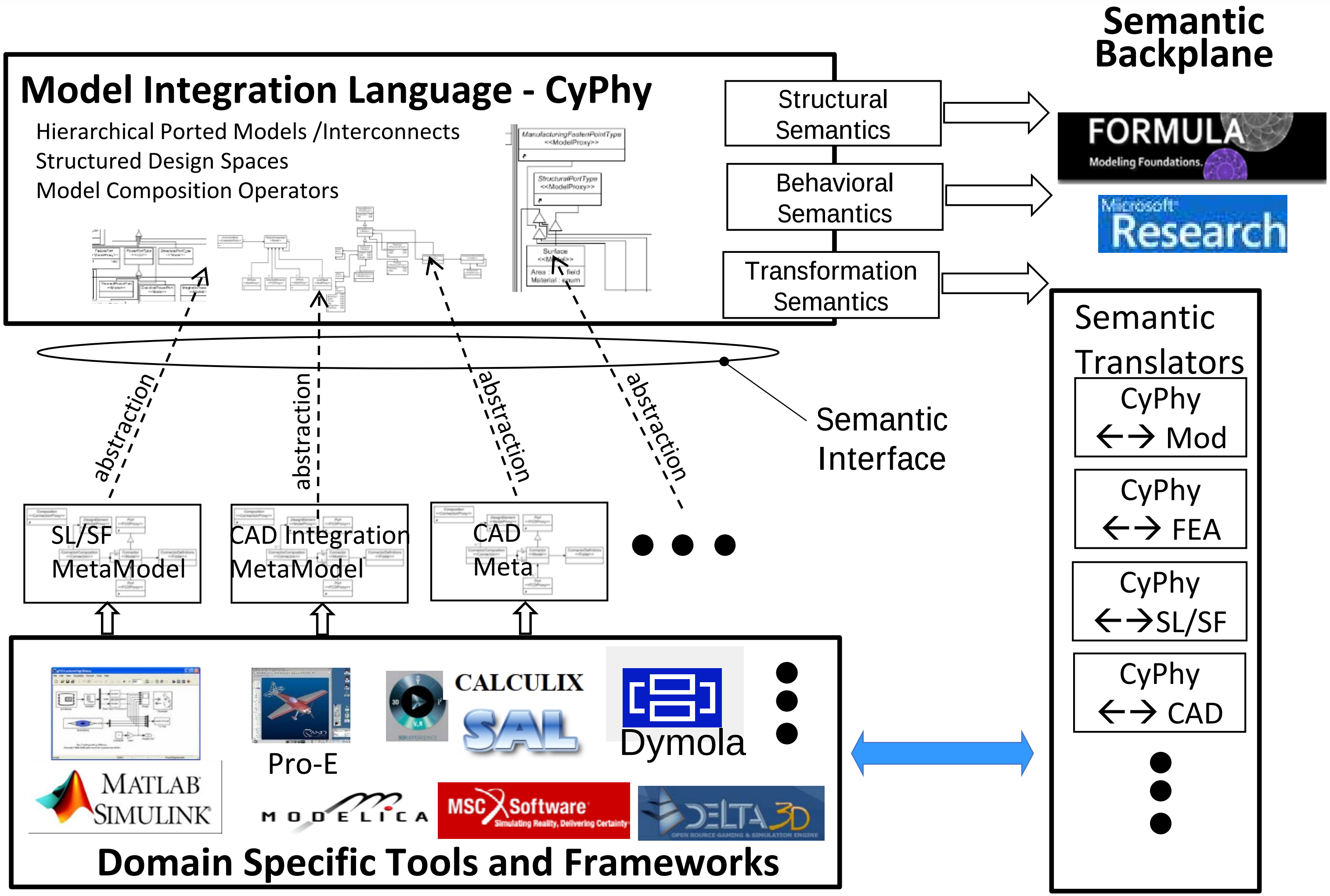
http://bit.ly/META-TOOLS

Tools to Catalyze Digital Twin Business - Meta Tool Suite Architecture



DR TED BAPTY • www.isis.Vanderbilt.edu • http://bit.ly/META-TOOL-SUITE

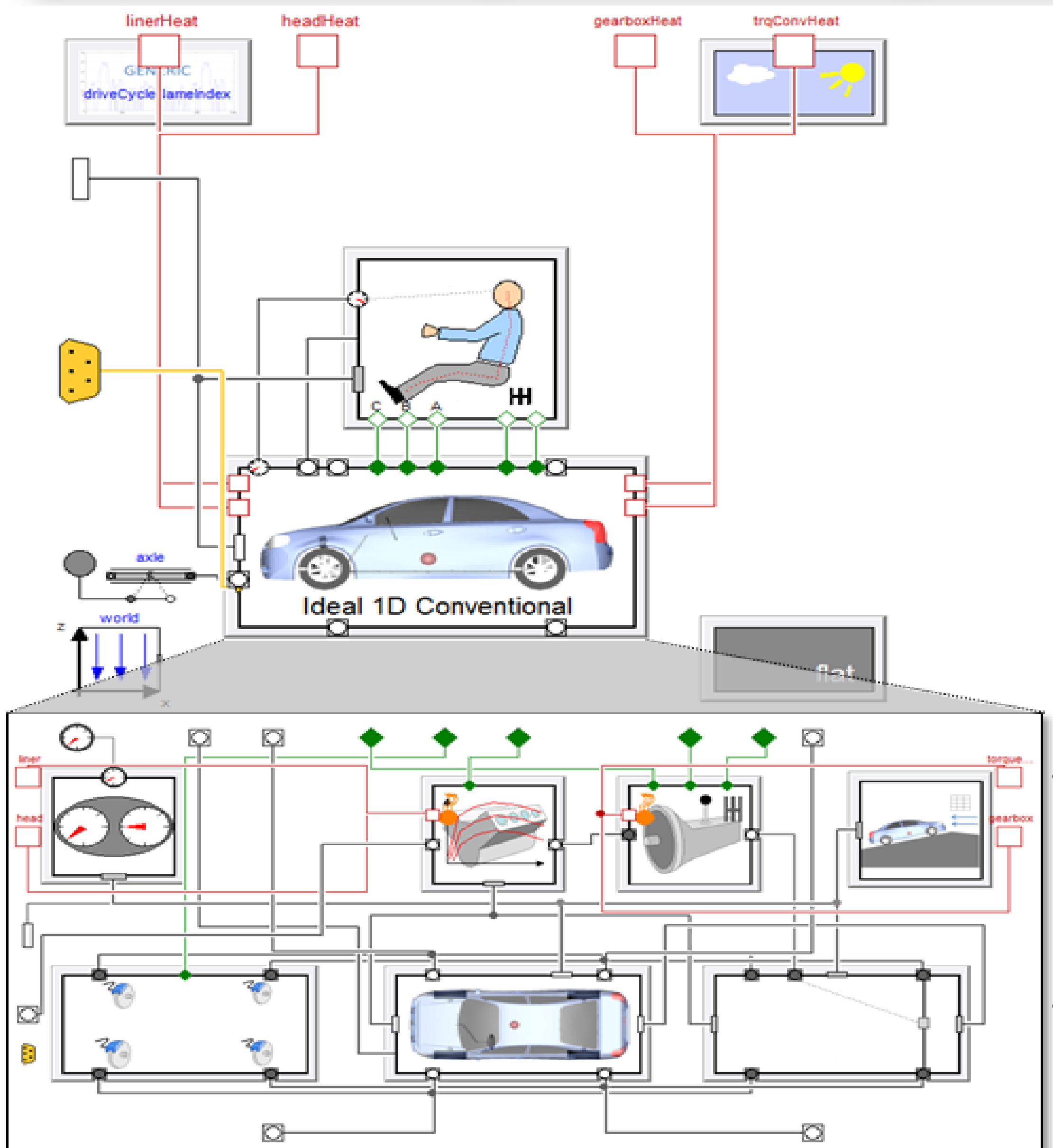
Digital Twin Tool Kit - Model Integration Platform using CyPhyML



Semantically Sound, Open Language Engineering Environment; Accommodates New Tools & Languages

http://bit.ly/META-TOOLS

Tools for Digital Twins
Decomposition of Complex Simulations



- Partition: Driver vehicle (Vehicle mechanics, Electrical and Driver) and Thermal Management (Fluid and Thermal parts of the model)

- Simulation with different processes and clock-rates but achieves correct behavior

Neema, H., J. Gohl, Z. Lattmann, J. Sztipanovits, G. Karsai, S. Neema, T. Bapty, J. Batteh, H. Tummescheit, and C. Sureshkumar, "**Model-Based Integration Platform for FMI Co-Simulation and Heterogeneous Simulations of Cyber-Physical Systems**" in Proceedings of the 10th International Modelica Conference, Lund University, Solvegatan 20A, SE-223 62 LUND, Modelica Association and Linkoping University Electronic Press, pp. 235-245, 03/2014.

Tools to Build and Test the Component Models for Digital Twins

Combine AVM model with meta tool suite as a tool to create digital twin or a representation of any dynamic (clinical) environment (eg patient attached to various devices from ER to OR from post-operative ICU to discharge status).

Creation of a digital twin as an entity level agent based model is essential to analytics and simulation of what-if scenarios (deterministic) to better prepare for the non-deterministic states (emergency). This approach is not limited to machines but crucial for any "atom" which may be connected bits (data).

Digital duplication may be the underpinning of almost all elements in the context of connectivity (IoT, IIoT). Data from each individual node of this model (eg sensor data from each part in a machine with hundreds of parts) will feed the digital twin connected to algorithm engines (cloud/fog/mist) to drive real-time analytics, provide feedback to improve efficiency or precision of the device or process or decision support in a manner that is context-aware and delivers cognitive intelligence at the edge to boost autonomy.

Time sensitive networks may demand that tools, such as, AI (CNN, RNN) and algorithms reside at the edge which creates a new paradigm where the analytical machines travel to data for latency bounded critical applications.

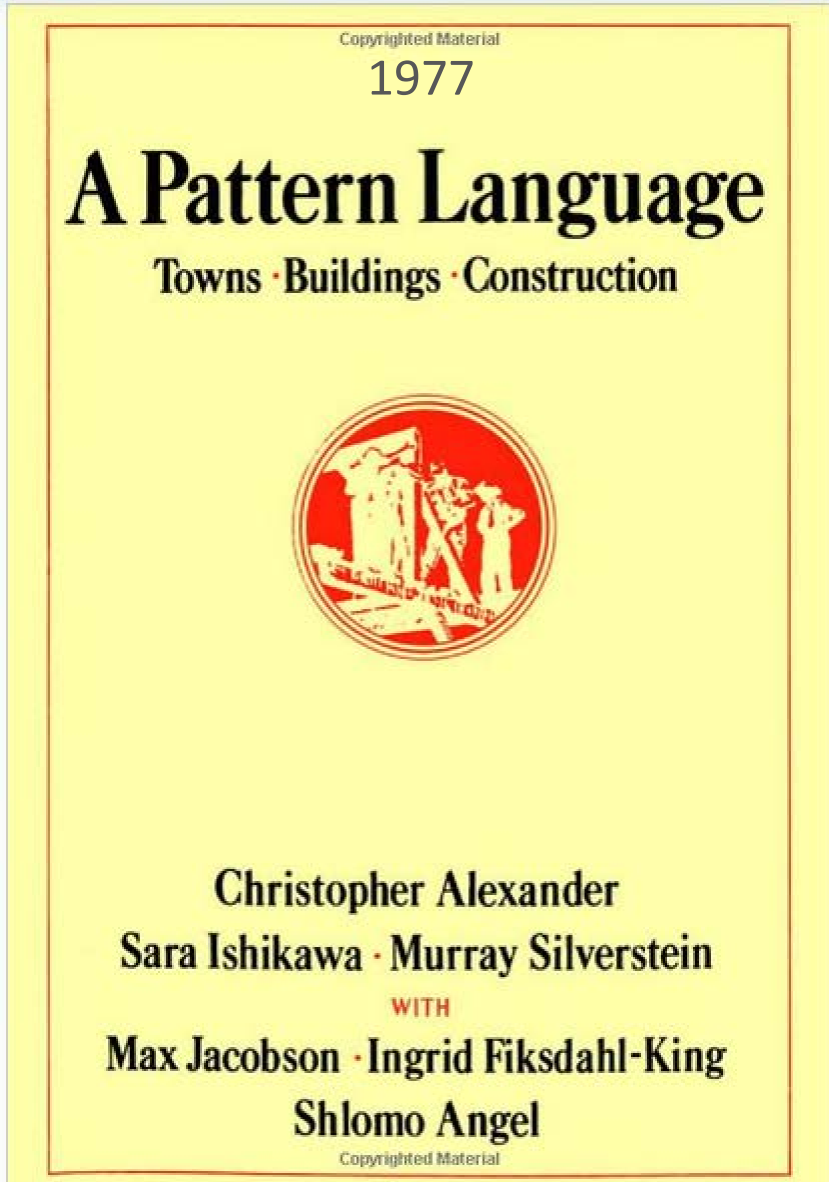
www.cs.cmu.edu/~ckaestne/pdf/SCP12.pdf ▪ www.vuse.vanderbilt.edu/~koutsoxd/www/Publications/Modelica2014_ecp14096037.pdf

Digital Twin Cities

Re-visit an old idea with new eyes
Digital Twins for Smart Cities?

A note to city planners and urban architects of the future – Create cities which are Digital by Design

A “Modelica” for Smart Cities ?



The contribution to the street.

Section 246 on page 1137 in Pattern Language by Christopher Alexander (1977)
http://library.uniteddiversity.coop/Ecological_Building/A_Pattern_Language.pdf

Pattern Language Revolution – OOP, UML, JAVA

- **Creational patterns:**
    - Deal with initializing and configuring classes and objects
- **Structural patterns**:
    - Deal with decoupling interface and implementation of classes and objects
    - Composition of classes or objects
- **Behavioral patterns**:
    - Deal with dynamic interactions among societies of classes and objects
    - How they distribute responsibility

- *A Pattern Language: Towns, Buildings, Construction,* Christopher Alexander, 1977
- *The Timeless Way of Building,* Christopher Alexander, 1979
- *Using Pattern Languages for Object-Oriented Programs* (a paper at the OOPSLA-87 conference), Ward Cunningham and Kent Beck, 1987
- *Design Patterns,* Erich Gamma, Richard Helm, John Vlissides, and Ralph Johnson (known as the "Gang of Four", or GoF), 1994
- *Refactoring: Improving the Design of Existing Code,* Martin Fowler, 2000

Pattern Language Evolution – githut.info

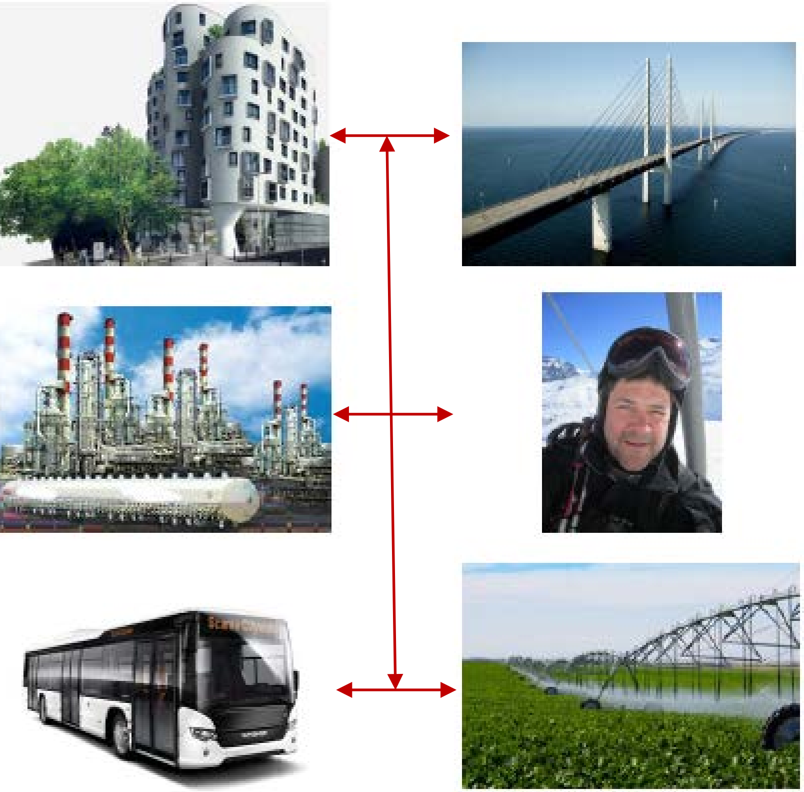
Re-visit “pattern” in terms of smart city concepts and apply the principle but with the goal of creating agent based models for every “component”

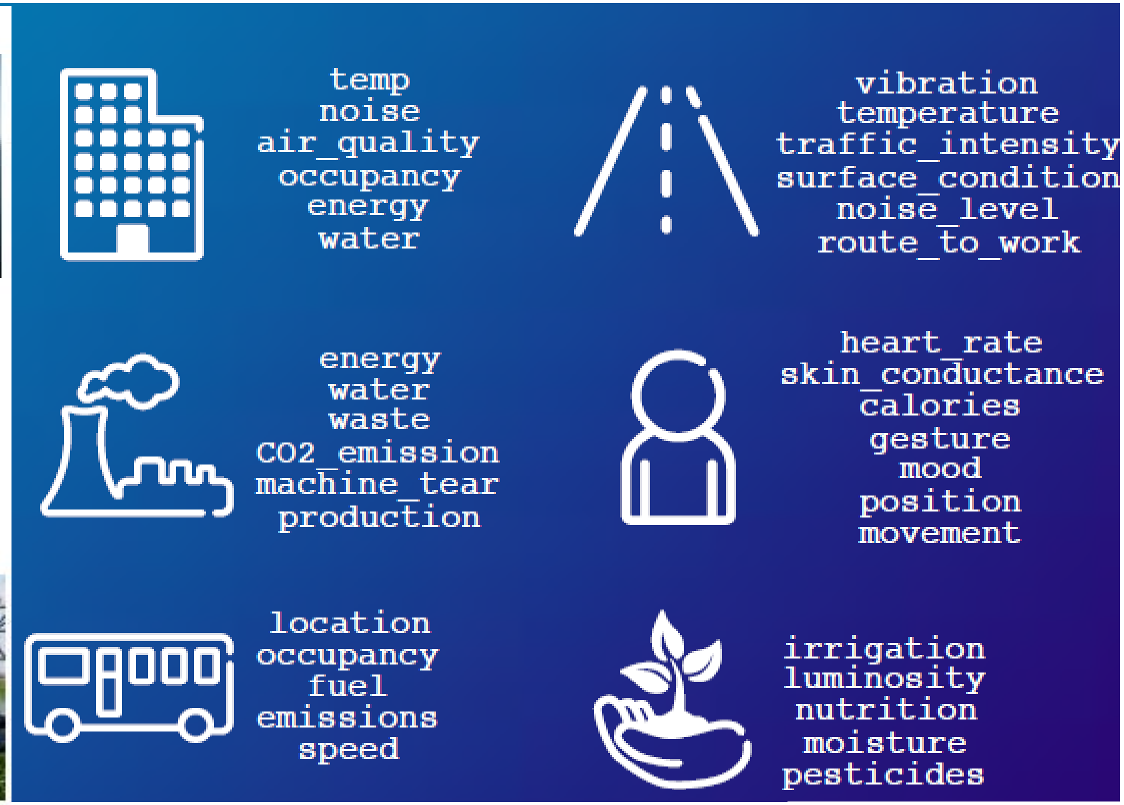
What factors may influence the use and ecosystem of a building (or shopping mall or train station or park area)

- Before a city planner asks questions related to this topic, the elements in this question must be decomposed to unit level hierarchical components and their attributes/characteristics as well as tasks and process – eg building made up of rooms, bathrooms, HVAC, roof, garage, foundation, sewer system

DETECT, CONNECT, CONTEXT, INTELLECT

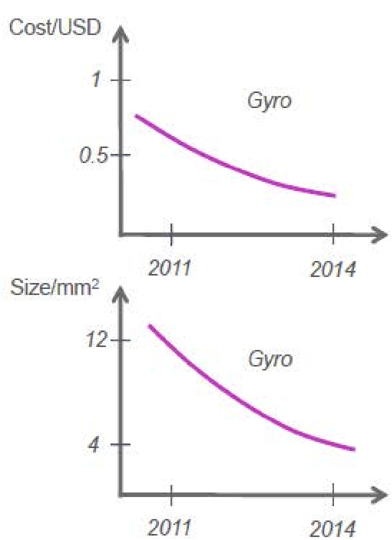
REPRESENT, SENSE, SEMANTICS, RESPONSE





Sensors

- Barometric pressure
- Accelerometer
- Gyroscope
- Magnetometer
- CO_2, O_2, other
- Heart rate
- Galvanic Skin Response
- Luminosity
- Sound
- Temperature
- Ultrasonic
- Gas flow
- Radiation
- ...



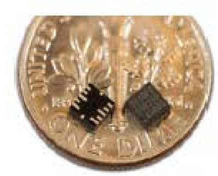
BMP280
- Pressure sensor
- Current: 2.74 µA @ 1 Hz
- Accuracy: ±0.12 hPa (± 1 m)
- Size: 2.0*2.0*0.95 mm³
- Price: 1.55 € @ 1000

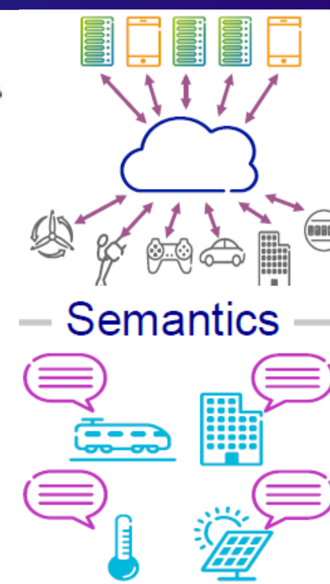
BMP280 (BMP180)

3-axis accelerometer sensor

mCube

MC3420
- 3-axis accelerometer
- Current: 30 µA @ 128 Hz
- Event detection. tap, shake, drop, tilt, orientation (P/L)
- Size: 2.0*2.0*0.92 mm³
- Price: 0.843 € @ 1000



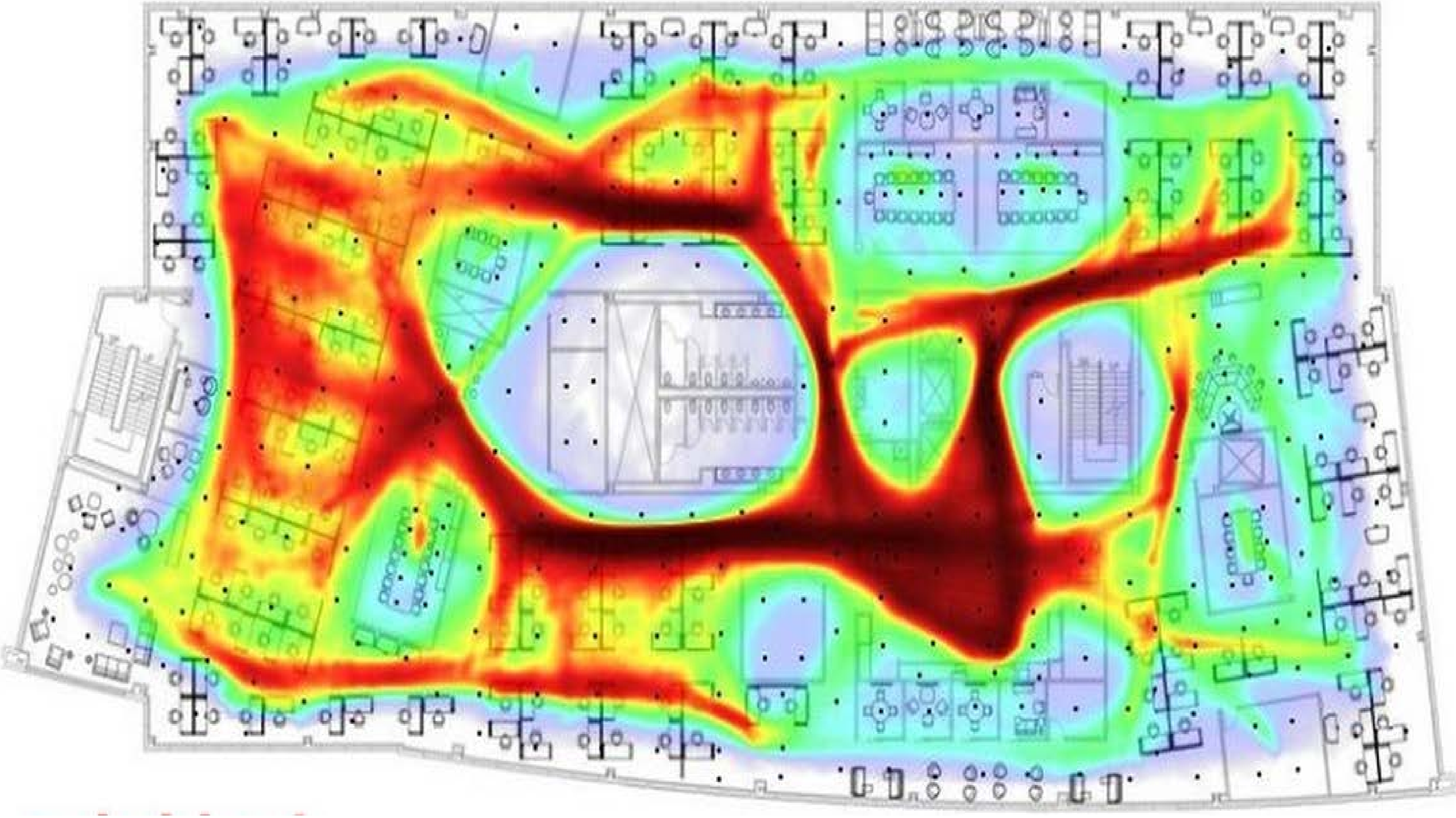


Re-visit “pattern” in terms of smart city concepts and apply the principle but with the goal of creating agent based models for every “component”

What factors may influence the use and ecosystem of a building (or shopping mall or train station or park area)

- How many people occupy the building during what hours?
- How many people may visit these offices?
- How many parking spaces will be necessary?
- Where will the occupants and visitors park?
- How long will it take to enter/exit during rush hour?
- What type of traffic condition it may create locally?
- What provisions are there for public transportation?
- How many people may use the toilets at what frequency?
- How much water will be used in the building?
- How much energy will be consumed?
- What type of waste will be generated?

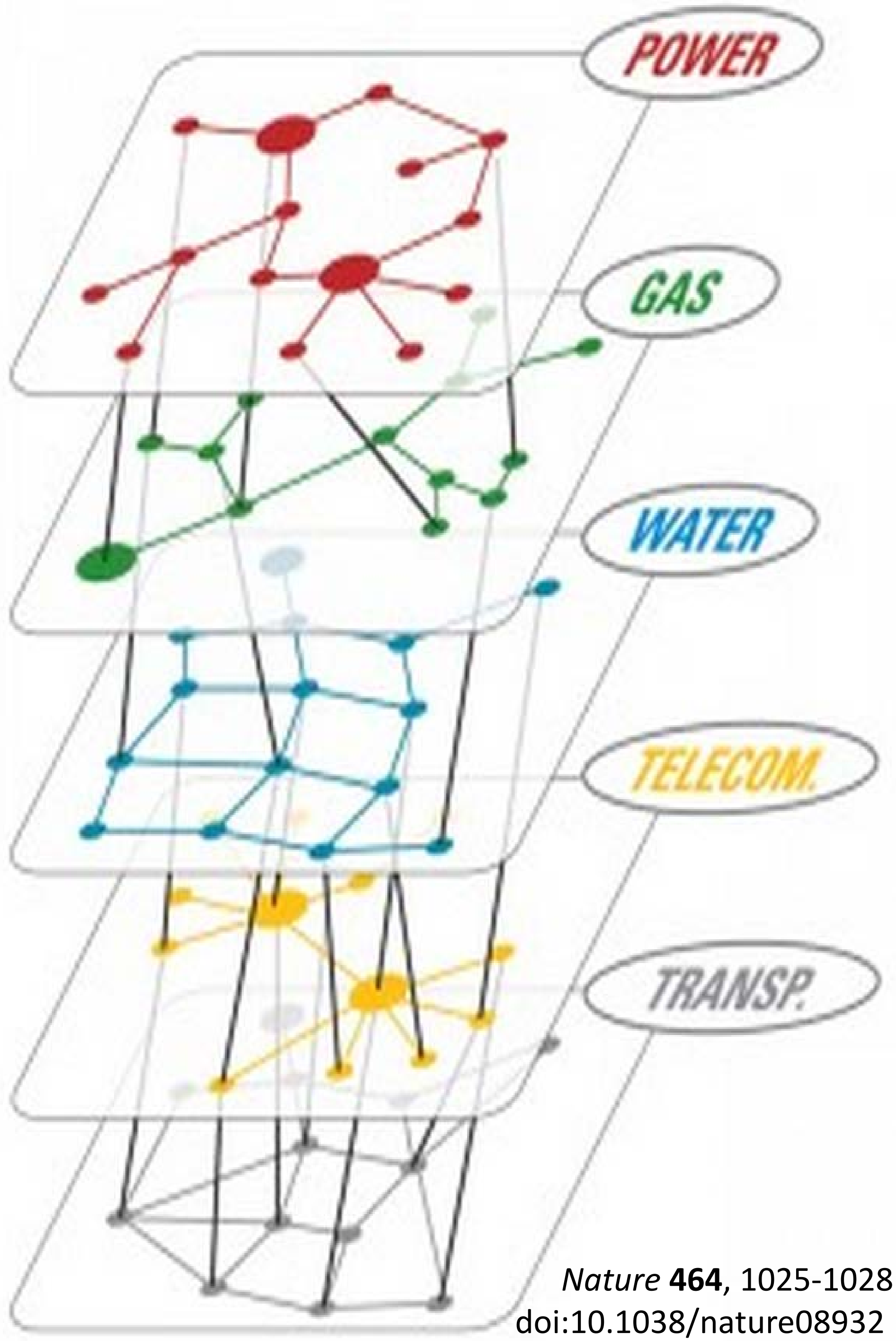
Users will only need to input their data – room utilization/floor traffic



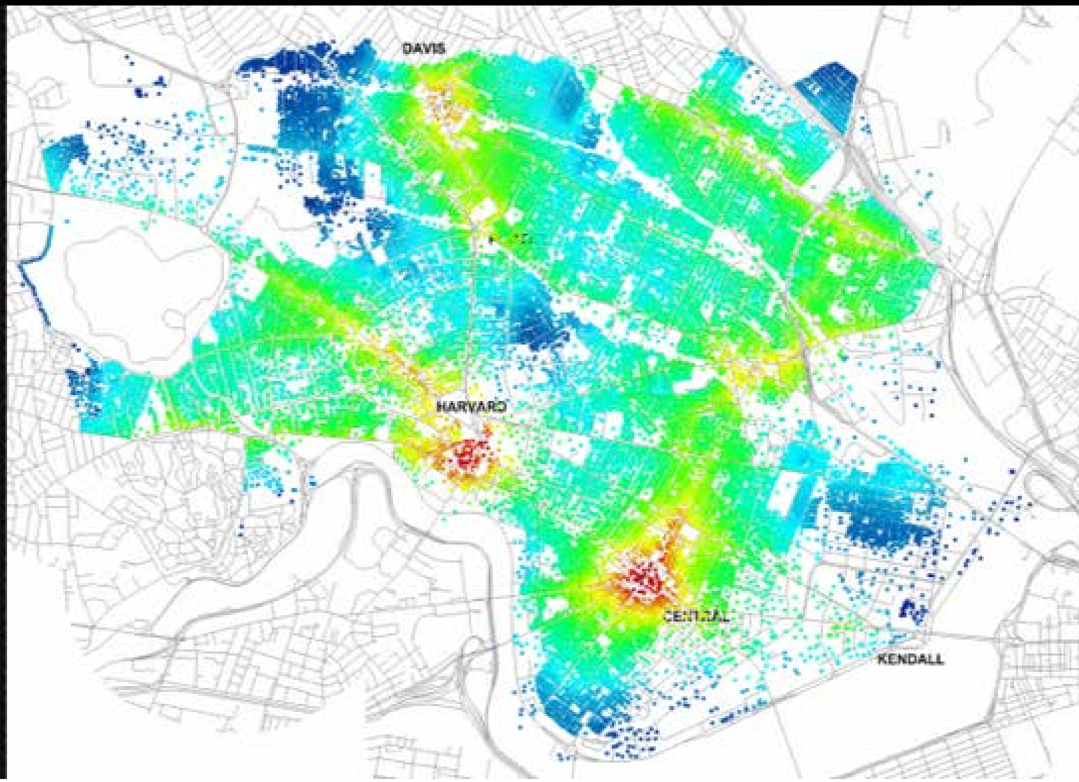
Cities as Cascade of Networks

Creation of a digital twins using entity level agent based model is essential to analytics and simulation of what-if scenarios (deterministic) to better prepare for the non-deterministic states (emergency). This approach is not limited to any field but applicable when any FSM or cluster of "atoms" connected to bits (data).

Digital duplication will be the underpinning of all most all elements in the context of IoT, IIoT. Data from each individual node (eg sensor data from each part in a machine with hundreds of parts) will feed the digital twin connected to algorithm engines in the cloud or the edge to drive real-time analytics, provide feedback to improve efficiency or precision of the machine or device or process or decision support system in a manner that is context-aware and delivers intelligence of value or boosts autonomy or provides a profitable service or saves lives.



Nature **464**, 1025-1028
doi:10.1038/nature08932



FULL SCREEN

With the new Urban Network Analysis software plugin from the MIT-Singapore International Design Center, architects and urban planners can describe spatial patterns of cities using mathematical network analysis methods. Here, a screen shot from the plugin shows accessibility to public transit (bus and metro) from individual buildings in Cambridge and Somerville, Massachusetts.

Image courtesy of Andres Sevtsuk/City Form Lab.

MIT-Singapore design center creates free software tool to analyze cities as spatial networks

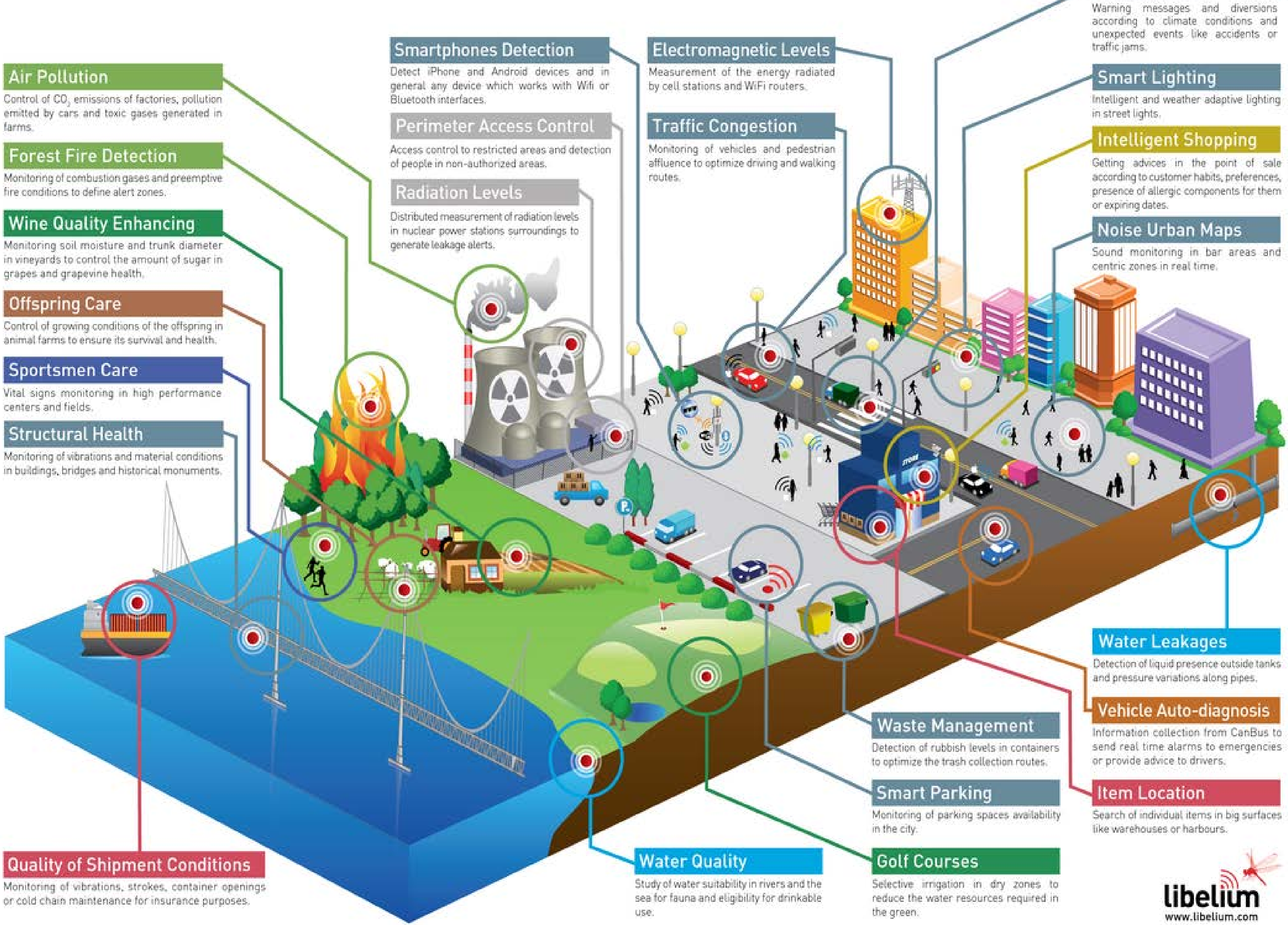
New plugin aids in understanding social and economic consequences of city planning.

The Target – Outcome

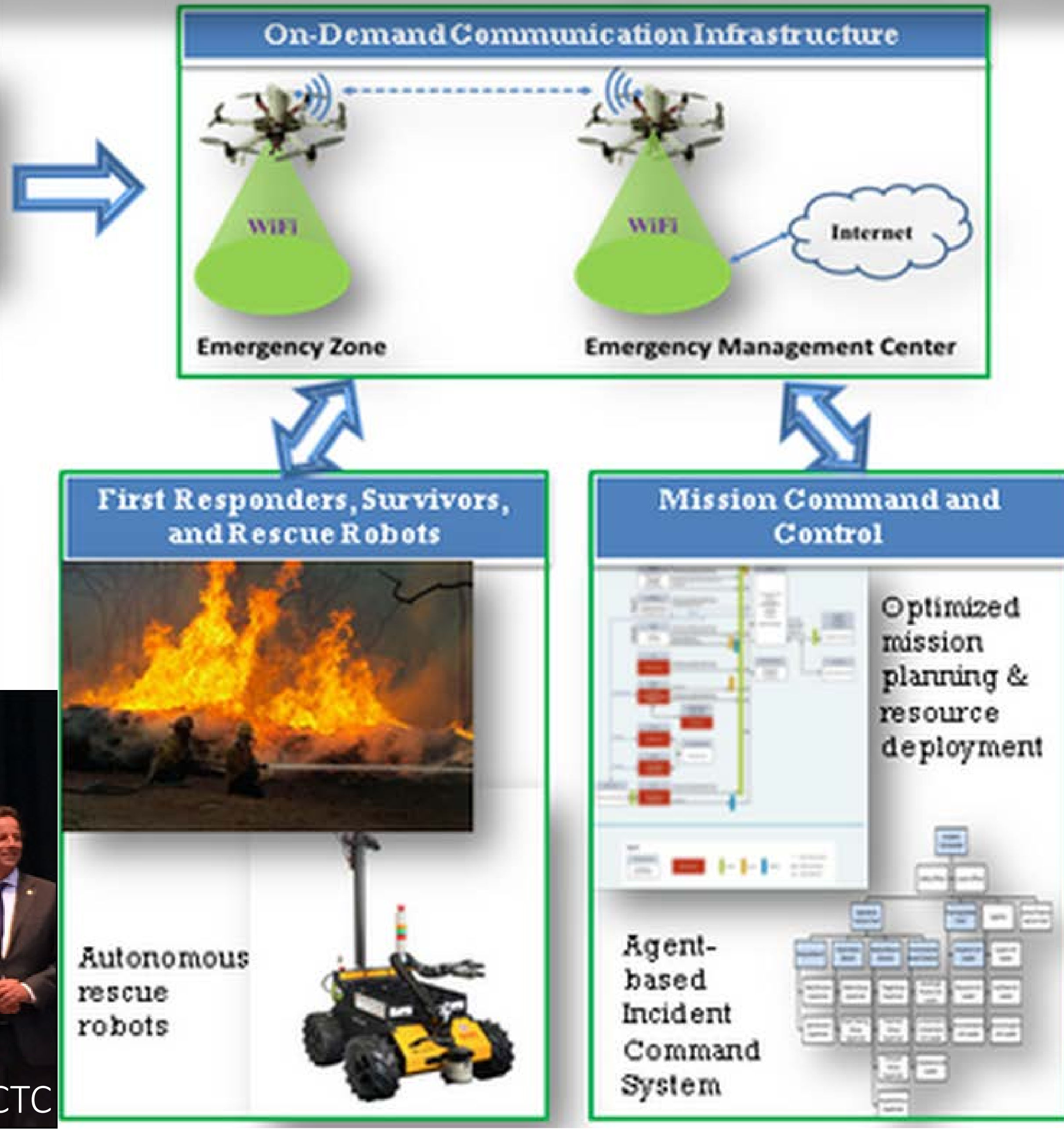
- Component repository
- Configure
- Go Live

City clerks and non-experts can plan, modify, run what-if scenarios to prepare for resiliency and emergency. Also, monitor security, asset intelligence, civic services, transport, pollution.

Smart Cities → Smart Nations → Smart World → Smarter Planet



SERS ● NIST Global Cities Team Challenge (June 1, DC)



Smart Emergency Response System

To connect cyber-physical technologies with humans in the loop to save lives, rescue people, and attend to their critical needs when disaster strikes.


Queen Maxima of Netherlands at GCTC

What we didn't discuss but is at the heart of all

CREATING DESIGN STANDARDS and STANDARD BY DESIGN

as well as

INTEROPERABILITY BETWEEN STANDARDS

SEMANTIC DESIGN INTEROPERABILITY

SHARED ONTOLOGY ? OPEN DATA DICTIONARIES ? SCHEMAS ?

RESOURCE DESCRIPTION FRAMEWORK (RDF) ● http://bit.do/W3C-RDF

\- AI & Analytics

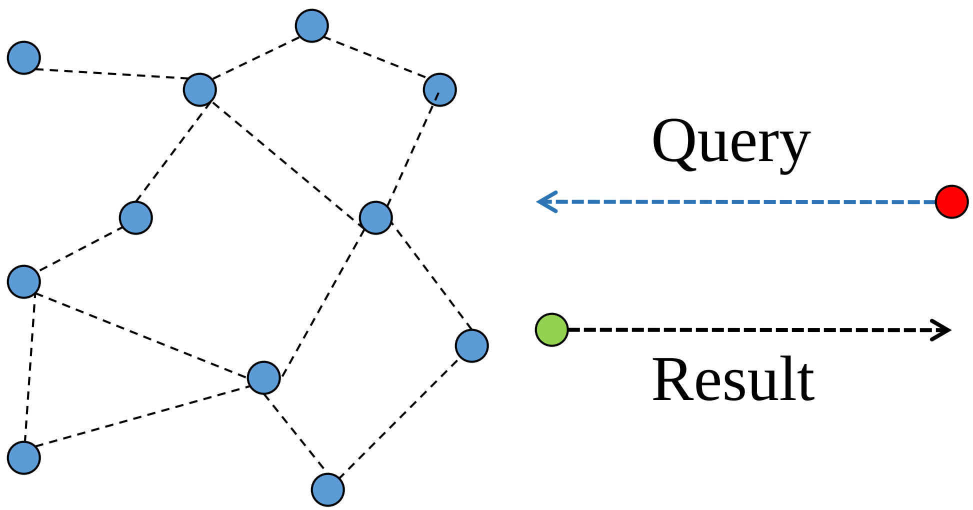
http://bit.ly/MIT-IOT

Assume we are connected and secure

What about data, context, analytics, intelligence and cognition?

Essentially these are all sensor / communication networks

WSN in-network Processing



www.cs.colorado.edu/~rhan/CSCI_7143_001_Fall_2003/agr24.ps

Data in Networks

Data Analytics using Neural Networks

Neurons connect to process data / information using pattern recognition tools

Syntactic Web

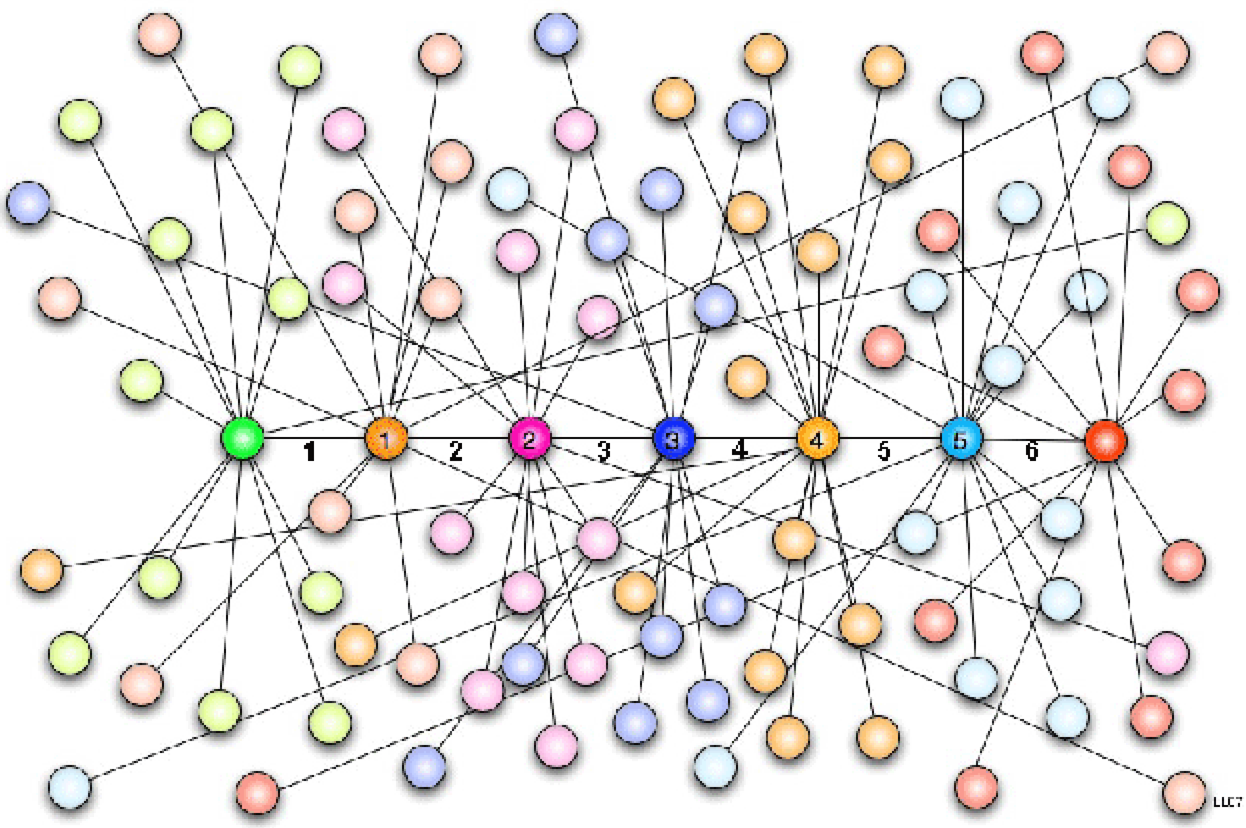
Semantic Web

Synapses connect, converge, coalesce data from various regions for contextual response

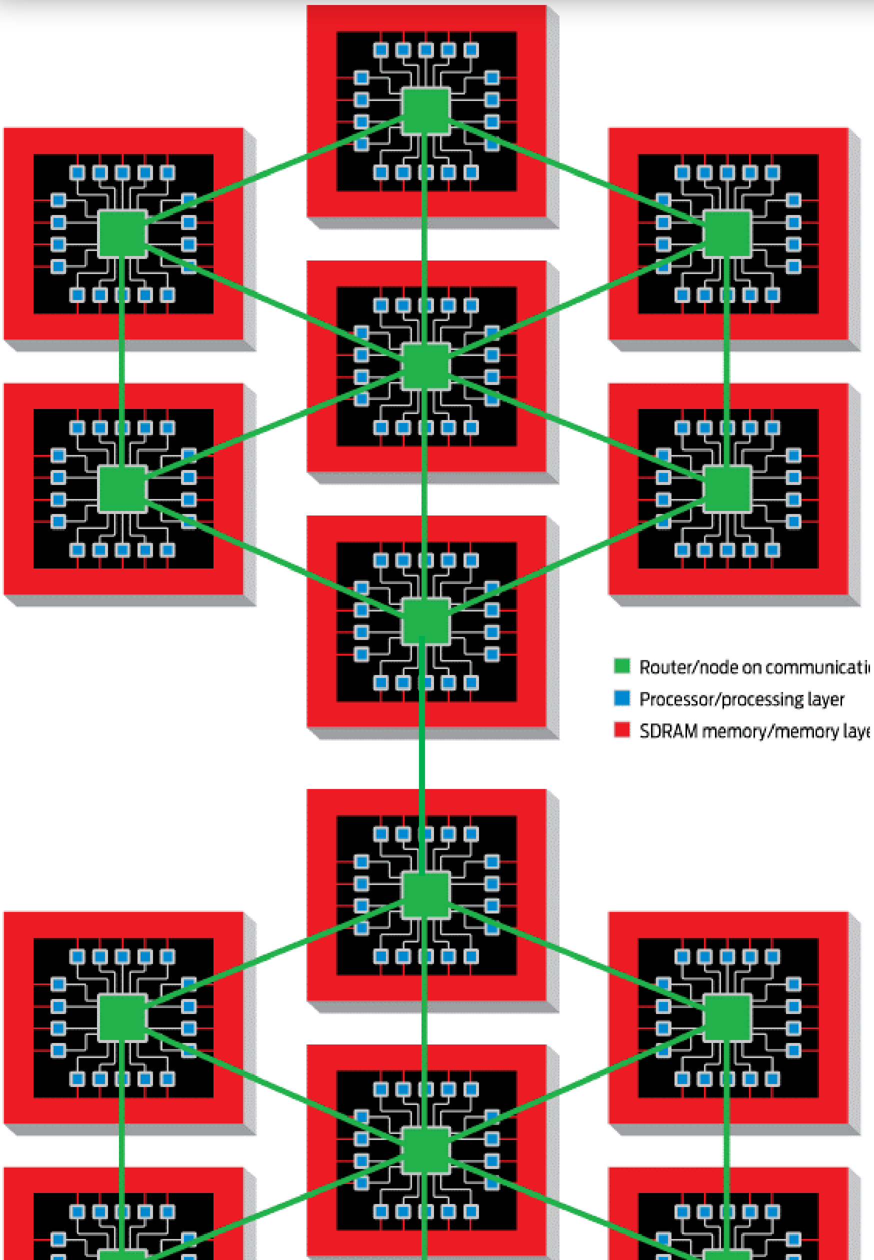
Syntactic Web

Semantic Web

Synaptic Web



Neuro-Synaptic Chips & Multi-core platforms for parallel processing of noisy, multi-modal, unstructured data

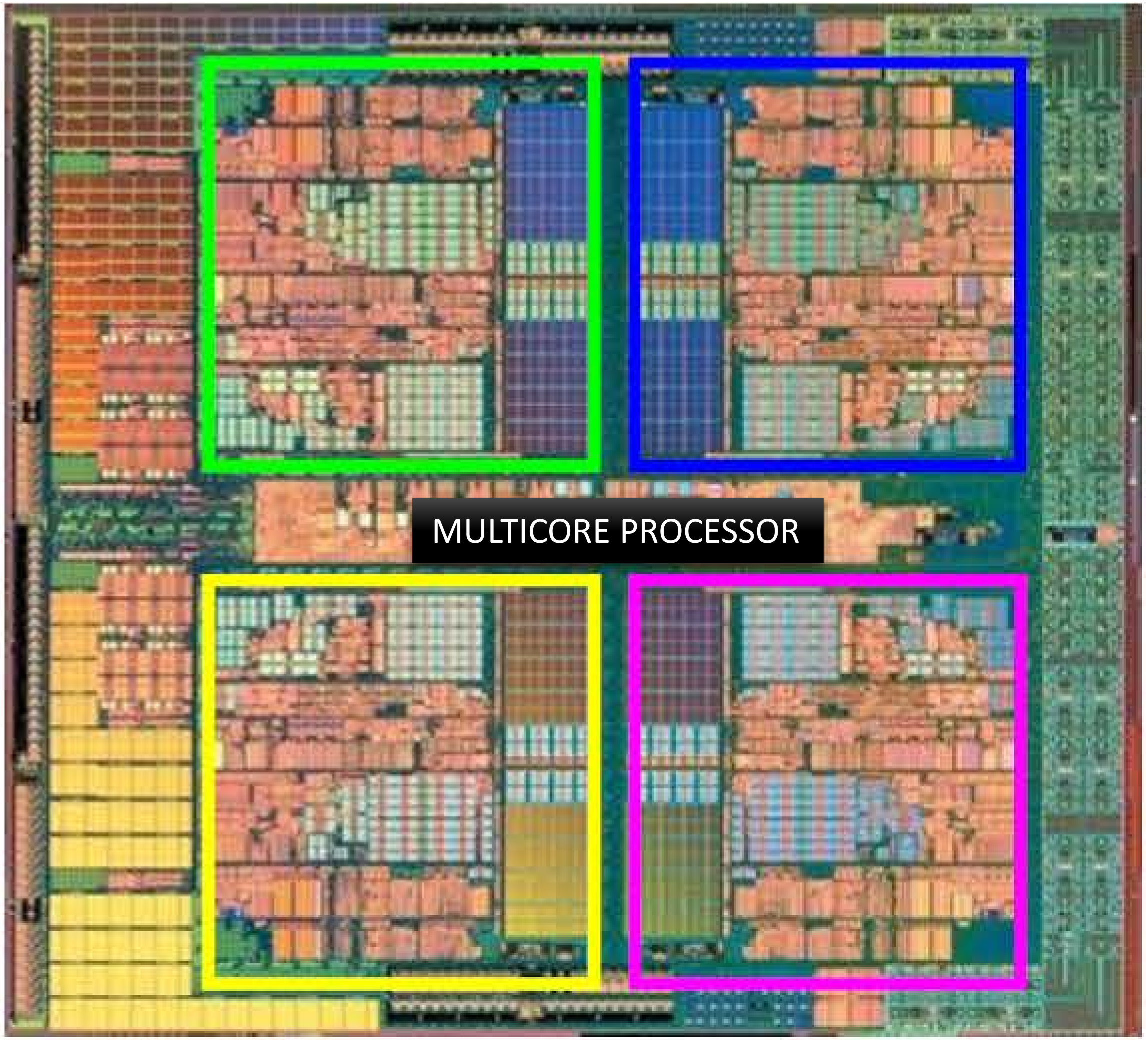


IIoT Application – Embedded Fault Detection for Safety-Critical Systems

without reliance on the need for physical redundancy

Data Driven
Anomaly Detection

Model Based
Fault Detection

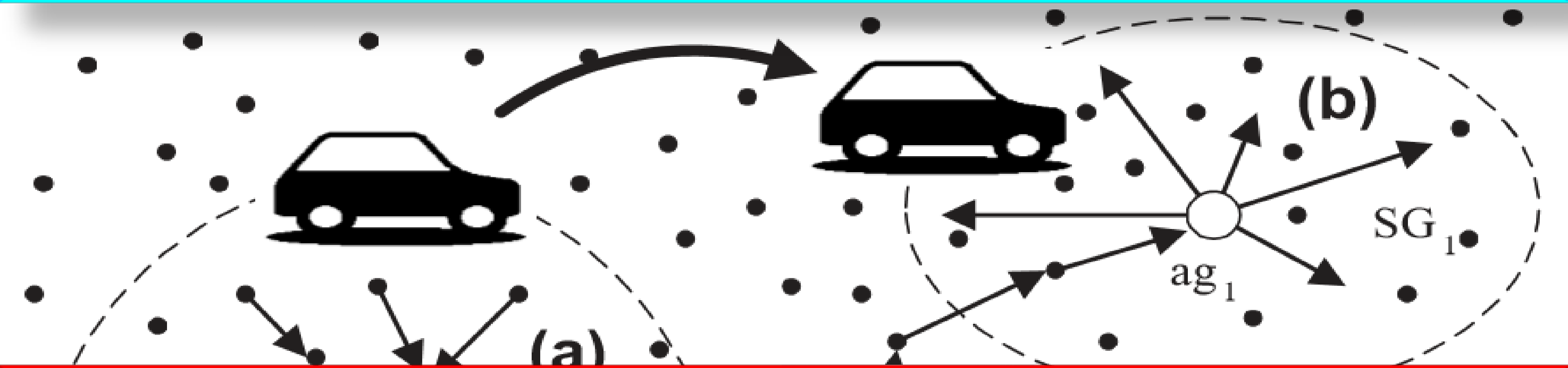


Software Monitors
FDI Supervisor

Control Algorithms
Signal Processing

Aviation • In-flight monitoring edge data and predictive maintenance based on edge analytics

CNN • Edge Network Processing



Convolutional Networks for Fast, Energy-Efficient Neuromorphic Computing

Steven K. Esser,* Paul A. Merolla,* John V. Arthur,* Andrew S. Cassidy,* Rathinakumar Appuswamy,* Alexander Andreopoulos,* David J. Berg,* Jeffrey L. McKinstry,* Timothy Melano,* Davis R. Barch,* Carmelo di Nolfo,* Pallab Datta,* Arnon Amir,* Brian Taba,* Myron D. Flickner,* and Dharmendra S. Modha*

*IBM Research – Almaden

EDGE INTELLIGENCE

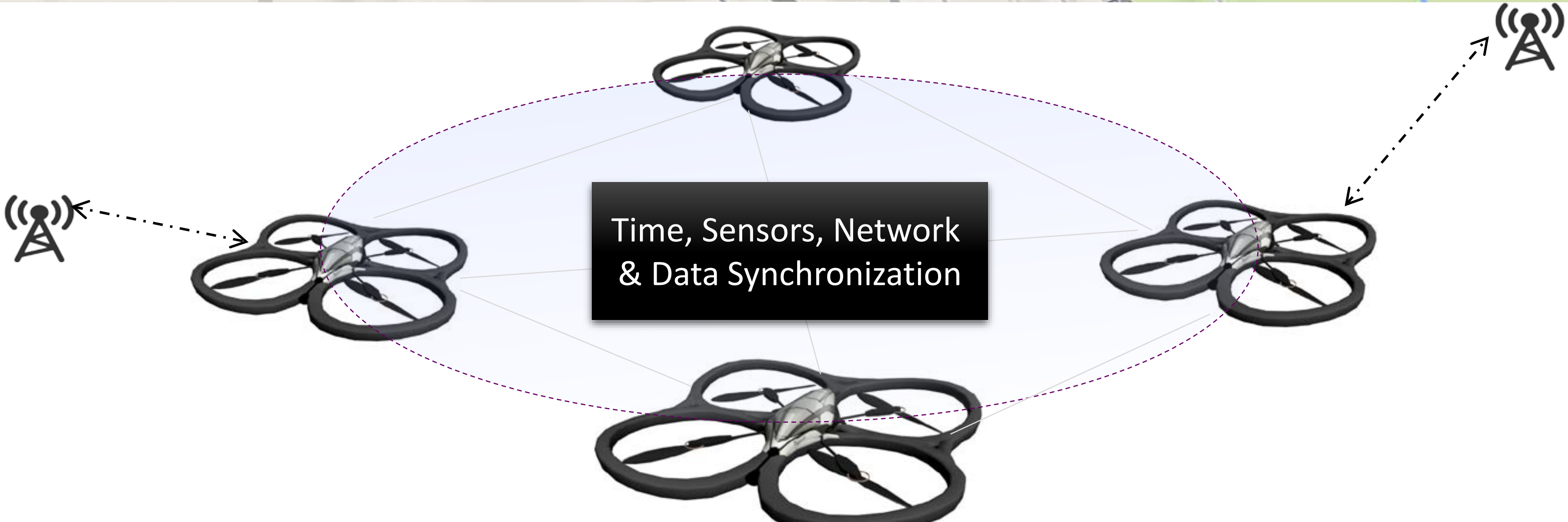
Eyeriss: An Energy-Efficient Reconfigurable Accelerator for Deep Convolutional Neural Networks

EYERISS

Citation	Chen, Yu-Hsin, Tushar Krishna, Joel Emer, and Vivienne Sze. "Eyeriss: An Energy-Efficient Reconfigurable Accelerator for Deep Convolutional Neural Networks." in ISSCC 2016, IEEE International Solid-State Circuits Conference, Jan. 31-Feb. 4, 2016. San Francisco, CA.
As Published	https://submissions.mirasmart.com/isscc2016/PDF/ISSCC2016AdvanceProgram.pdf
Publisher	Institute of Electrical and Electronics Engineers (IEEE)

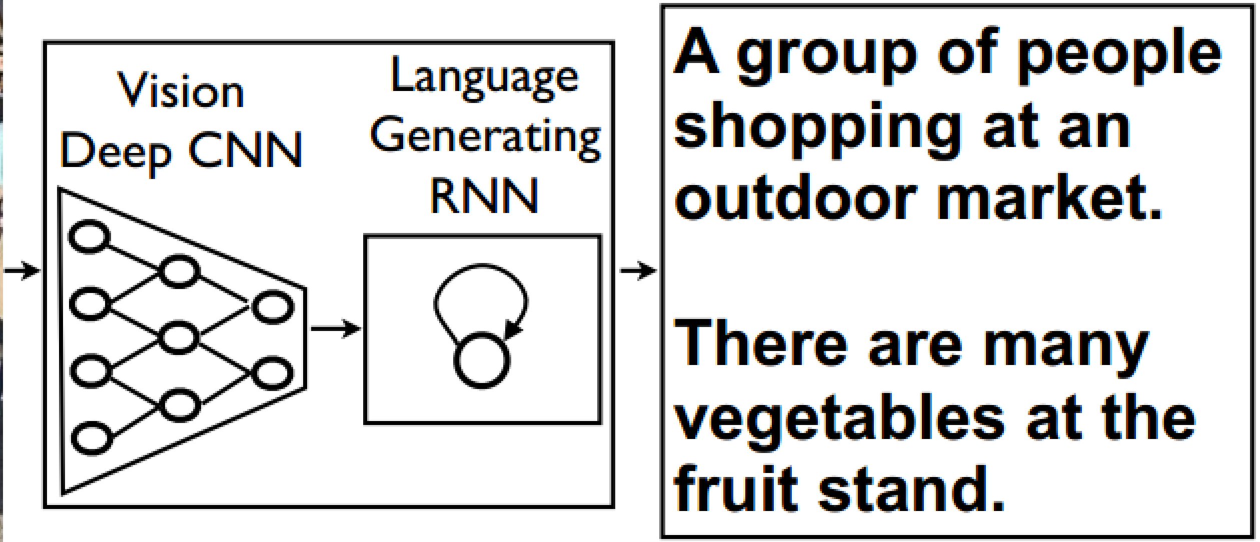
Transportation Coordination - Emergency “Crash to Care” Response

Transportation of real-time data key to emergency search and rescue drones



Dhananjay Anand, NIST

CNN at the Edge - Collision Avoidance for Autonomous Objects



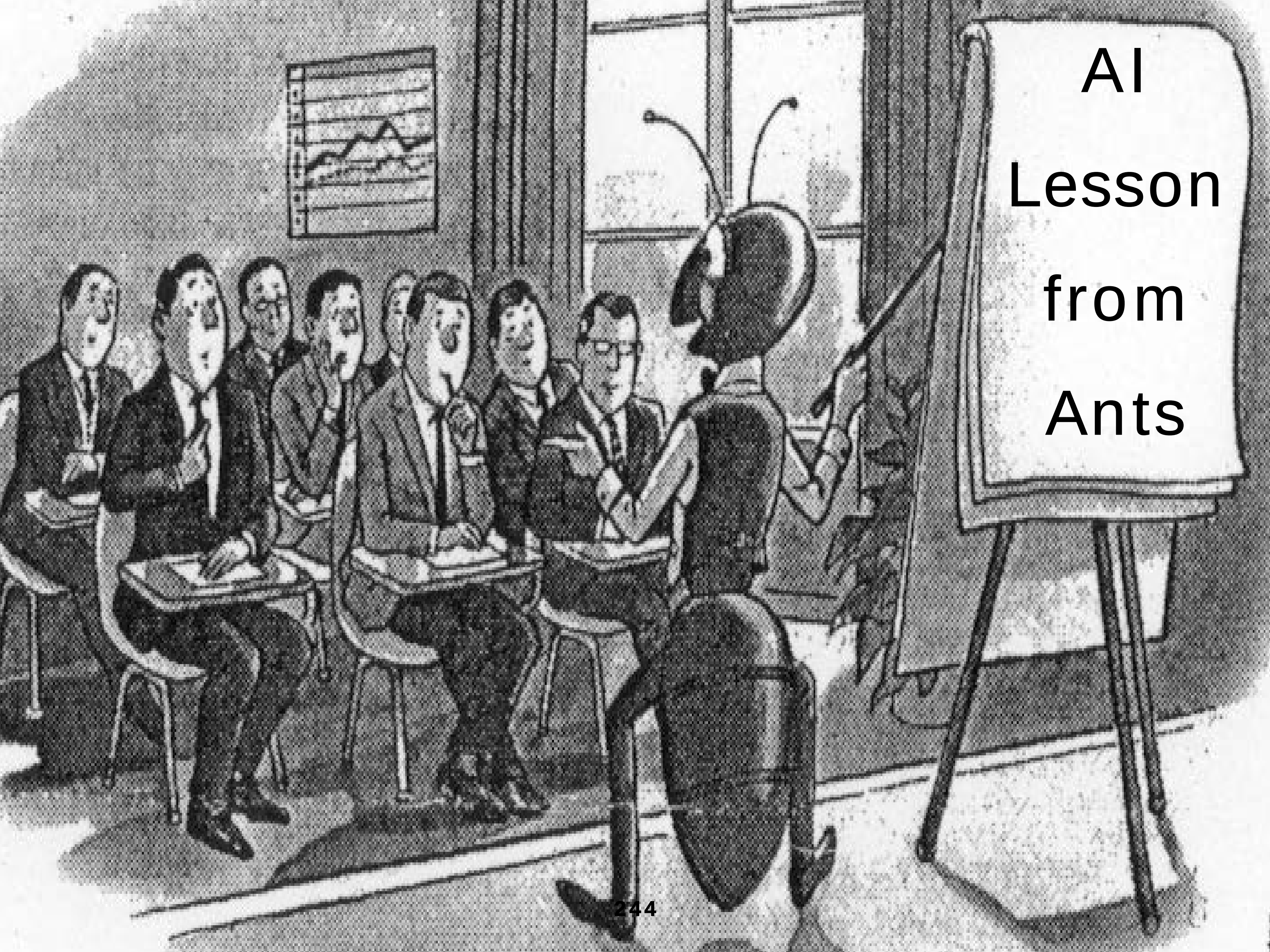
http://arxiv.org/pdf/1411.4555v1.pdf

To translate languages, Recurrent Neural Network (RNN) transforms a French sentence into a vector representation, and a second RNN uses that vector representation to generate a target sentence in German. Replace first RNN and input words with deep Convolutional Neural Network (CNN) trained to classify objects in images and add known classes of objects in semantic baffles with corresponding behavior (plastic bag versus wooden plank) with assigned probability of object in the image (environment). Feed CNN's rich encoding of the image into a RNN designed to produce phrases. We can then train the whole system directly on images and their captions, so it maximizes the likelihood that descriptions it produces best match the training descriptions for each image. The natural language spoken by human (inside vehicle) better trains the algorithms.

Author's idea is adapted from → http://googleresearch.blogspot.co.uk/2014/11/a-picture-is-worth-thousand-coherent.html

Neural Paradigm Shift?

The design of classical weighted neural networks


AI
Lesson
from
Ants

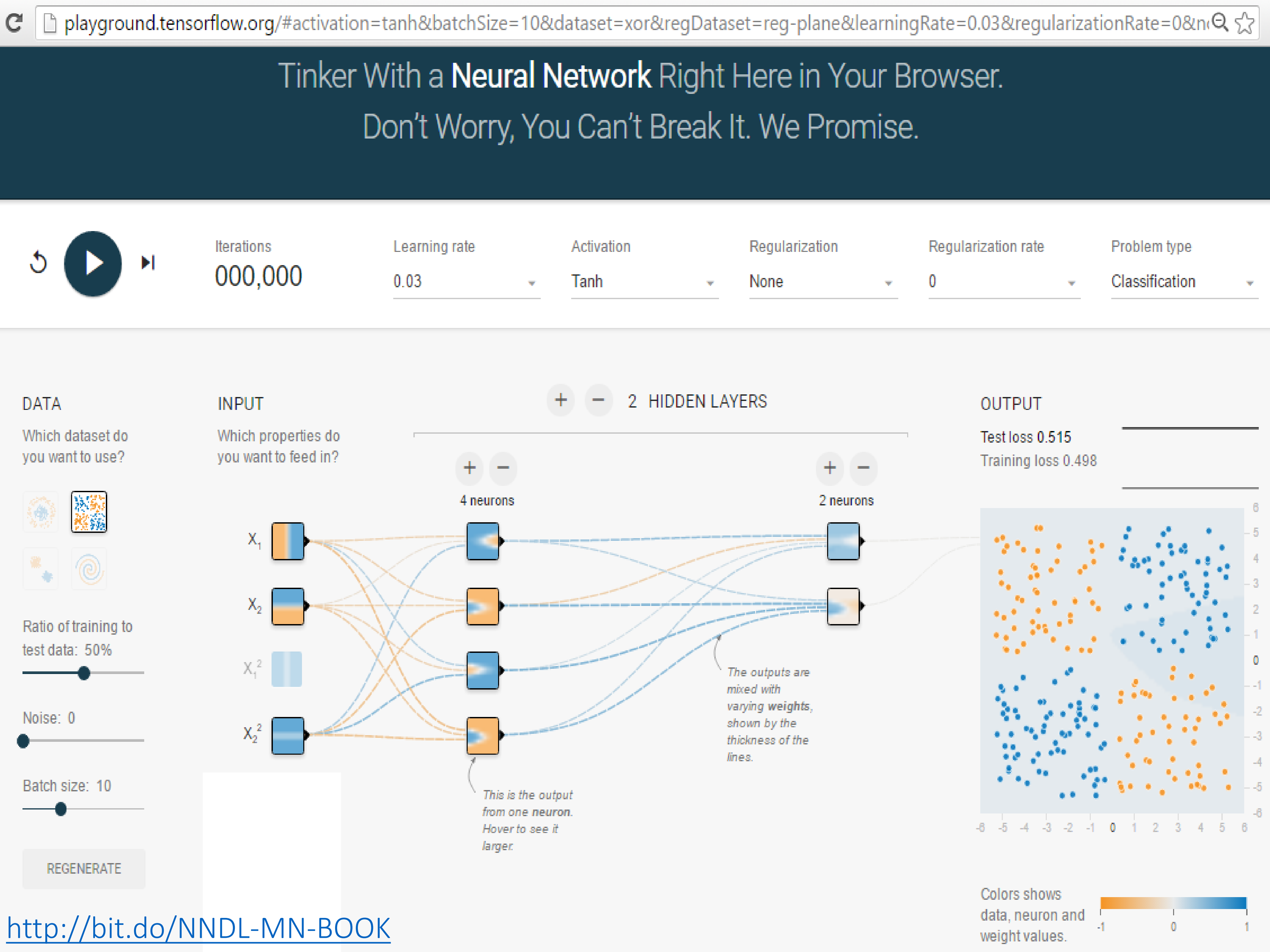
ANN, RNN, CNN – AI applications and limitations

The road to digital twins is paved with data and harvesting intelligent analytics is key to performance improvements. One component in the machine learning (ML) tool kit is AI and use of artificial neural networks (ANN) and related techniques.

The purpose of this digression is to point out that ANN type applications in the context of digital twins may be sufficiently served by the classical ANN approach of combining topological (structural) nets with weights (synaptic or functional criteria).

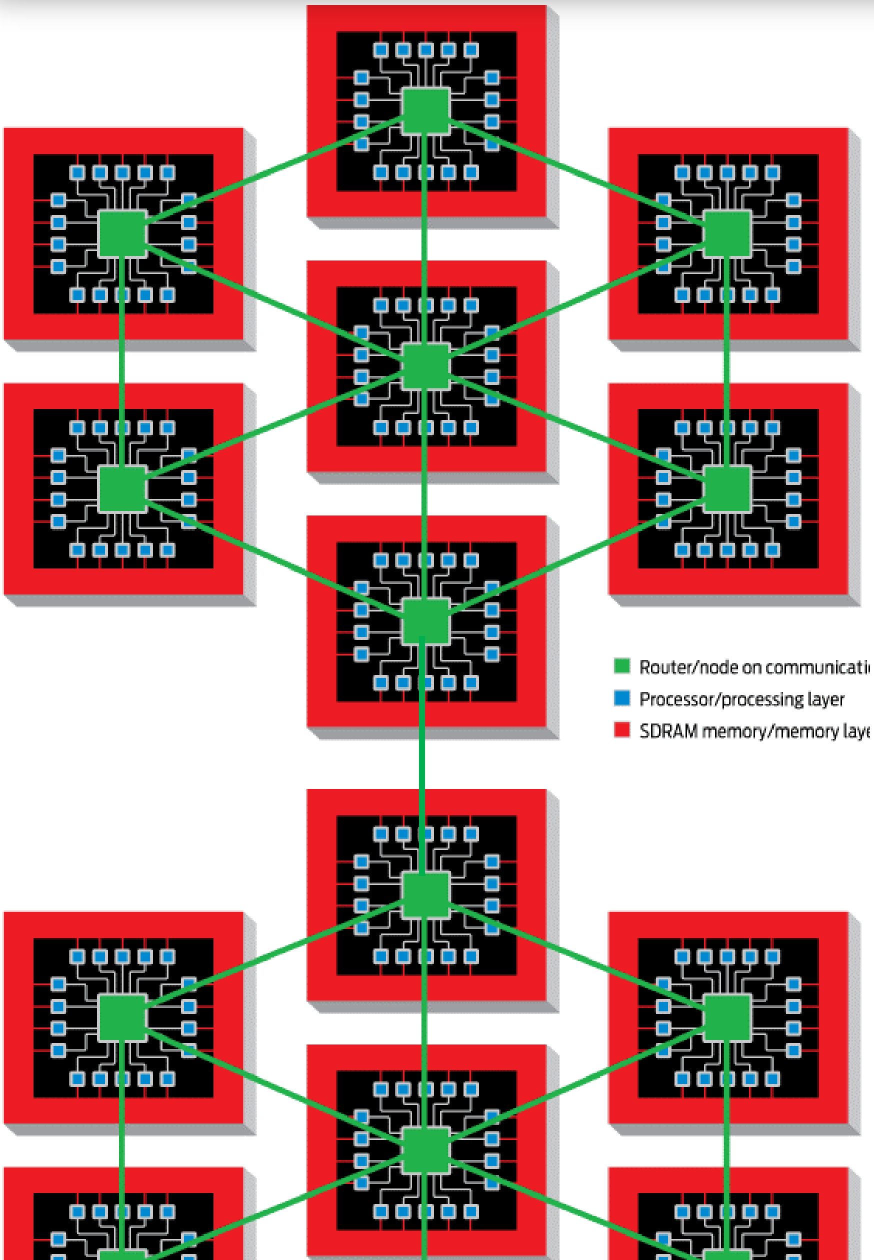
However, the author wishes to point out that the traditional inferential use of ANN may be quite insufficient for adaptable intelligence which may be required of complex systems (entire shop floors, healthcare emergency operations, smart cities, urban transportation, loading dock operations, aerospace industry, swarms of nano-satellites, finance and cybersecurity).

We must evolve from classical ANN which emulates neural network topology to developmentally inspired engineering design based on neurogenesis. By creating programs which can *generate* neural networks we enable the program to learn to adapt, naturally. That is a separate discussion.

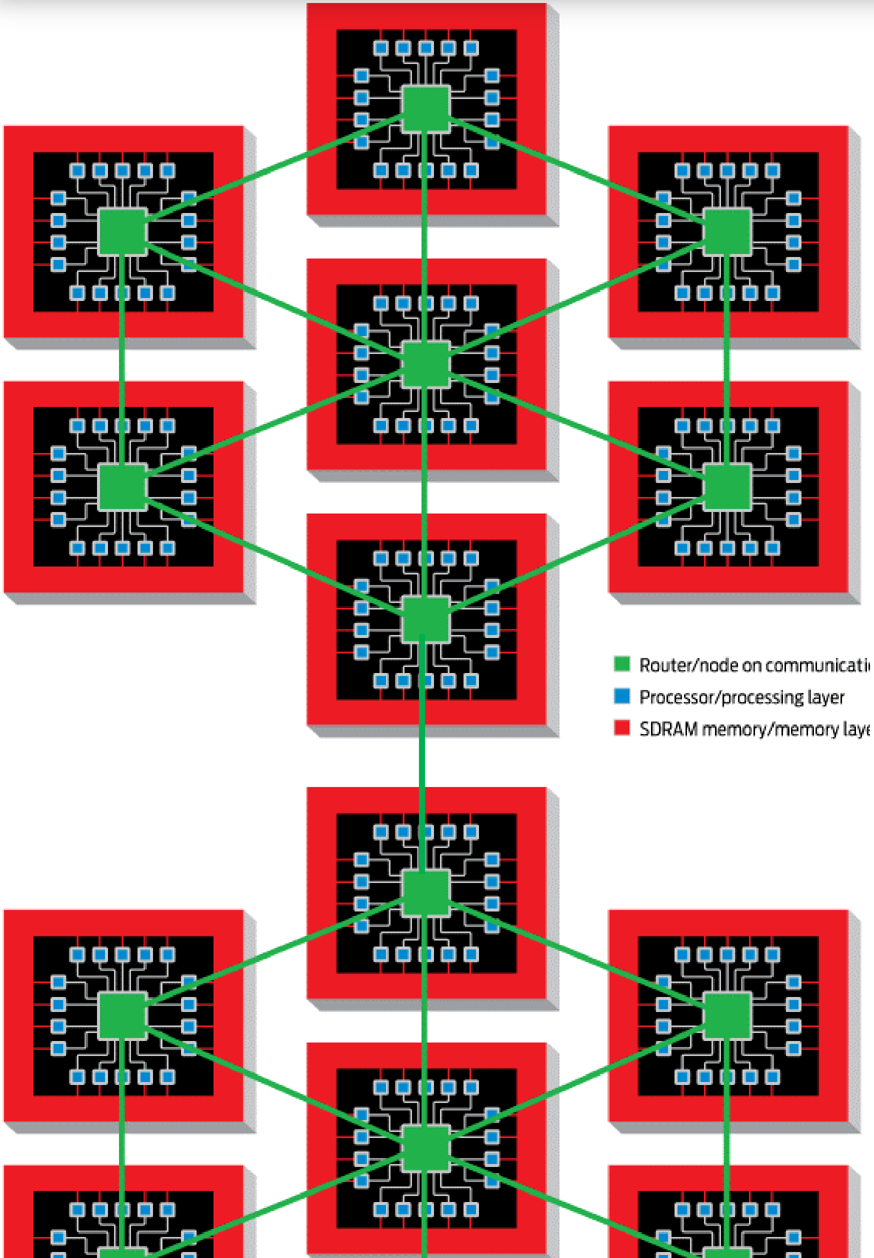


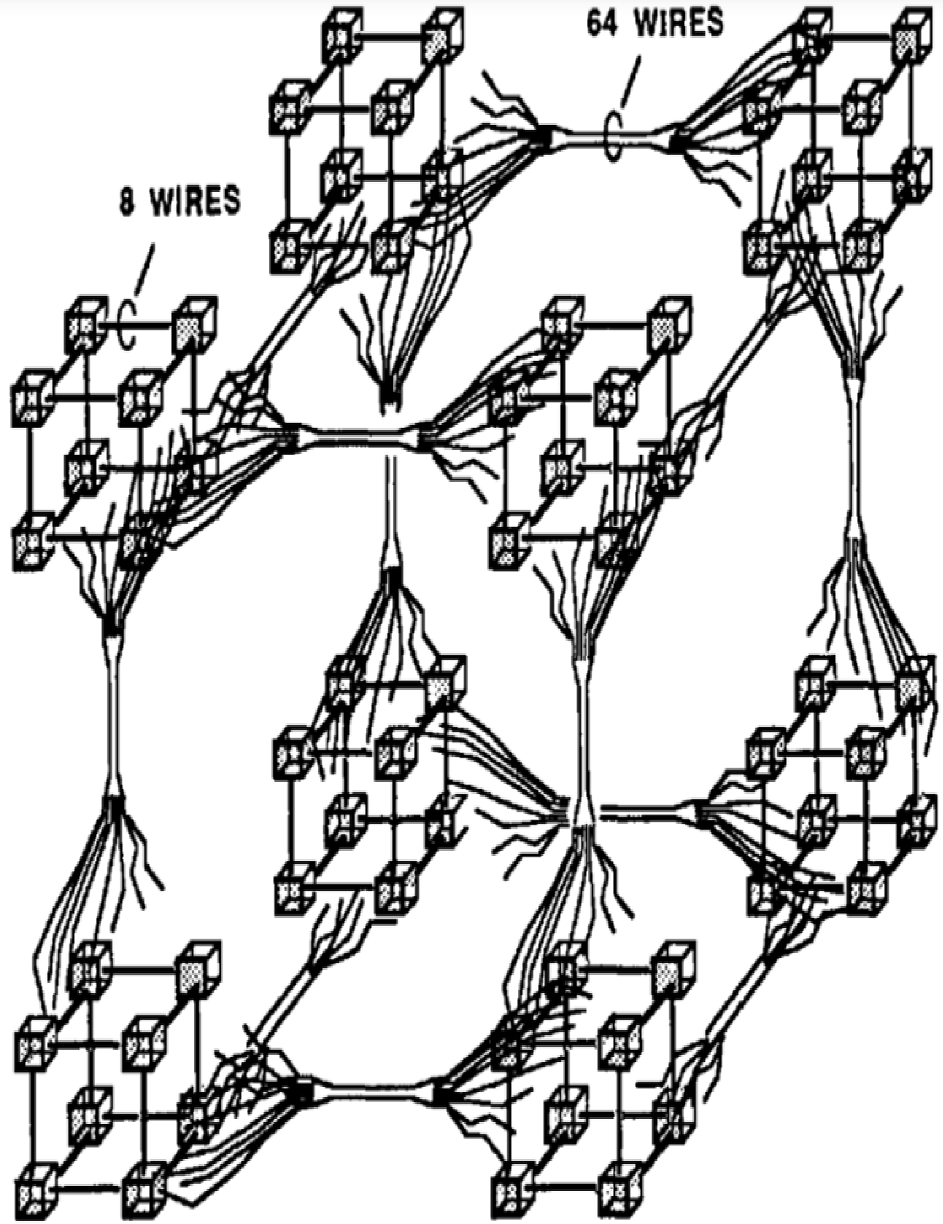
http://bit.do/NNDL-MN-BOOK

Neuro-Synaptic Chips & Multi-core platforms for parallel processing of noisy, multi-modal, unstructured data

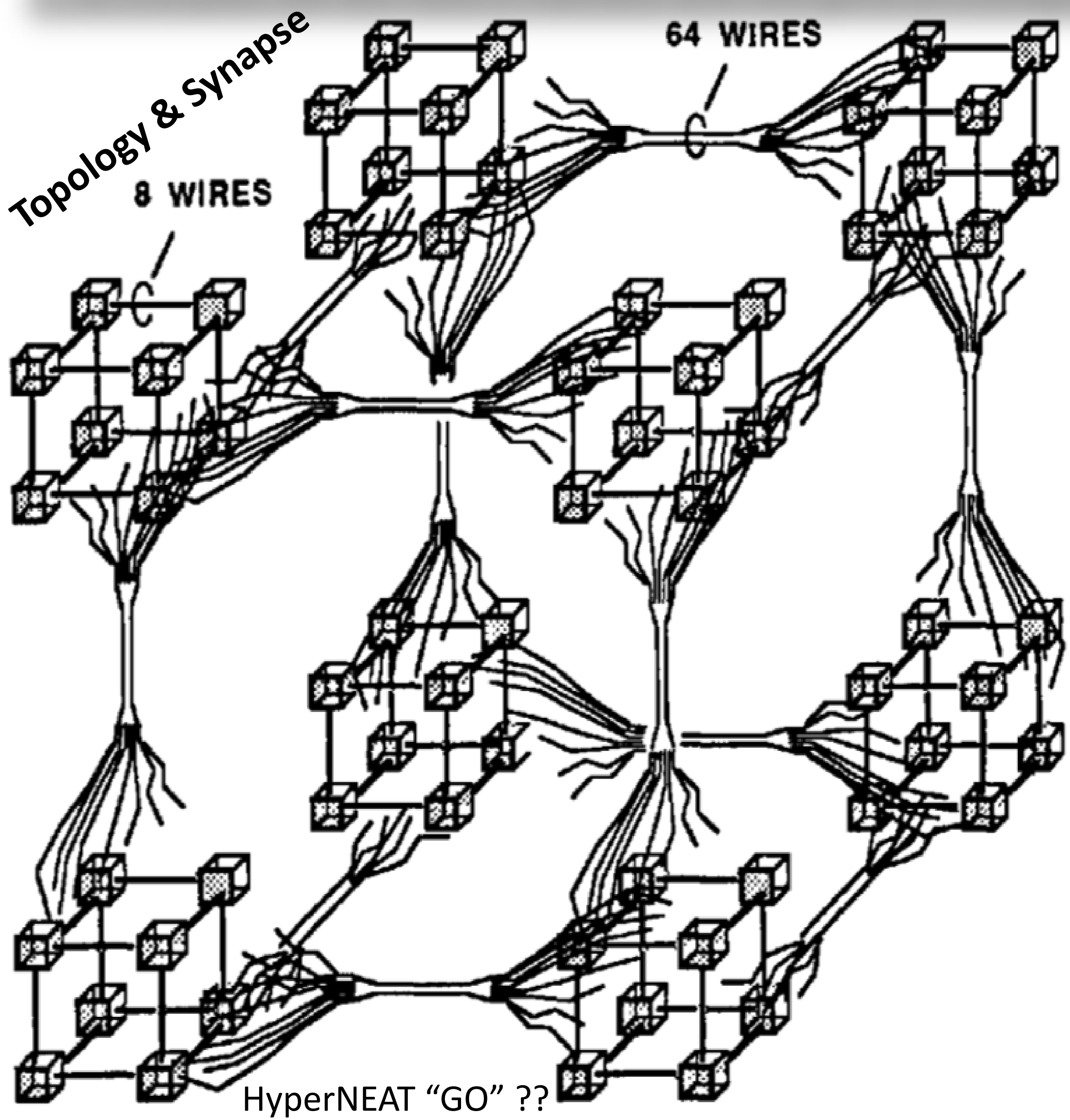


Neuro-Synaptic Chips by D. Modha (IBM) v Marvin Lee Minsky "Cube on Cube" (1959)





Intelligence is not a point, it is a tapestry of linked data, analysis & thinking punctuated by experience.
"Within a generation the problem of creating 'artificial intelligence' will substantially be solved." 1967
"In 3-8 years we will have a machine with the general intelligence of an average human being." 1970



Here, 8 agents make a little cube, and 8 such cubes make a 64-agent supercube.

If we join 8 of these supercubes, we'll have 512 agents. And if we repeat this cube-on-cube pattern ten times, the resulting supercube will contain a billion agents!

But if we link each agent to 30 others instead of only 6, then each agent could communicate with a billion others in only 6 steps.

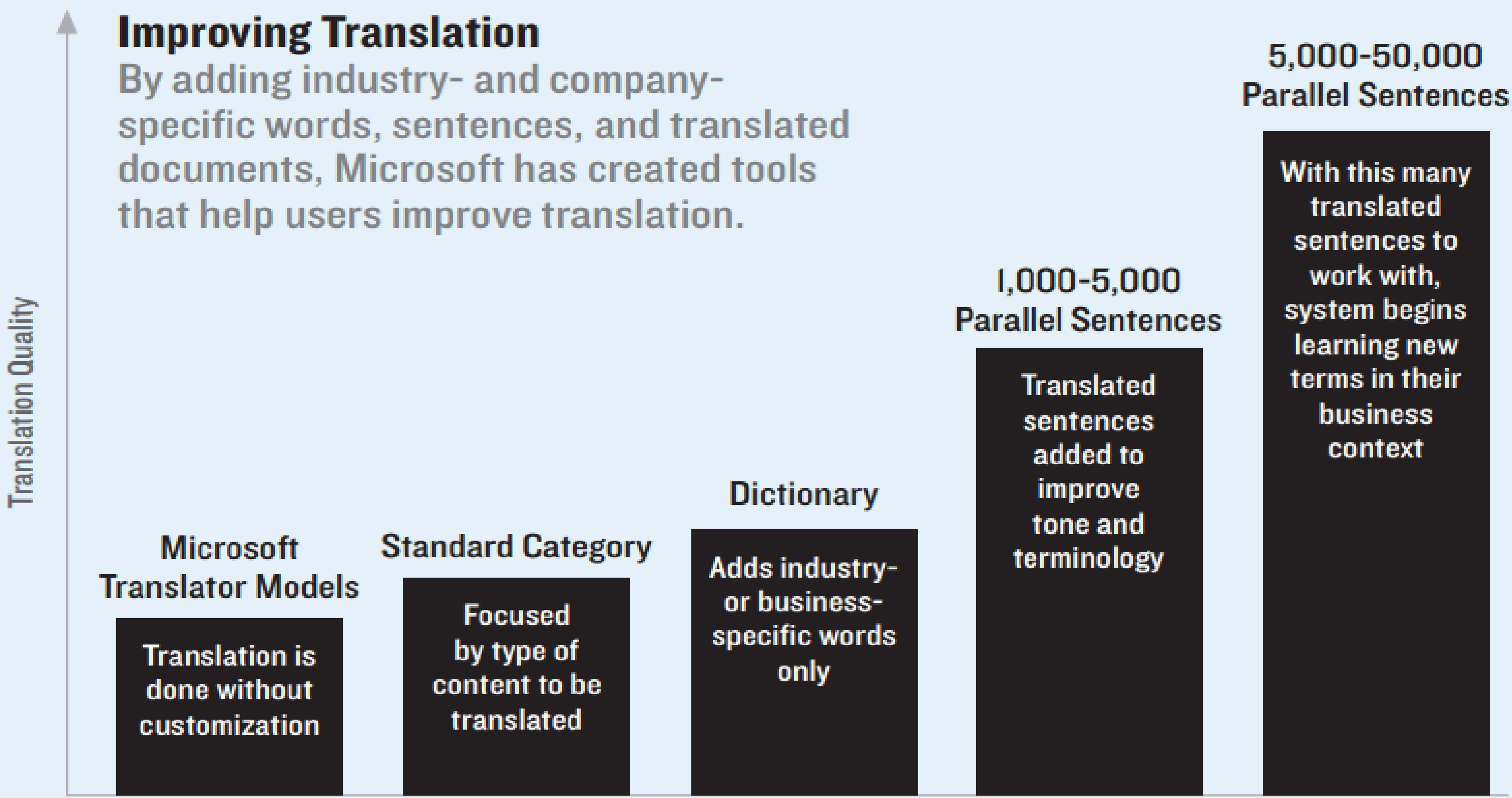
THE SOCIETY OF MIND
Marvin Lee Minsky (1959)

Post-Minsky Progress?

https://jixta.files.wordpress.com/2015/11/machinelearningalgorithms.png file:///C:/Users/shoumen/Downloads/techreview_20160506-dl.pdf

乡在东北,辽宁省,鞍山市. A few seconds later, a friendly synthetic voice told me: "My hometown is in the northeast in China, Liaoning Province, Anshan."

Hardcoded Multi-Lingual Skype
Is this AI or "brain" in a box?

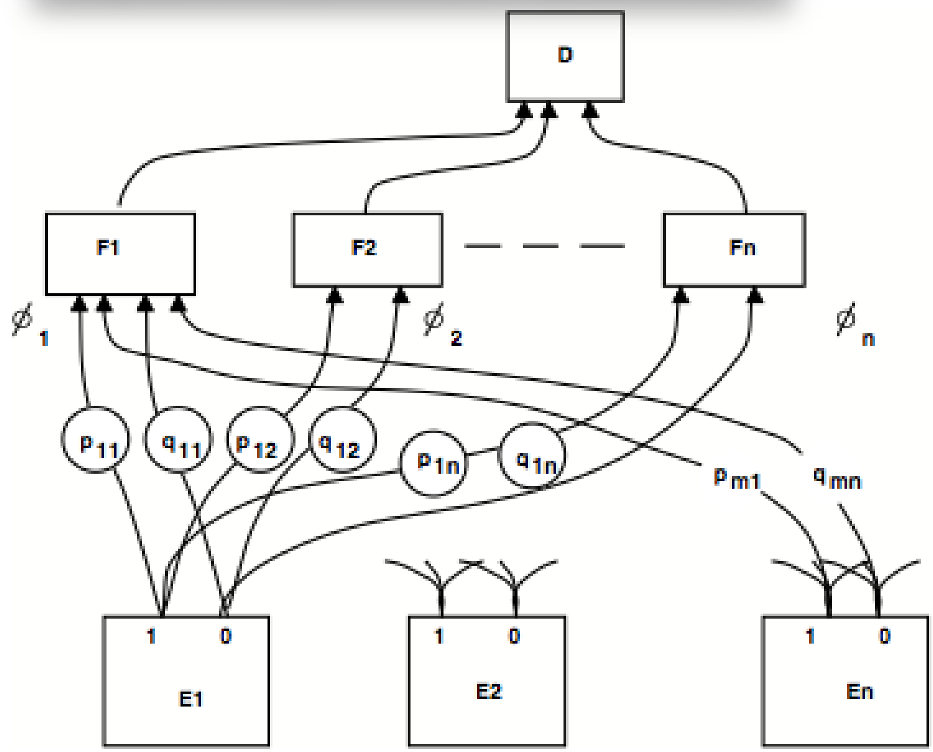


Marvin Lee Minsky (9 Aug 1927 - 24 Jan 2016) made incorrect predictions but still relevant today

In a paper (1960), after enumerating 5 basic categories of 'making computers solve really hard problems' (search, pattern-recognition, learning, planning, and induction), he mentions several algorithms which are still the basic ML tools:
hill climbing, naive Bayesian classification, perceptrons, reinforcement learning and neural nets.

Mentions that one part of Bayesian classification "can be made by a simple network device" and describes implementation of math game by a network of resistors designed by Claude Shannon.

http://bit.do/MINSKY-CHOMSKY

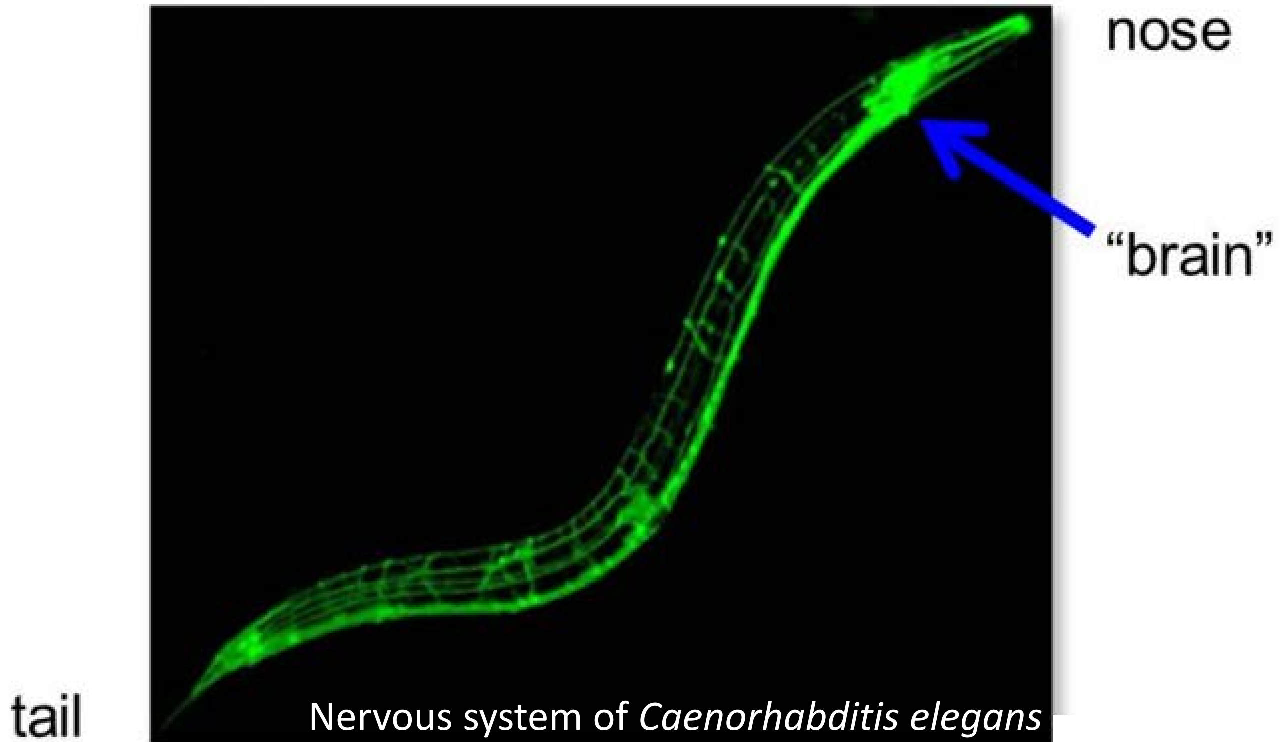


"Predictions that AI lie 15 to 25 years in the future are most common, from experts and non-experts."
See - https://intelligence.org/files/PredictingAI.pdf

IBM's Dharmendra Modha - "Before the end of 2020 we will be able to produce a brain in a box" 31 March 2016

fMRI based semantic maps of language related information across human cerebral cortex
www.youtube.com/watch?v=uMolKD4a6H0

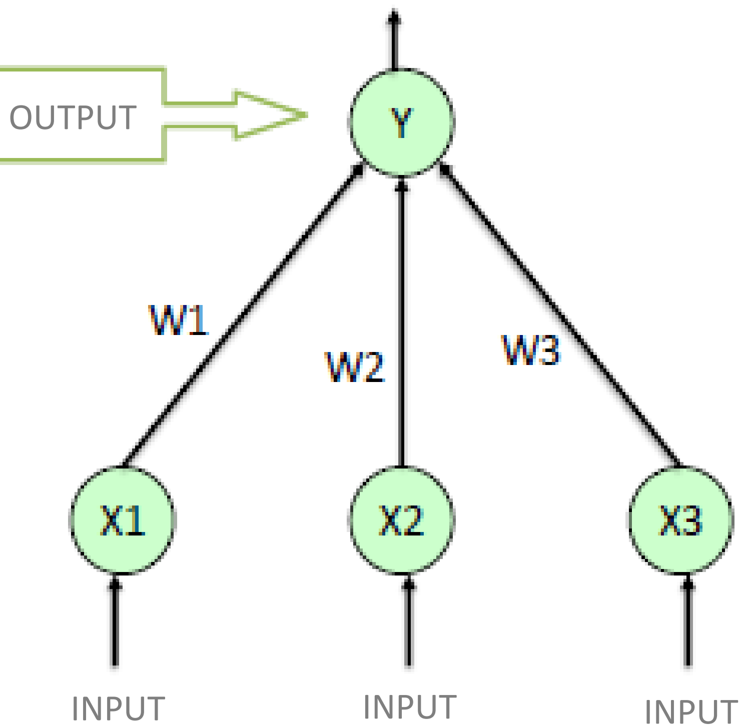
Whose "Brain in a Box" ?



Is topology and synaptic weight guided inferential output equivalent to brain or brain-like performance?

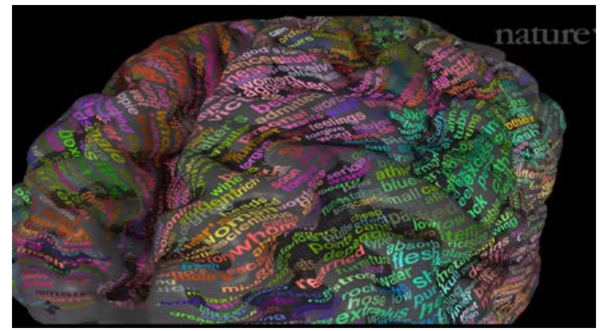
www.nobelprize.org/nobel_prizes/medicine/laureates/2002/horvitz-facts.html

Single Layer Perceptron



How inadequate is synaptic weight?

Explore the word "top" revealed by fMRI
www.youtube.com/watch?v=k61nJkx5aDQ



UC Berkeley
www.youtube.com/watch?v=uMolKD4a6H0

In a computational neural network, a vector or set of inputs $\mathbf{x}$ and outputs $\mathbf{y}$, or pre- and post-synaptic neurons respectively, are interconnected with synaptic weights represented by the matrix w, where for a linear neuron

$$y_j = \sum_i w_{ij} x_i \quad \text{or} \quad \mathbf{y} = w\mathbf{x}.$$

The synaptic weight is changed by using a learning rule, the most basic of which is Hebb's rule, which is usually stated in biological terms as

> *Neurons that fire together, wire together.*

Computationally, this means that if a large signal from one of the input neurons results in a large signal from one of the output neurons, then the synaptic weight between those two neurons will increase. The rule is unstable, however, and is typically modified using such variations as Oja's rule, radial basis functions or the backpropagation algorithm.

https://en.wikipedia.org/wiki/Synaptic_weight

Whose semantic map? Which ontology?

fMRI of English words

What about Mandarin, Hindi, Arabic, Swahili, Finnish or Thai?

SYNTAX, SEMANTICS, CONTEXT

TOP

TOP LESS

OVER THE TOP

TOP OF WALL

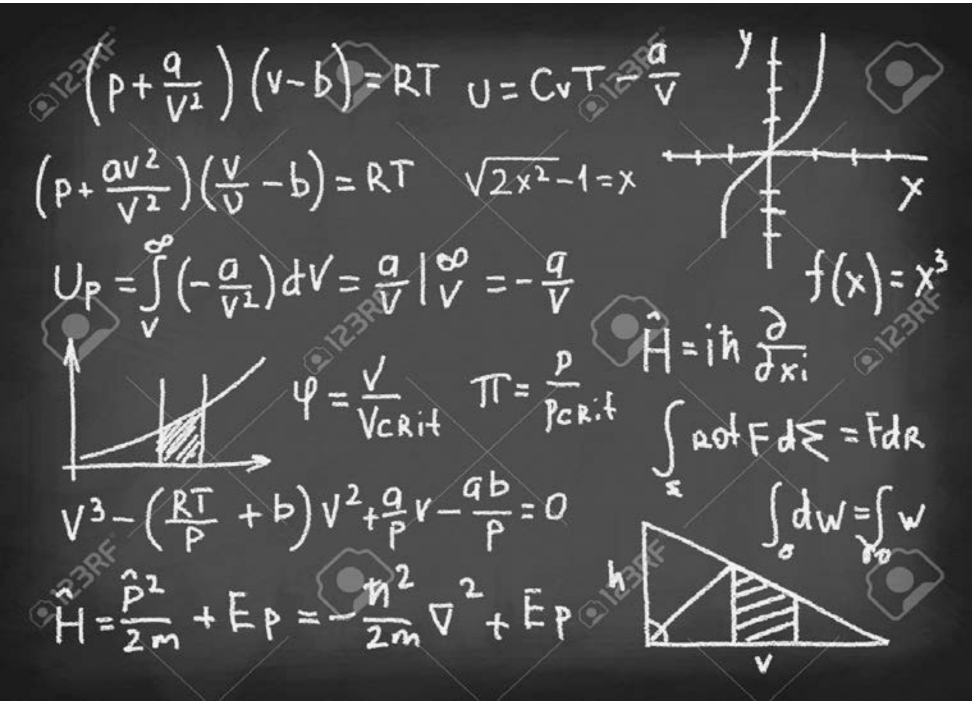
Which part of your brain “lights” up

TOP

TOPLESS

TOP LESS

TOP LESS



OVER THE TOP

TOP OF WALL

TOP Edit | 最佳
Zuì jiā

TOPLESS | 赤裸上身
Chìluǒ shàngshēn

TOP LESS | 爐頂
Lú dǐng

OVER THE TOP | 越過高峰
Yuèguò gāofēng

TOP OF WALL Edit | 頂壁
Dǐng bì

Google Translate from English to Chinese (Traditional)

Semantic Ambiguity ?

2006
Chalmers
Sweden

Call 1 **Loud cry, shout**	喊叫	喊叫
Call 2 **Animal's call**	嚎叫	嚎叫
Call 3 **Telephone call**	电话	电话
Call 4 **House visit**	需求	需求

Semantics v Ontology

Semantic Differences

Call 1
Loud cry, shout
喊叫 喊叫

Call 2
Animal's call
嚎叫 嚎叫

Call 3
Telephone call
电话 电话

Call 4
House visit
需求 需求

Liping Wang Englund
2016 • Gothenberg

Email liping.wang@mets

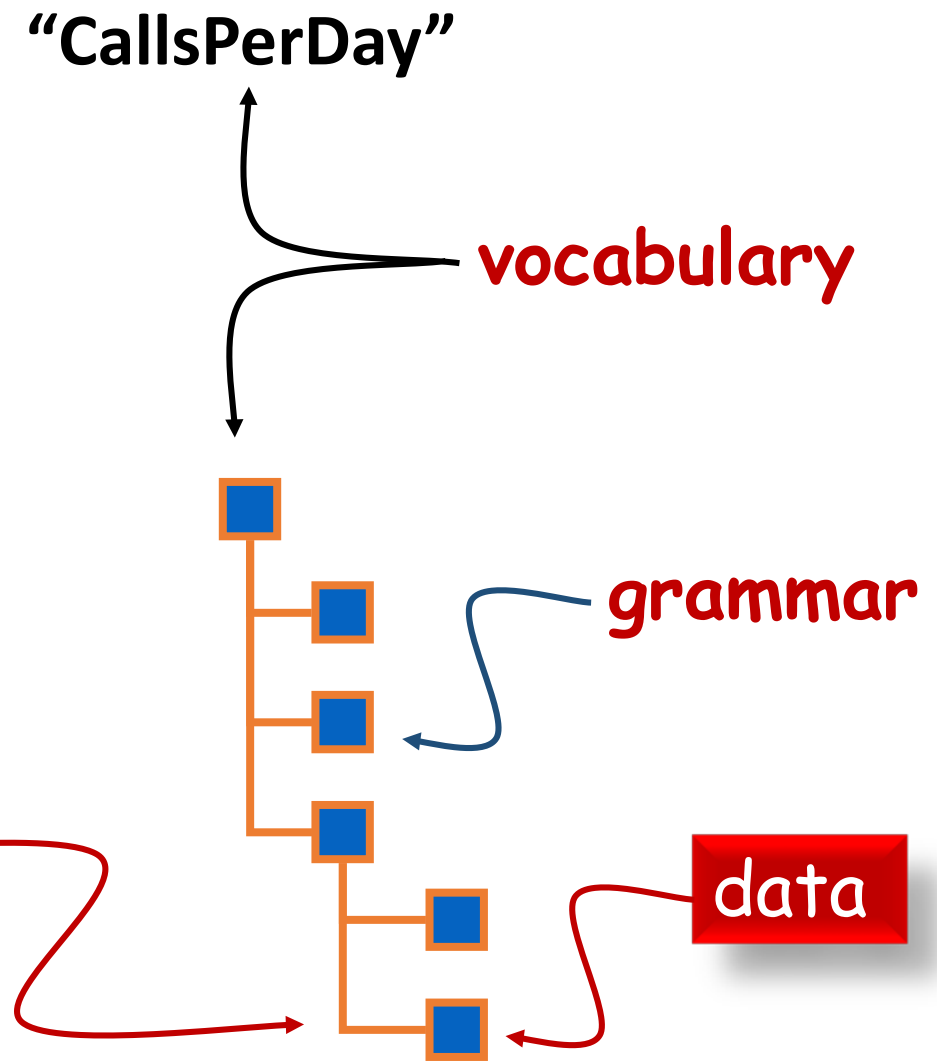
Liping Wang Englund
Project Logistics Manager at Metso Power
Gothenburg, Sweden | Chemicals
Previous Metso Power, Volvo Penta, Maersk Line
Education CSCP(Certified Supply Chain Professional)

Data, Structure, Relations

<CompanyData>
<CompanyName>
MIT
</CompanyName>
<Location>
Cambridge
</location>
<CallData>
<RecordDate>
Sat 7 Jun 2003
</RecordDate>
<CallsPerDay>
536
</CallsPerDay>
</CallData>
</CompanyData>

Data, Structure, Relations, Syntax, Semantics

```
<CompanyData>
  <CompanyName>
   MIT
  </CompanyName>
  <Location>
   Cambridge
  </location>
  <CallData>
    <RecordDate>
     Sat 7 Jun 2003
    </RecordDate>
    <CallsPerDay>
               536
    </CallsPerDay>
  </CallData>
</CompanyData>
```



EVOLUTION

2003 Ontology Working Language (OWL) DAML + OIL
DARPA Agent Markup Language + Ontology Inference Layer

1999 XML-based Physical Markup Language (PML)
RFID Object Description Language (AIDC, MIT)

1998 eXtensible Markup Language (XML)
World Wide Web Consortium (W3C)

1996 eXtensible Markup Language (XML)
World Wide Web Consortium (W3C) Initiative

1993 HTML Browser Mosaic - Marc Andreessen
National Center for Supercomputing Applications (NCSA) University of Illinois

1989 HyperText Markup Language (HTML) - Tim Berners-Lee, CERN

1986 SGML - International Organization for Standardization (ISO)

1983 SGML Computer Graphics Association (CGA)

1978 Standard General Markup Language (SGML) ANSI Initiative

1975 Document Composition Facility (DCF)

1971 Document Type Definition (DTD)

1969 General Markup Language (GML) - Charles Goldfarb, Ed Mosher, Ray Lorie

2003

XML Explosion

4ML
AML
AML
AML
AML
AML
AML
ABML
ABML
ACML
ACML
ACAP
ACS X12
ADML
AECM
AFML
AGML
AHML
AIML
AIML
AIF
AL3
ANML
ANNOTEA
ANATML
APML
APPML
AQL
APPEL
ARML
ARML
ASML
ASML
ASTM
ARML
ARML
ASML

ARML
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ATML
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AWML
AXML
AXML
AXML
AXML
BML
BML
BML
BML
BML
BML
BannerML
BCXML
BEEP
BGML
BHTML
BIBLIOML
BIOML
BIPS
BizCodes
BLM XML
BPML
BRML
BSML
BCXML
BEEP
BGML
BHTML

BiblioML
BCXML
BEEP
BGML
BHTML
BIBLIOML
BIOML
BIPS
BizCodes
BLM XML
BPML
BRML
BSML
CML
xCML
CaXML
CaseXML
xCBL
CBML
CDA
CDF
CDISC
CELLML
ChessGML
ChordML
ChordQL
CIM
CIML
CIDS
CIDX
xCIL
CLT
CNRP
ComicsML
CIM
CIML
CIDS

CIDX
xCIL
CLT
CNRP
ComicsML
Covad xLink
CPL
CP eXchange
CSS
CVML
CWMI
CycML
DML
DAML
DaliML
DaqXML
DAS
DASL
DCMI
DOI
DeltaV
DIG35
DLML
DMML
DocBook
DocScope
DoD XML
DPRL
DRI
DSML
DSD
DXS
EML
EML
DLML
EAD
ebXML

eBIS-XML
ECML
eCo
EcoKnow
edaXML
EMSA
eosML
ESML
ETD-ML
FieldML
FINML
FITS
FIXML
FLBC
FLOWML
FPML
FSML
GML
GML
GML
GXML
GAME
GBXML
GDML
GEML
GEDML
GEN
GeoLang
GIML
GXD
GXL
Hy XM
HITIS
HR-XML
HRMML
HTML
HTTPL

HTTP-DRP
HumanML
HyTime
IML
ICML
IDE
IDML
IDWG
IEEE DTD
IFX
IMPP
IMS Global
InTML
IOTP
IRML
IXML
IXRetail
JabberXML
JDF
JDox
JECMM
JLife
JSML
JSML
JScoreML
KBML
LACITO
LandXML
LEDES
LegalXML
Life Data
LitML
LMML
LogML
LogML
LTSC XML
MAML

MatML
MathML
MBAM
MISML
MCF
MDDL
MDSI-XML
Metarule
MFDX
MIX
MMLL
MML
MML
MML
MoDL
MOS
MPML
MPXML
MRML
MSAML
MTML
MTML
MusicXML
NAML
xNAL
NAA Ads
Navy DTD
NewsML
NML
NISO DTB
NITF
NLMXML
NVML
OAGIS
OBI
OCF
ODF

ODRL
OeBPS
OFX
OIL
OIM
OLifE
OML
ONIX DTD
OOPML
OPML
OpenMath
Office XML
OPML
OPX
OSD
OTA
PML
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P3P
PDML
PDX
PEF XML
PetroML
PGML
PhysicsML
PICS
PMML
PNML
PNML
PNG
PrintML

PrintTalk
ProductionML
PSL
PSI
QML
QAML
QuickData
RBAC
RDDI
RDF
RDL
RecipeML
RELAX
RELAX NG
REXML
REPML
ResumeXML
RETML
RFML
RightsLang
RIXML
RoadmOPS
RosettaNet PIP
RSS
RuleML
SML
SML
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SML
SAML
SABLE
SAE J2008
SBML
Schemtron
SDML
SearchDM-XML
SGML

SHOE
SIF
SMML
SMBXML
SMDL
SDML
SMIL
SOAP
SODL
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SPML
SpeechML
SSML
STML
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STEPML
SVG
SWAP
SWMS
SyncML
TML
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TalkML
TaxML
TDL
TDML
TEI
ThML
TIM
TIM
TMML
TMX
TP
TPAML
TREX
TxLife

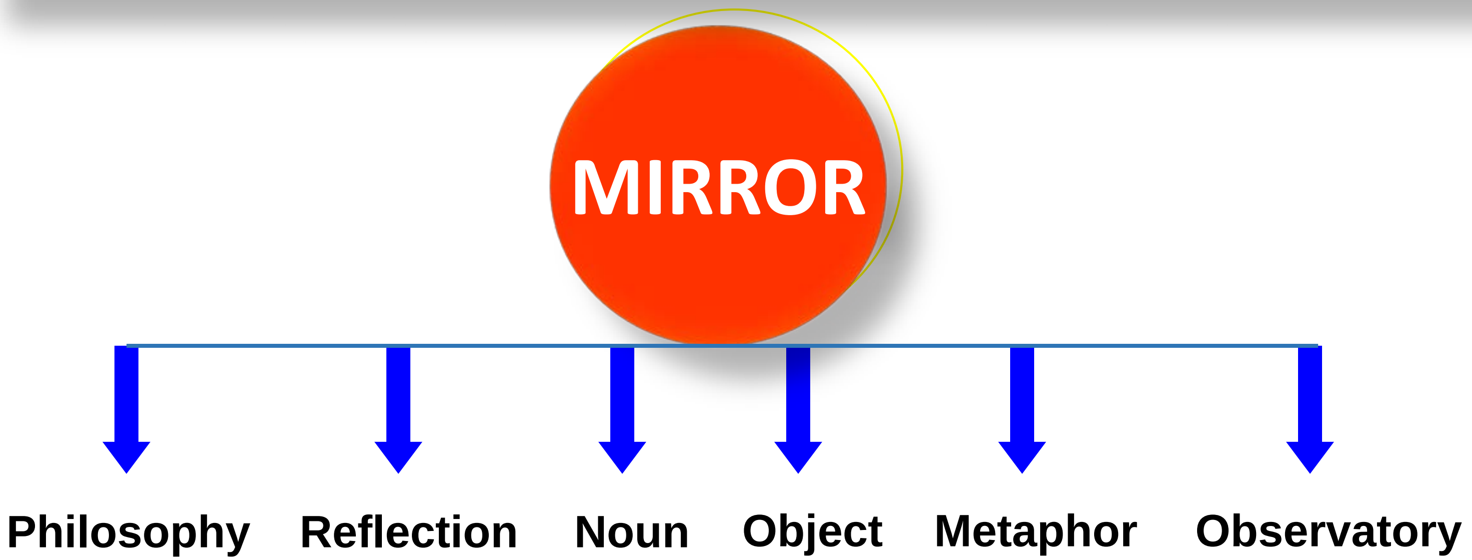
UML
UBL
UCLP
UDDI
UDEF
UIML
ULF
UMLS
UPnP
URI/URL
UXF
VML
vCalendar
vCard
VCML
VHG
VIML
VISA XML
VMML
VocML
VoiceXML
VRML
WAP
WDDX
WebML
WebDAV
WellML
WeldingXML
Wf-XML
WIDL
WITSML
WorldOS
WSML
WSIA
XML
XML Court
XML EDI

XML F
XML Key
XMLife
XML MP
XML News
XML RPC
XML Schema
XML Sign
XML Query
XML P7C
XML TP
XMLVoc
XML XCI
XAML
XACML
XBL
XSBEL
XBN
XBRL
XCFF
XCES
Xchart
Xdelta
XDF
XForms
XGF
XGL
XGMML
XHTML
XIOP
XLF
XLIFF
XLink
XMI
XMSG
XMTP
XNS

Houston, we have a problem …

2003

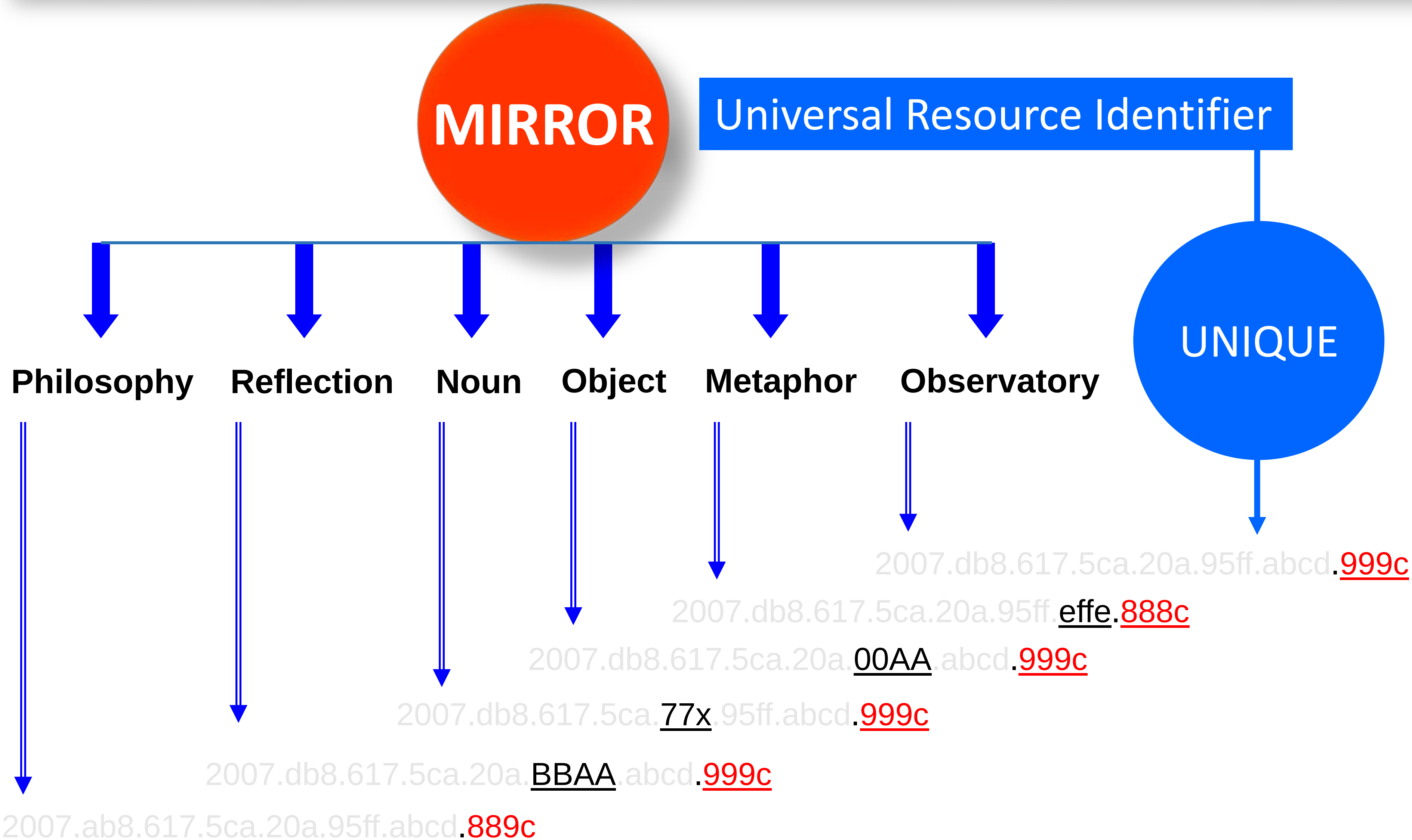
Ontology



Idea proposed by the author (Dr Shoumen Datta) ● http://esd.mit.edu/WPS/2007/esd-wp-2007-17.pdf

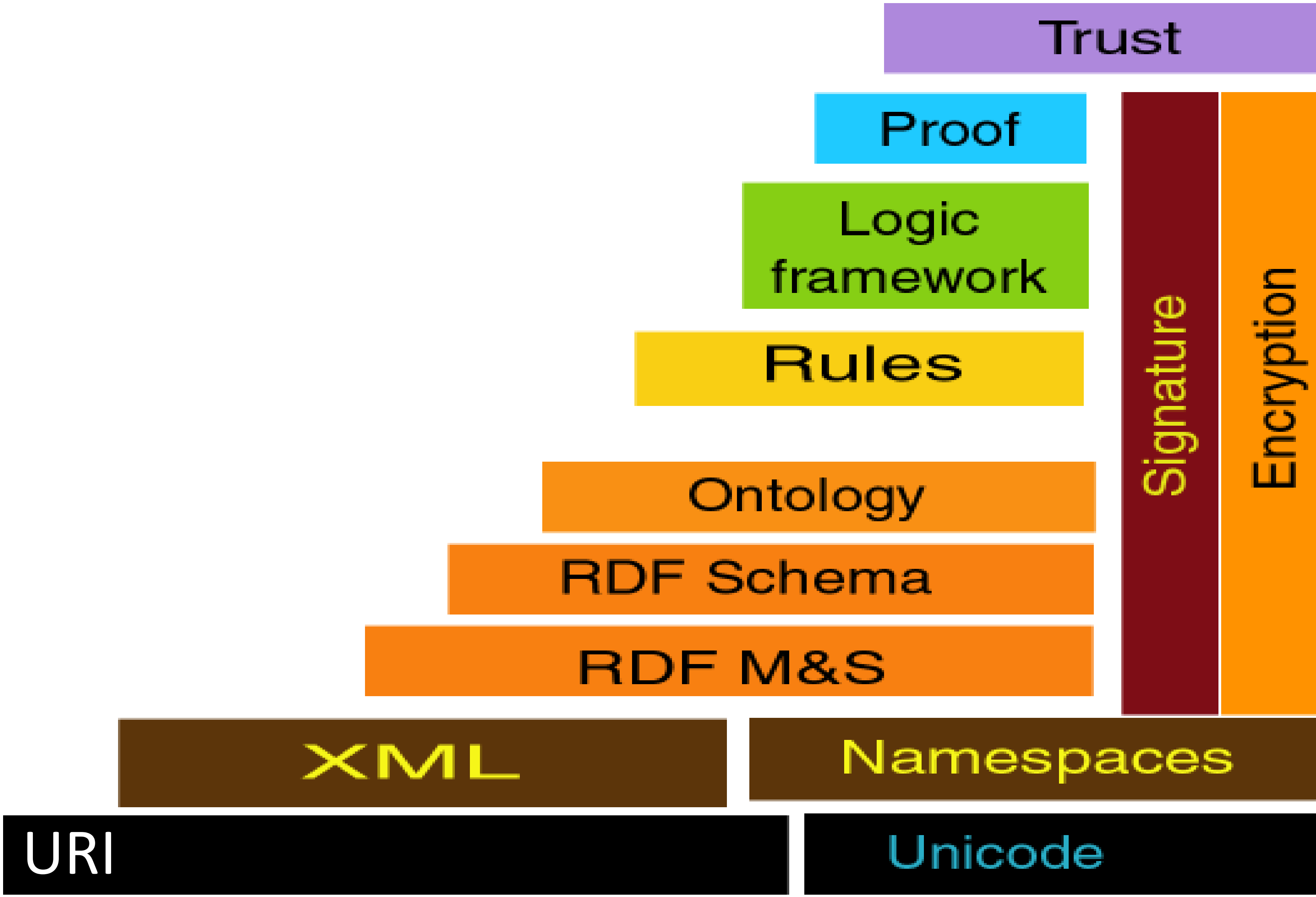
Digital Ontology?

Unique IPv6 type id as a sub-layer to URI abstraction in the Semantic layer cake?



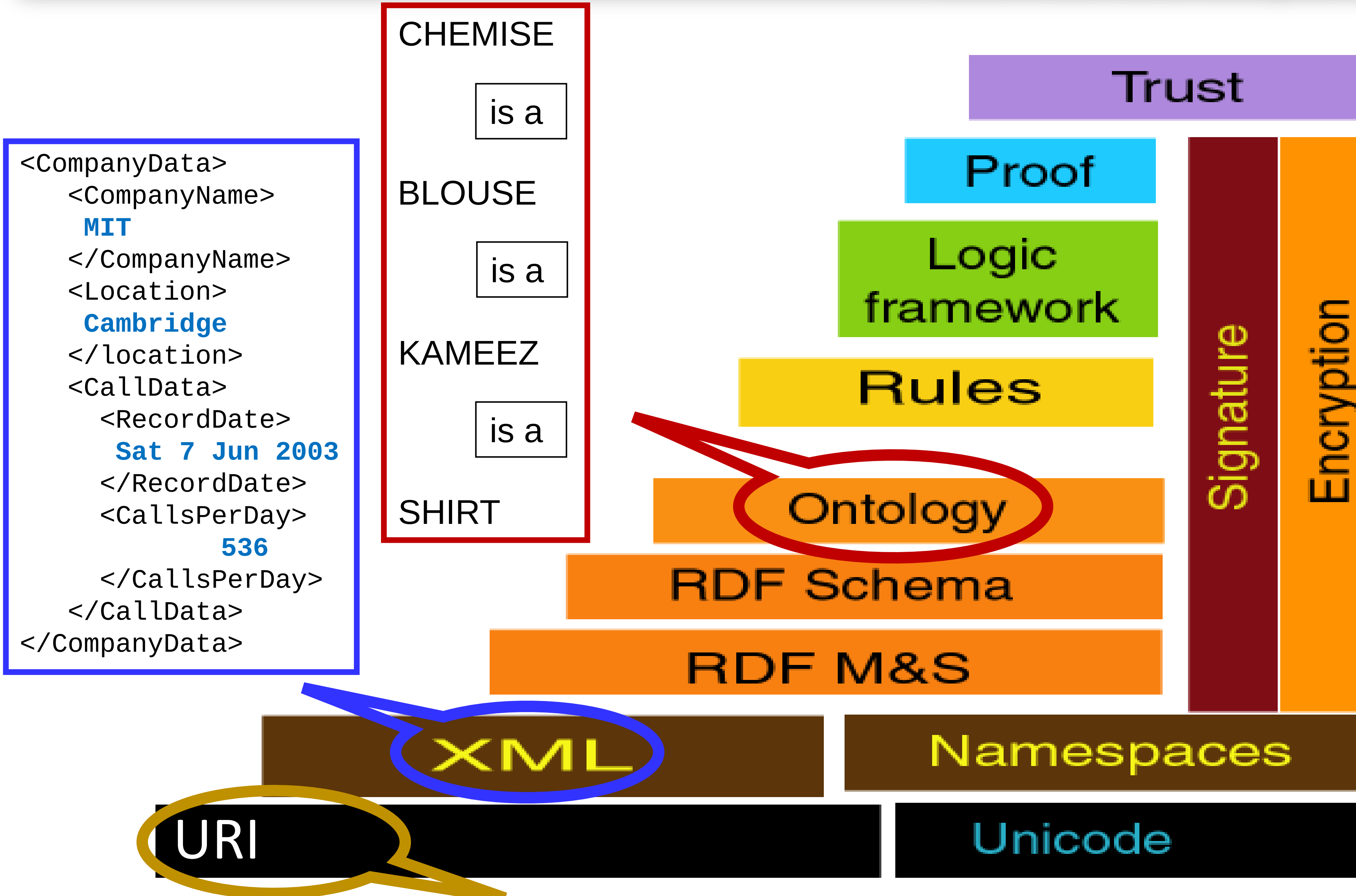
Idea proposed by the author (Dr Shoumen Datta) • http://esd.mit.edu/WPS/2007/esd-wp-2007-17.pdf

Semantic Web - *that did not happen* ● Semantic Layers



Tim Berners-Lee, MIT

Semantic Layers



Tim Berners-Lee, MIT

Universal, but not unique. Can Digital Ontology make it unique?

The reconciliation and convergence of ontology, semantics and context is essential for AI and analytics

Does that tarnish the aura of AI ?

No, not at all. It means that one must differentiate between optimal application and natural stupidity.

“Brain in a Box” by 2020 ?

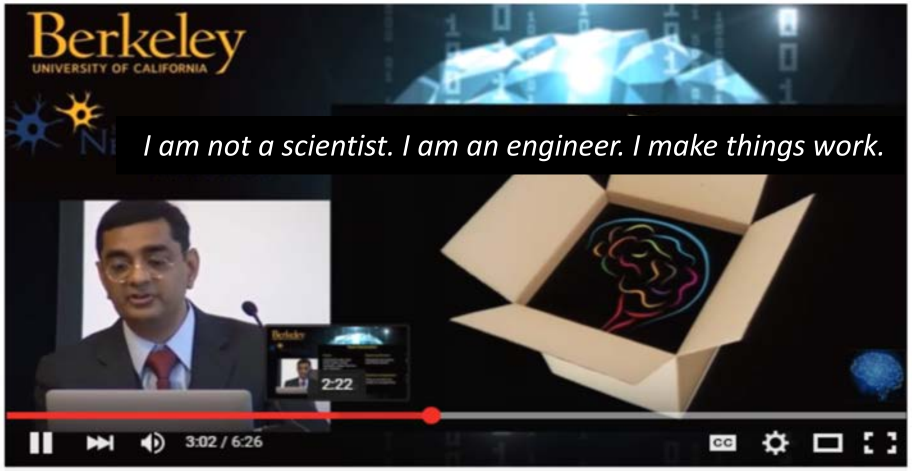
Natural speech reveals the semantic maps that tile human cerebral cortex

Alexander G. Huth, Wendy A. de Heer, Thomas L. Griffiths, Frédéric E. Theunissen & Jack L. Gallant

Affiliations | Contributions | Corresponding author

Nature **532**, 453–458 (28 April 2016) | doi:10.1038/nature17637
Received 08 January 2014 | Accepted 02 March 2016 | Published online 27 April 2016

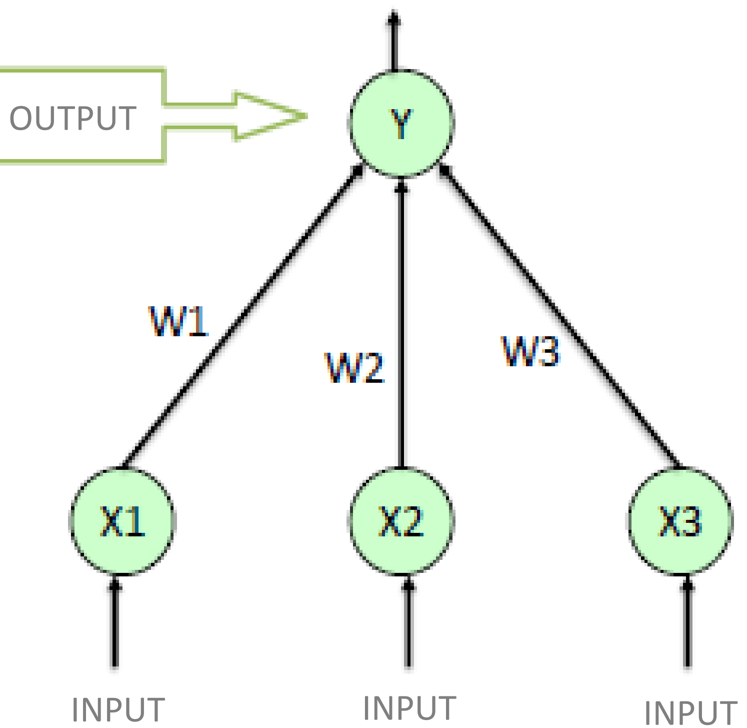
www.nature.com/nature/journal/v532/n7600/full/nature17637.html

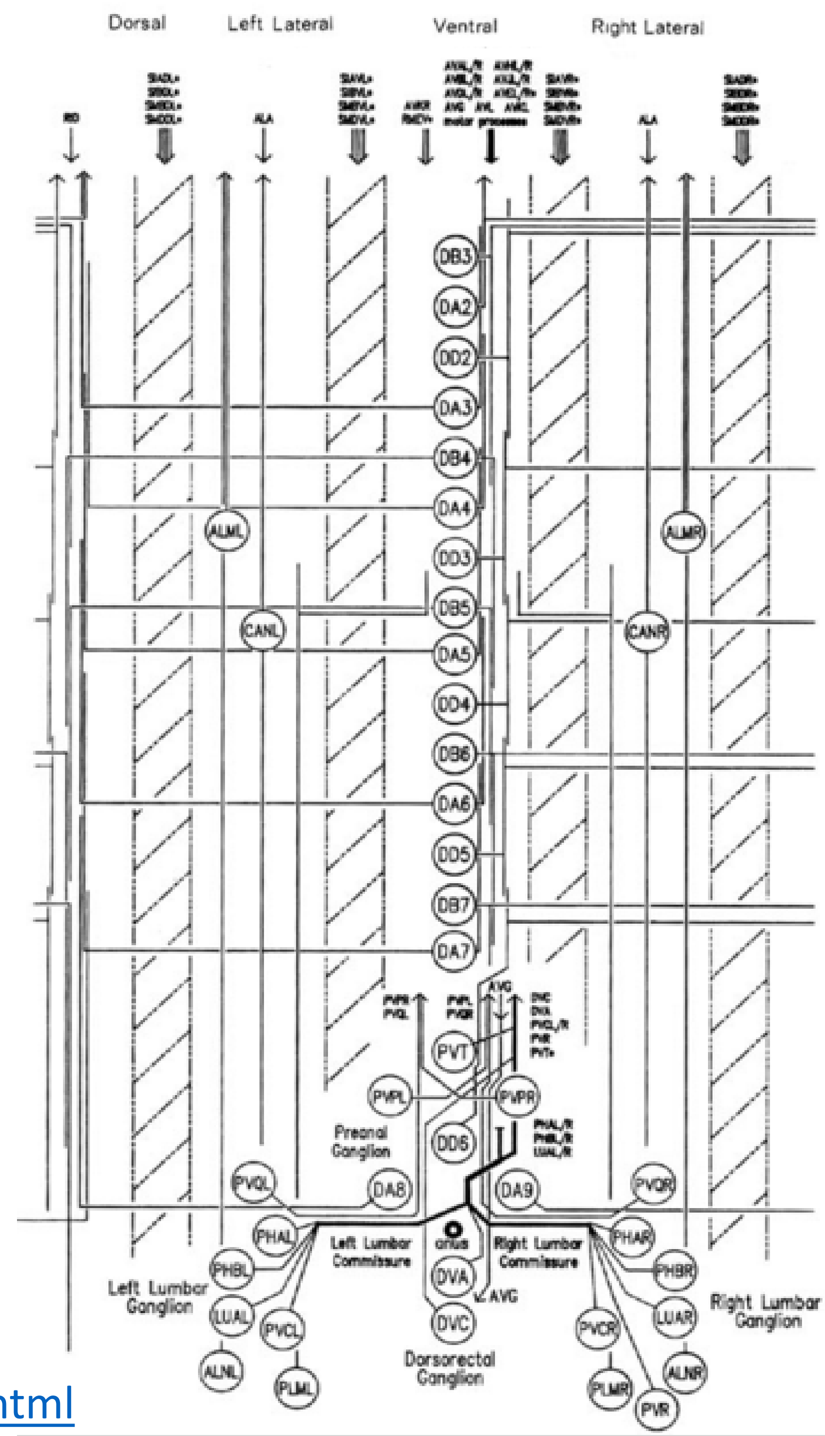


IBM's Dharmendra Modha - "Before the end of 2020 we will be able to produce a brain in a box" **31 March 2016**

http://bit.do/HUBRIS-KILLS

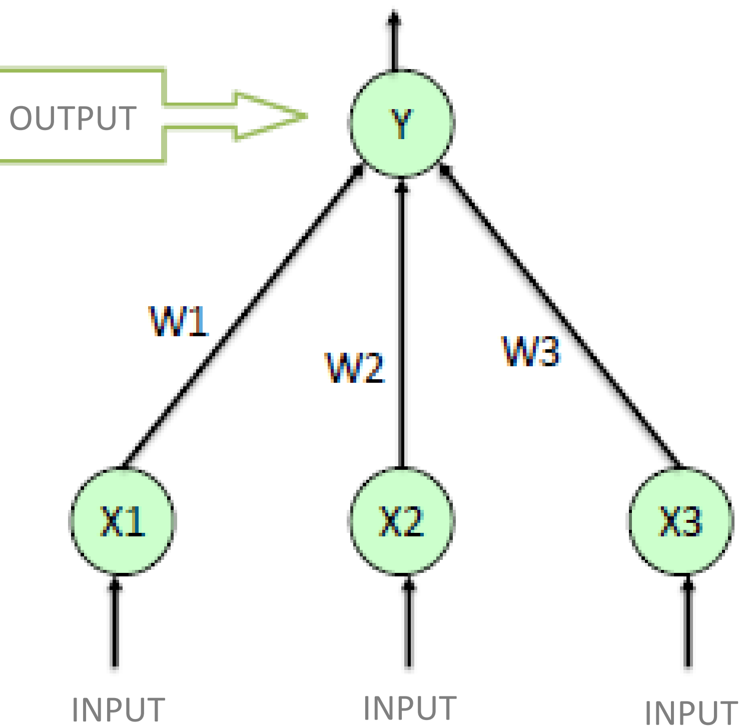
Single Layer Perceptron

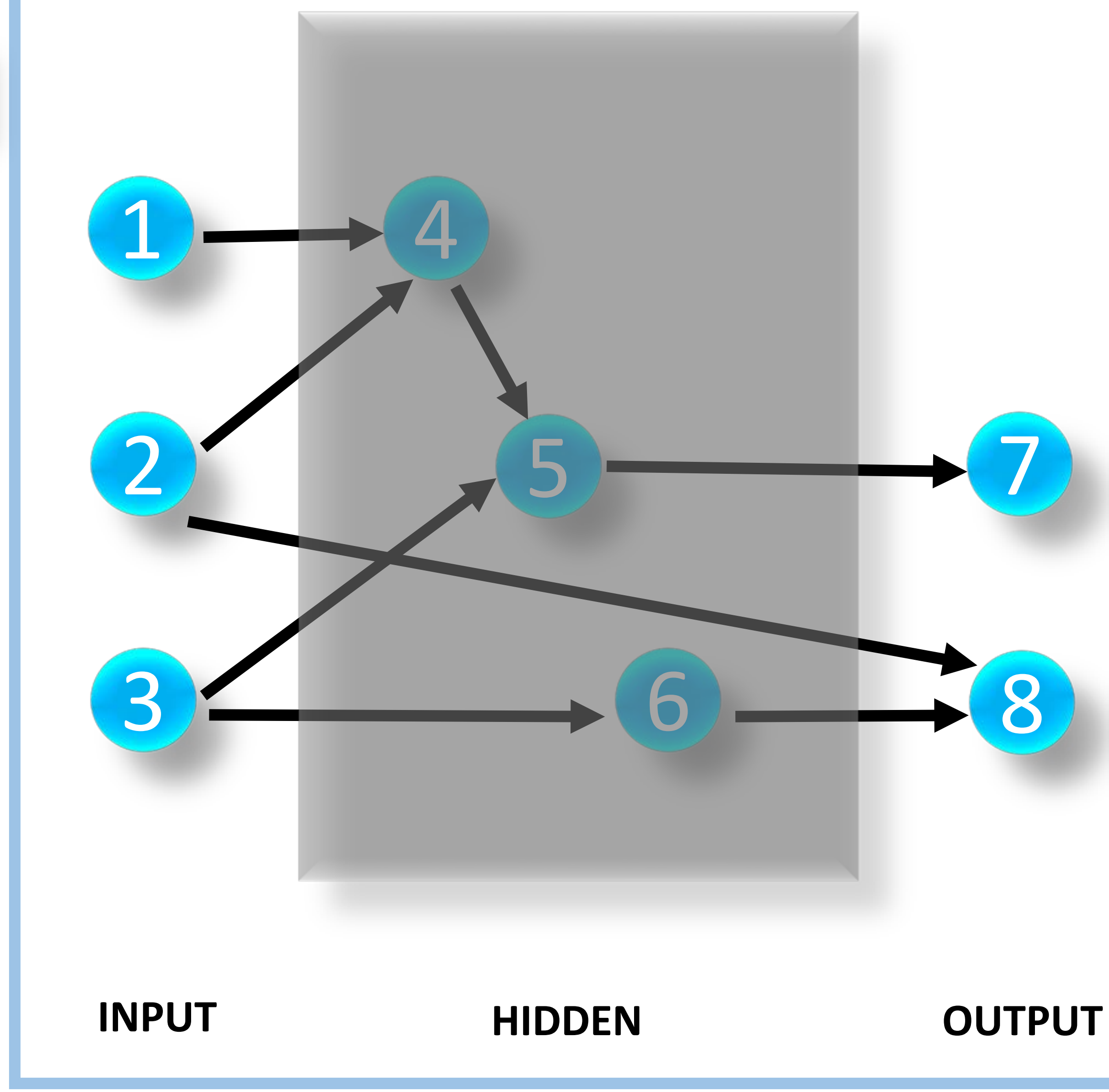




http://www.wormatlas.org/ver1/durbinv1.2/chapter1.html

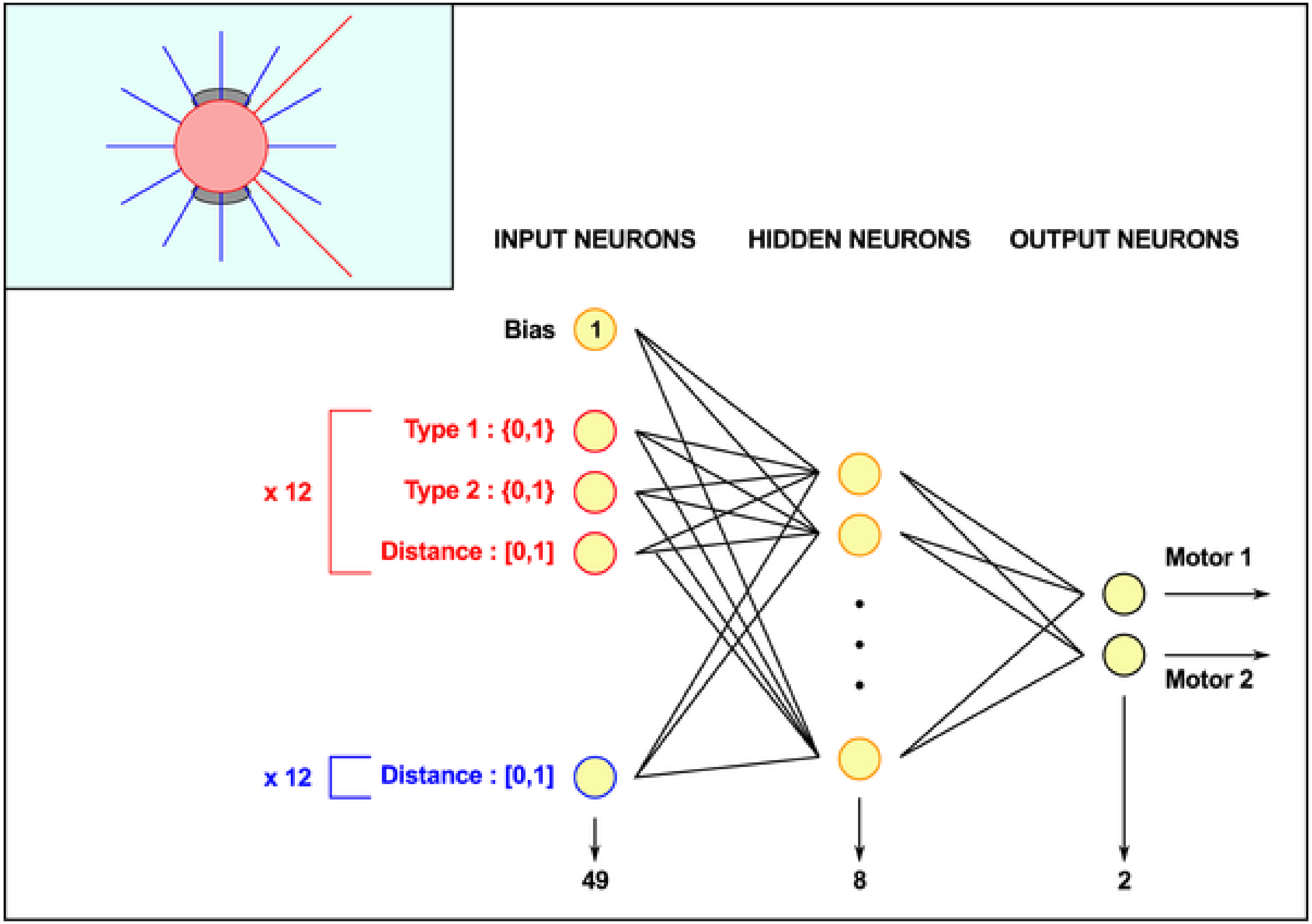
Single Layer Perceptron





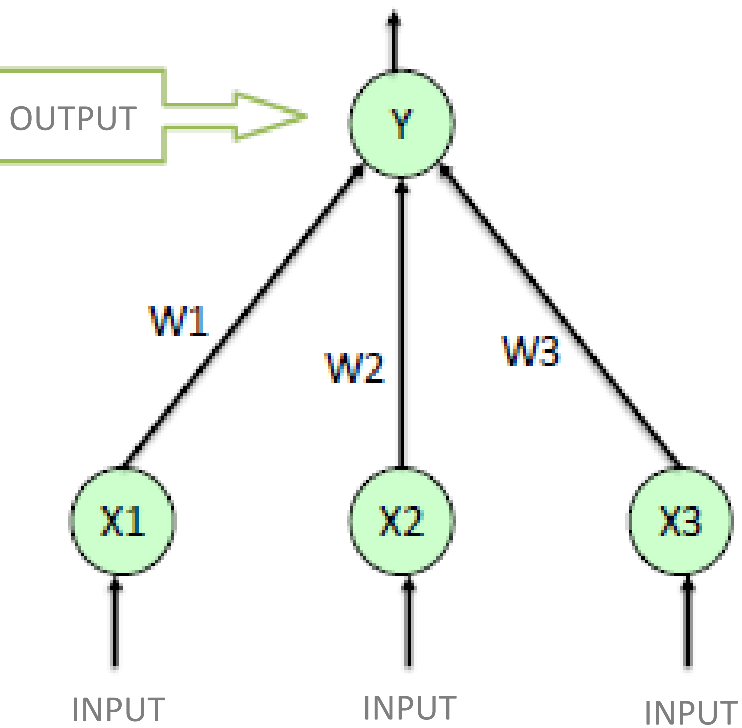
Feed-Forward

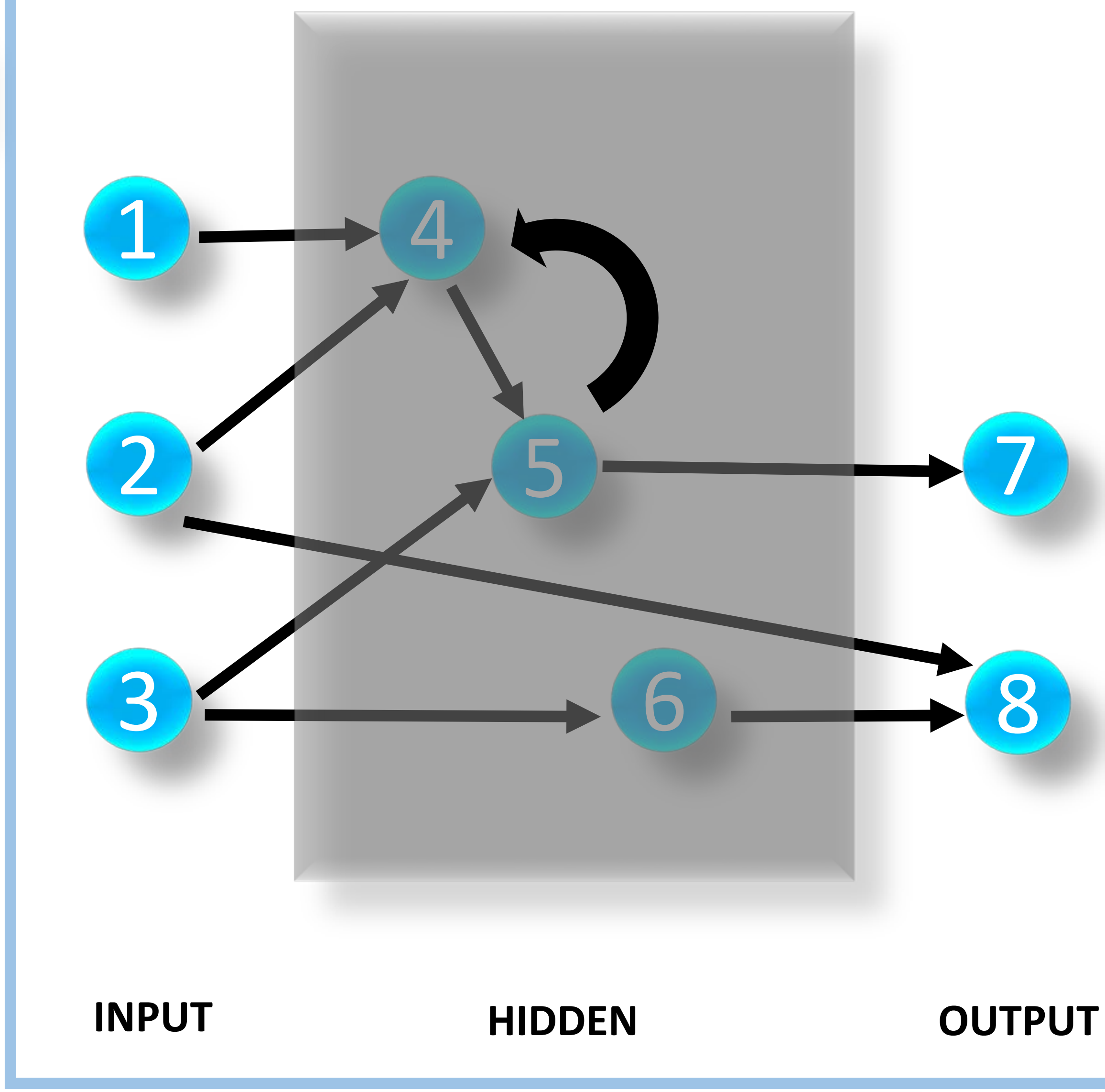
Simulated robotic agent (inset) and its ANN controller



Bernard A, André JB, Bredeche N (2016) To Cooperate or Not to Cooperate: Why Behavioural Mechanisms Matter. PLoS Computational Biology 12(5): e1004886. doi:10.1371/journal.pcbi.1004886 ● http://journals.plos.org/ploscompbiol/article?id=info:doi/10.1371/journal.pcbi.1004886

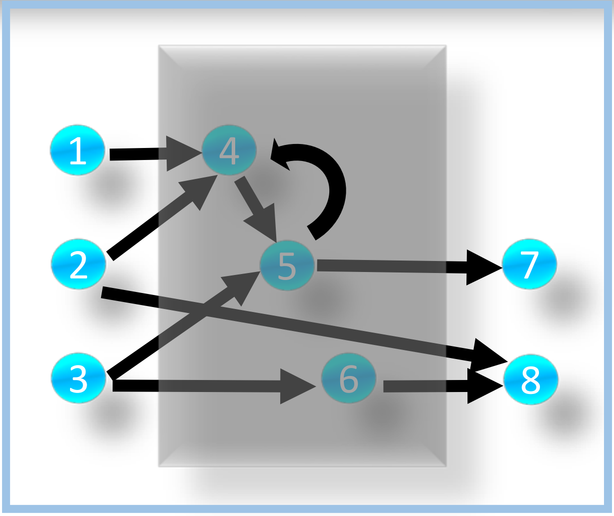
Single Layer Perceptron





Recurrent Neural Network

Representations for Neural Networks – Matrix & Graph

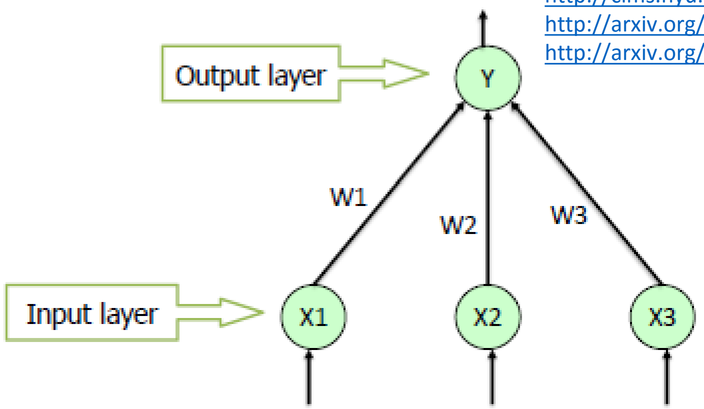


Recurrent Neural Network

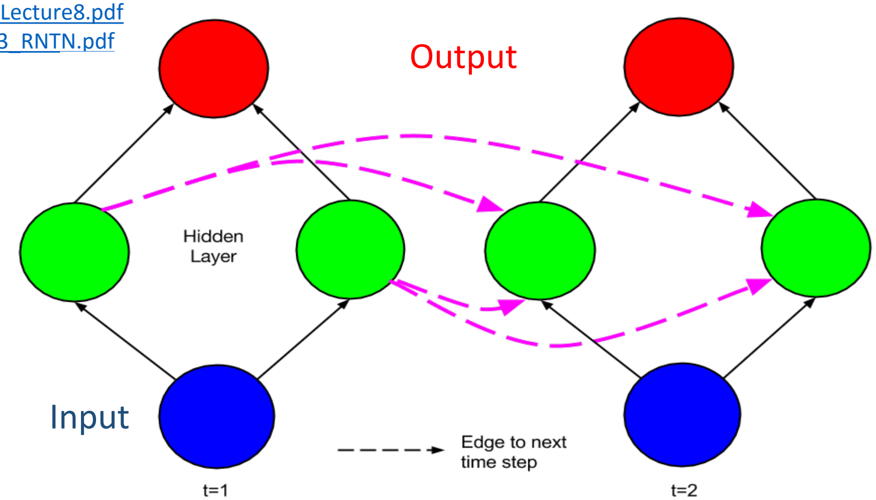
$$
\begin{array}{c|c}
 & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \end{matrix} \\
\begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{matrix} &
\begin{bmatrix}
0 & 0 & 0 & w_{14} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & w_{24} & 0 & 0 & 0 & w_{28} \\
0 & 0 & 0 & 0 & w_{35} & w_{36} & 0 & 0 \\
0 & 0 & 0 & 0 & w_{45} & 0 & 0 & 0 \\
0 & 0 & 0 & w_{54} & 0 & 0 & w_{57} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & w_{68} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\end{array}
$$

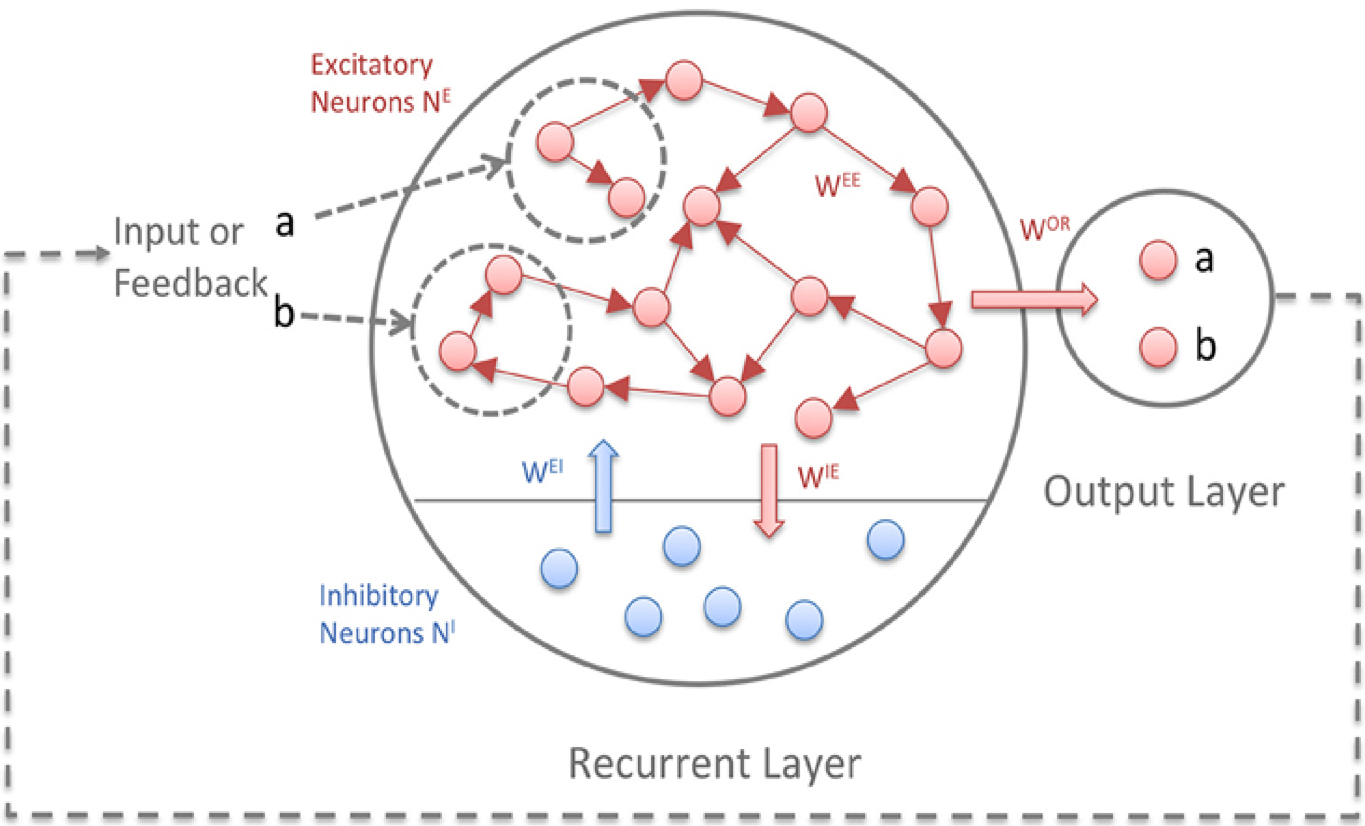
$(1,4, w_{14})$,
$(2,4, w_{24})$,
$(3,5, w_{35})$,
$(3,6, w_{36})$,
$(4,5, w_{45})$,
$(5,4, w_{54})$,
$(5,7, w_{57})$,
$(2,8, w_{28})$,
$(6,8, w_{68})$,

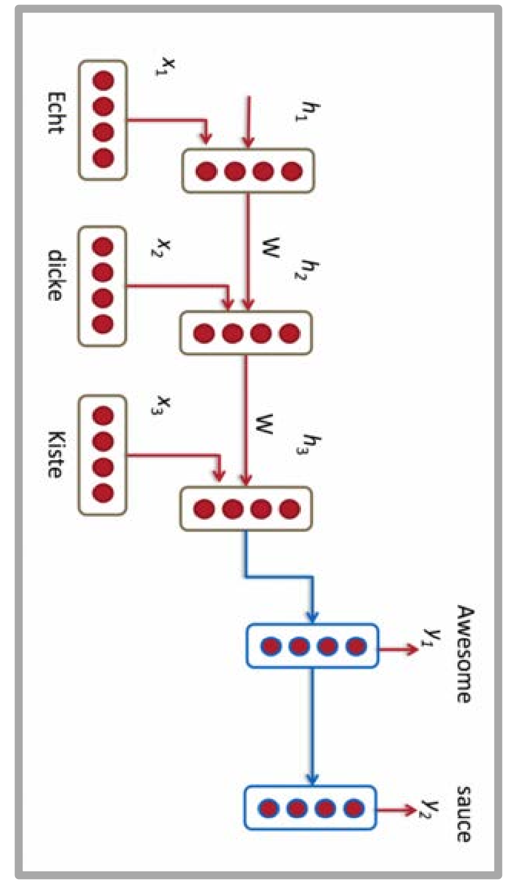
Single Layer Perceptron



http://cs224d.stanford.edu/lectures/CS224d-Lecture8.pdf
http://nlp.stanford.edu/~socherr/EMNLP2013_RNTN.pdf
http://cims.nyu.edu/~zeitouni/cupbook.pdf
http://arxiv.org/pdf/1409.3215v3.pdf
http://arxiv.org/pdf/1410.5401v2.pdf

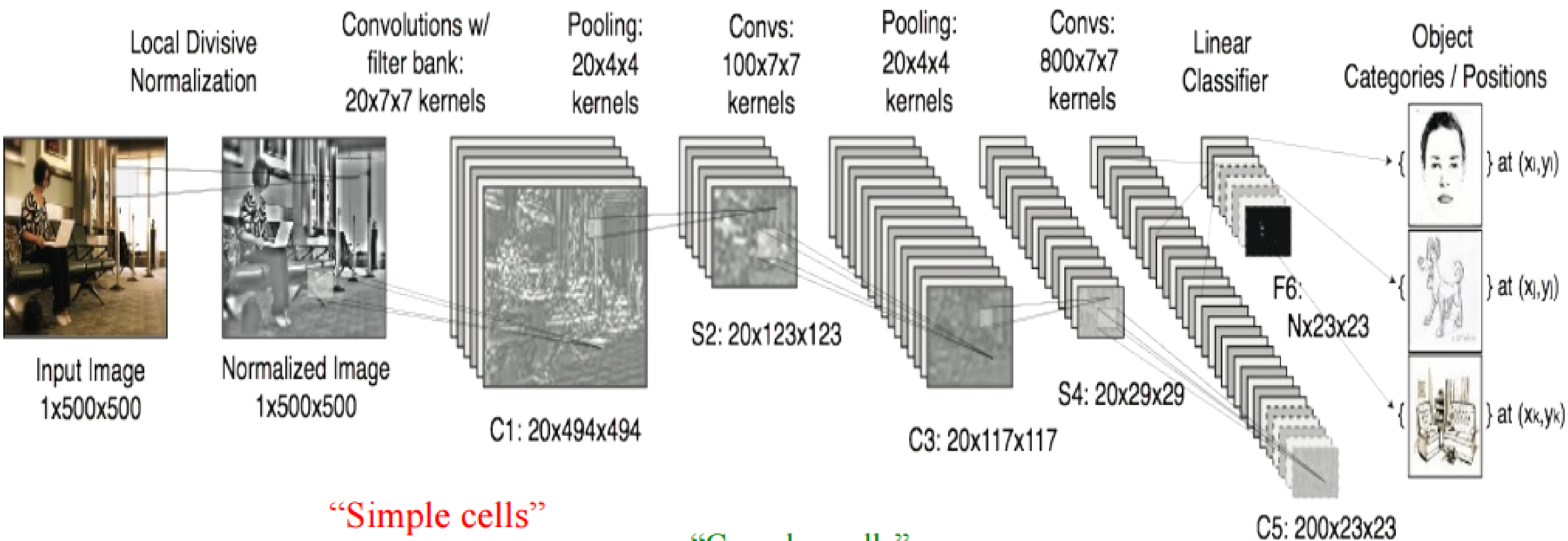


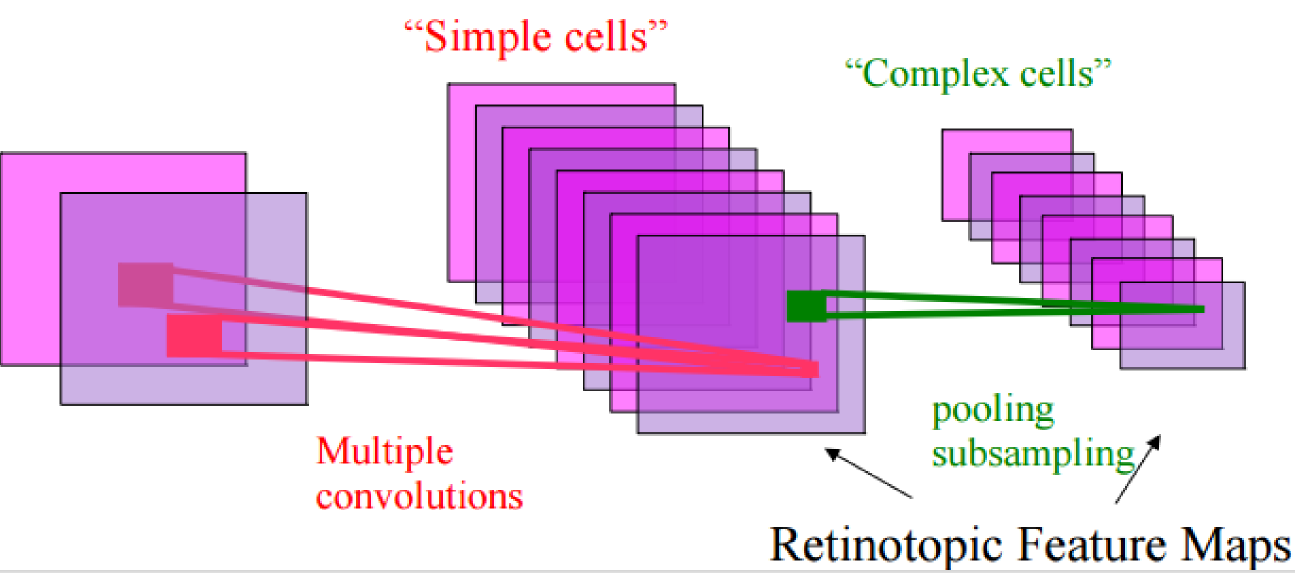




The Principle of Convolutional Neural Networks (CNN)

matt.colorado.edu/compcogworkshop/talks/lecun.pdf http://bit.do/NNDL-MN-BOOK





- Supervised Training
- Stochastic Gradient Descent

Computational Neuroscience

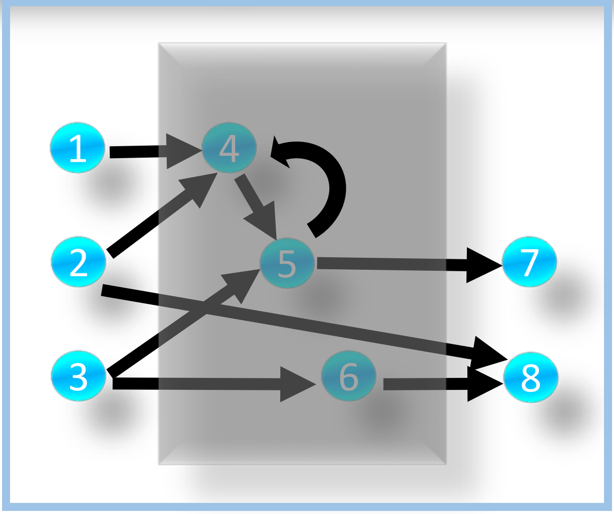
Neural Paradigm Shift

(this is not just semantics, this topic to be discussed in a separate presentation)

Neuroscientific Computation

Classical approach of ANN – predominantly inferential

Topological by design with generic weights generates inferential (obvious) output



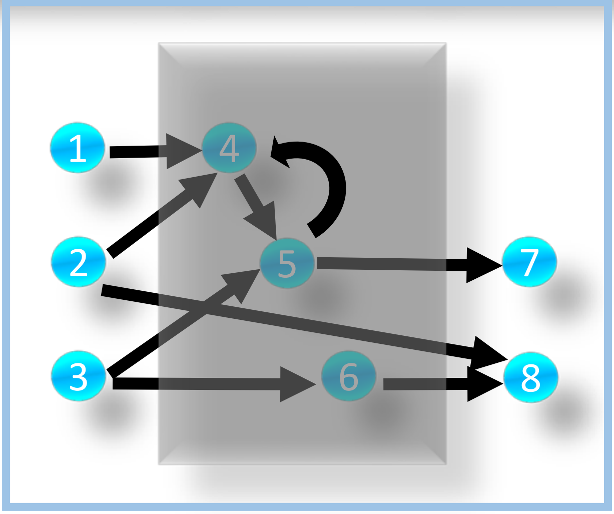
Recurrent Neural Network

$$
\begin{array}{c|c}
 & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \end{matrix} \\
\begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{matrix} &
\begin{bmatrix}
0 & 0 & 0 & w_{14} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & w_{24} & 0 & 0 & 0 & w_{28} \\
0 & 0 & 0 & 0 & w_{35} & w_{36} & 0 & 0 \\
0 & 0 & 0 & 0 & w_{45} & 0 & 0 & 0 \\
0 & 0 & 0 & w_{54} & 0 & 0 & w_{57} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & w_{68} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\end{array}
$$

$(1,4, w_{14})$,
$(2,4, w_{24})$,
$(3,5, w_{35})$,
$(3,6, w_{36})$,
$(4,5, w_{45})$,
$(5,4, w_{54})$,
$(5,7, w_{57})$,
$(2,8, w_{28})$,
$(6,8, w_{68})$,

Non-obvious (inferential) relationship analysis?

The weighted brain "ecosystem"
- epigenetic (seconds to days)
- ontogenic (days to years)
- phylogenic (generations)

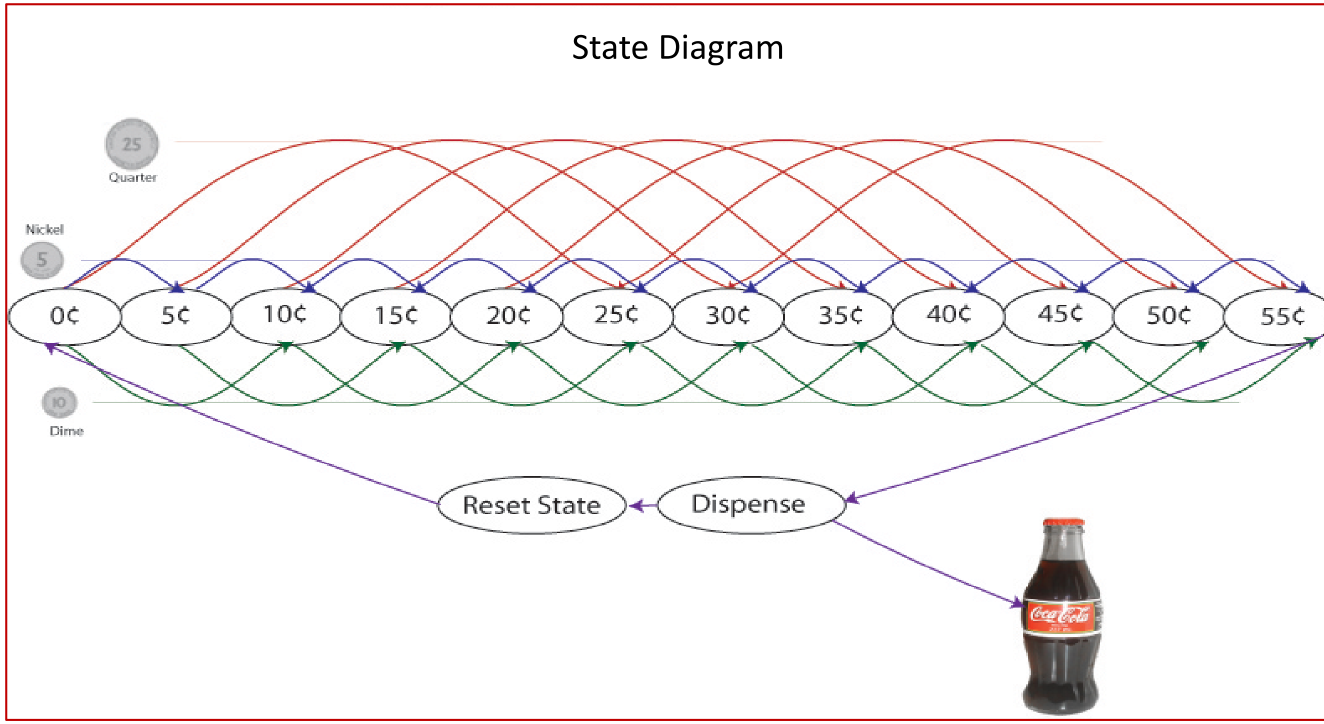


Recurrent Neural Network

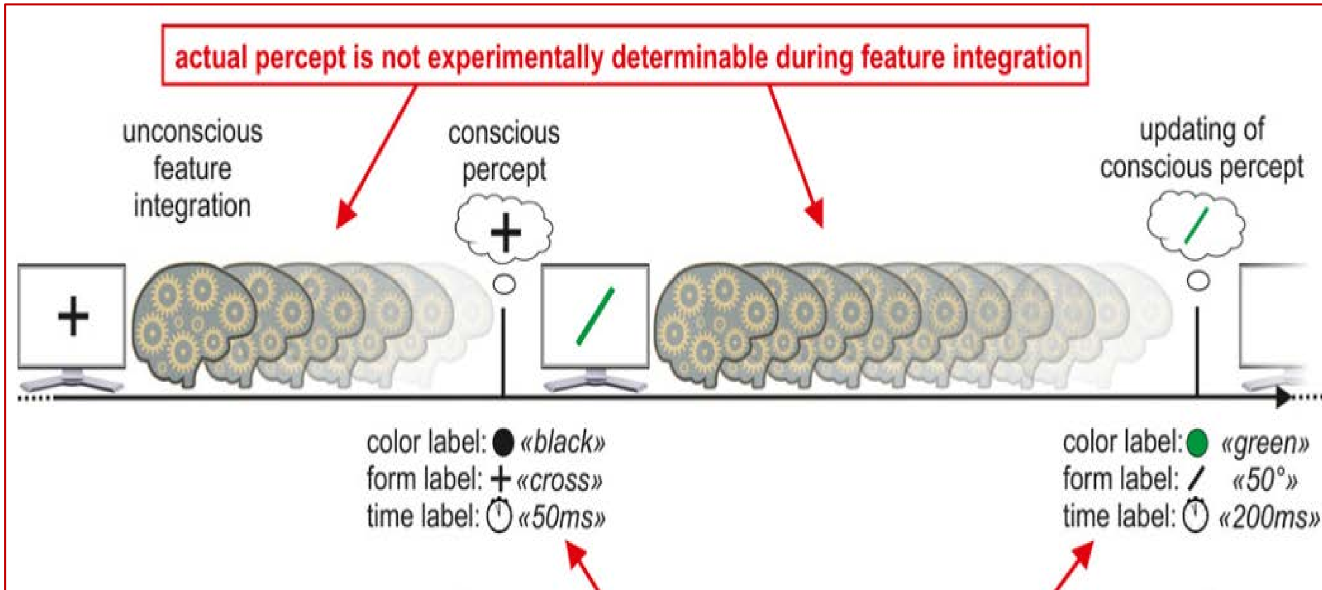
$$
\begin{array}{c|c}
 & \begin{array}{cccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \end{array} \\
\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{array} &
\begin{bmatrix}
0 & 0 & 0 & w_{14} & \boxed{0} & \boxed{0} & 0 & 0 \\
0 & 0 & 0 & w_{24} & 0 & 0 & \boxed{0} & w_{28} \\
0 & 0 & 0 & \boxed{0} & w_{35} & w_{36} & 0 & 0 \\
\boxed{0} & 0 & 0 & 0 & w_{45} & 0 & 0 & 0 \\
0 & \boxed{0} & 0 & w_{54} & 0 & 0 & w_{57} & 0 \\
0 & 0 & \boxed{0} & 0 & 0 & 0 & 0 & w_{68} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\end{array}
$$

We must evolve from use of classical ANN which emulates NN topology to developmentally inspired engineering design based on neurogenesis and brain development modelling by creating programs which *generate* neural networks, hence adaptable, naturally.

The model of a function



How the model functions



A two stage model of visual perception

http://journals.plos.org/plosbiology/article/asset?id=10.1371%2Fjournal.pbio.1002433.PDF

Even without bombastic claims of “brain in a box”

we may still obtain significant value from AI applications

to extract intelligent useful information from data.

www.nature.com/news/first-paralysed-person-to-be-reanimated-offers-neuroscience-insights-1.19749?WT.mc_id=TWT_NatureNews

SIGN POSTS ON THE ROAD AHEAD

First paralysed person to be 'reanimated' offers neuroscience insights

Technique moves man's arm by decoding his thoughts and electrically stimulating his own muscles.

Linda Geddes

13 April 2016

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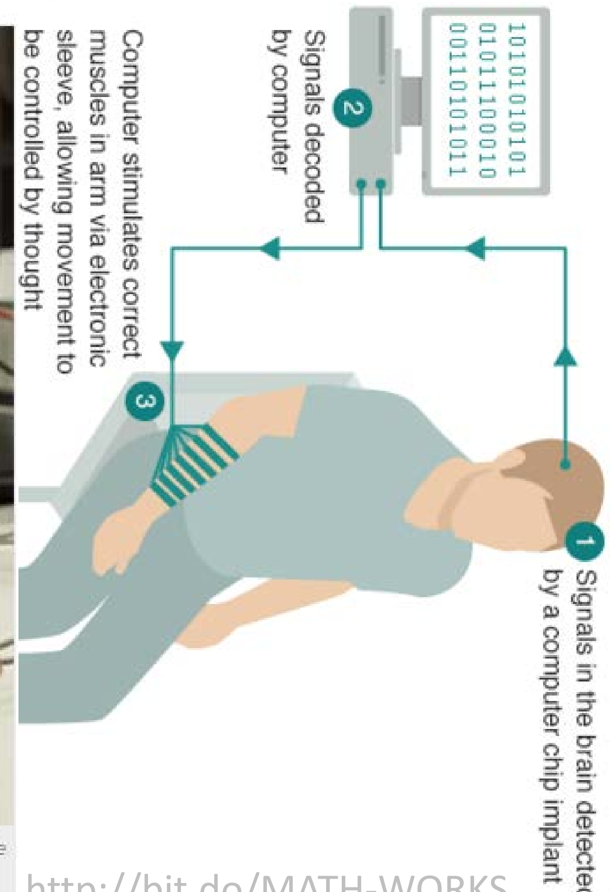
Ohio State University Wexner Medical Center/ Battelle

Ian Burkhart can make isolated finger movements and perform six different wrist and hand motions.

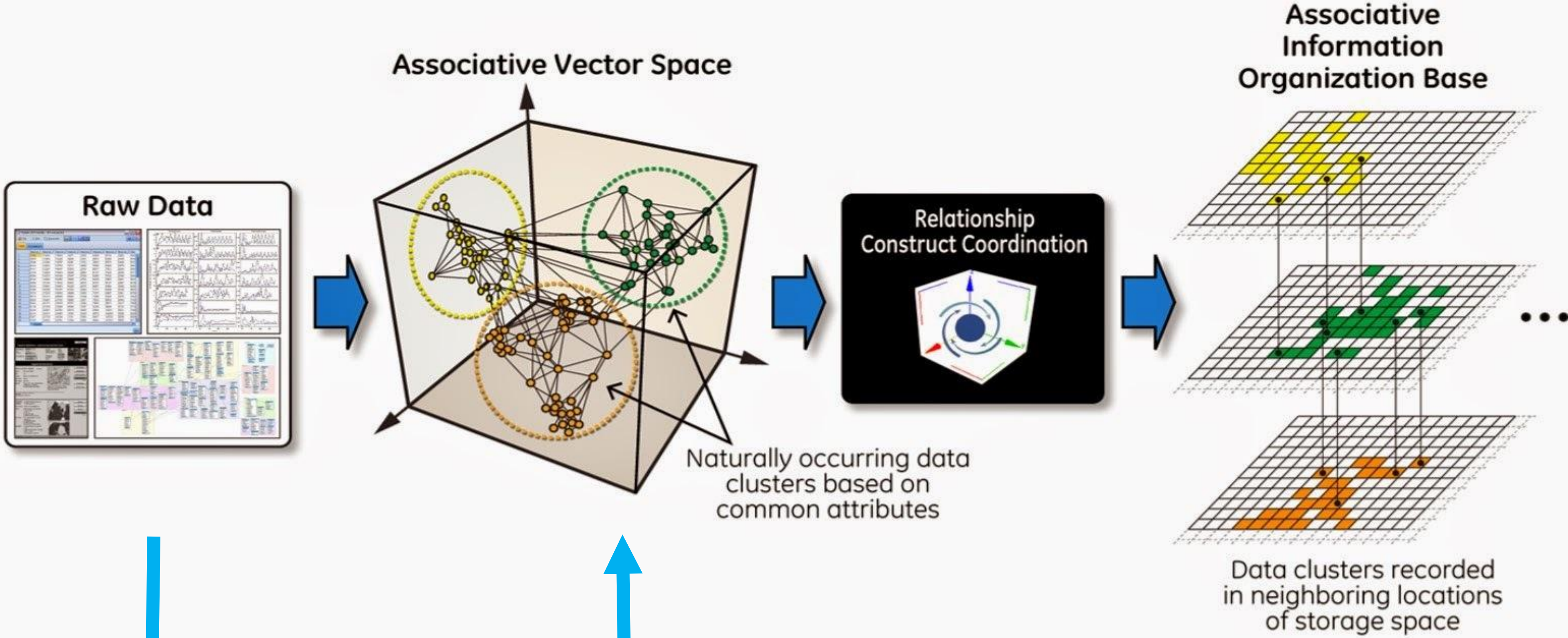


http://bit.do/MATH-WORKS

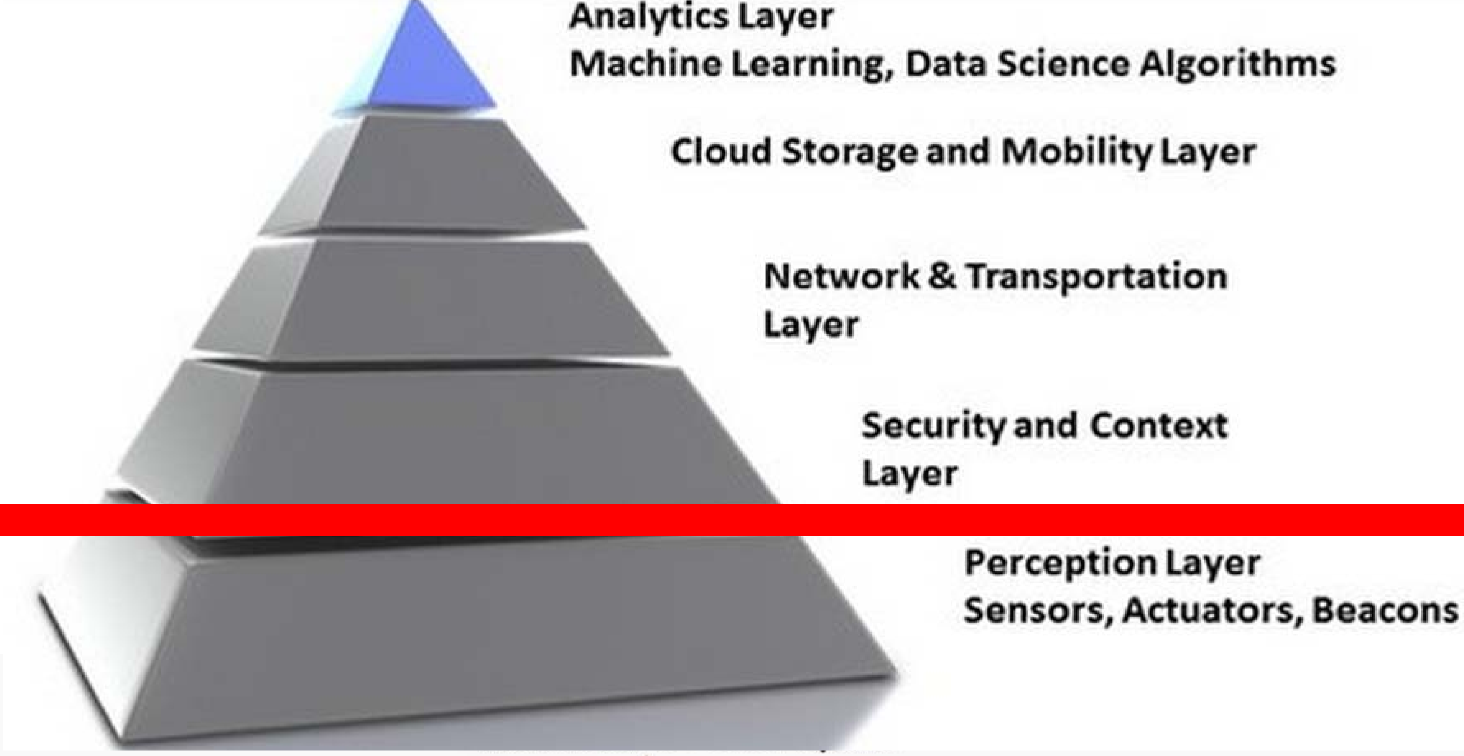
Emerging Frontier in AI & Data Analytics

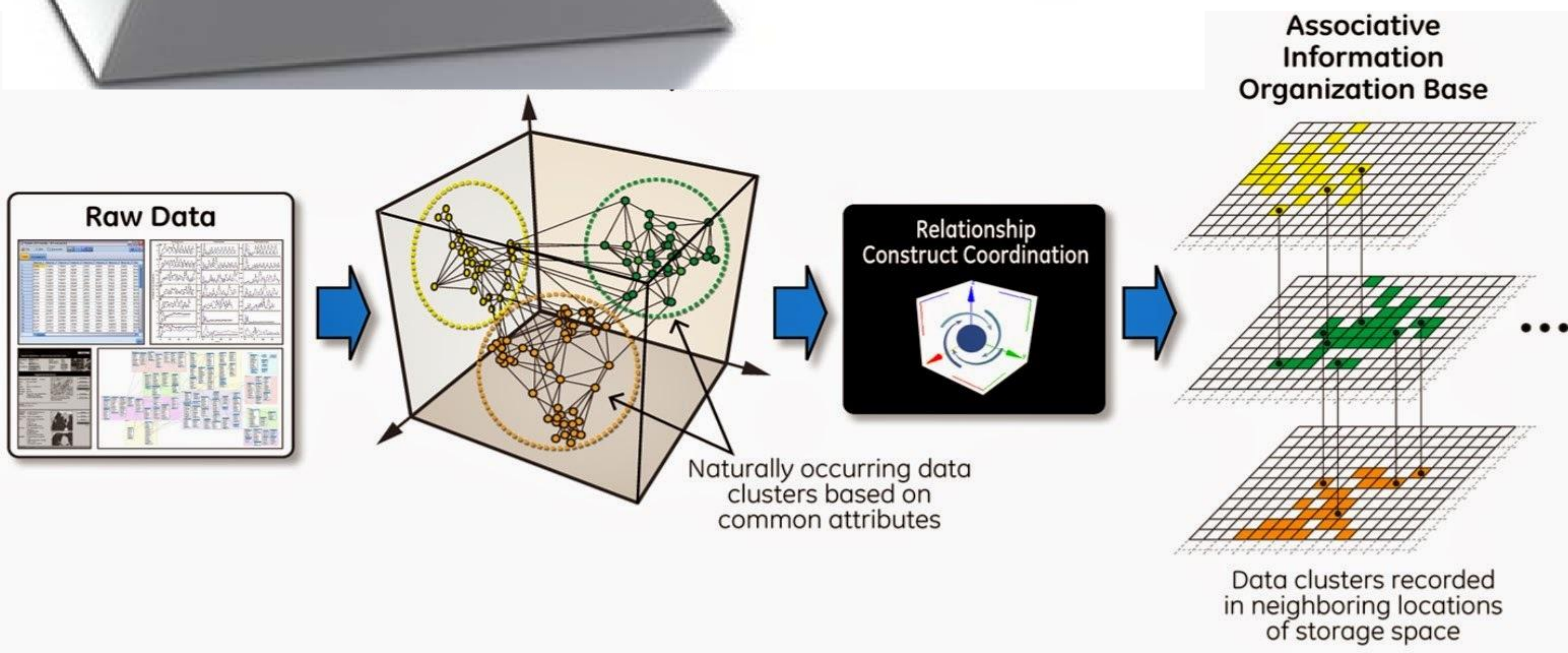
Data Curation

sorting out what we need

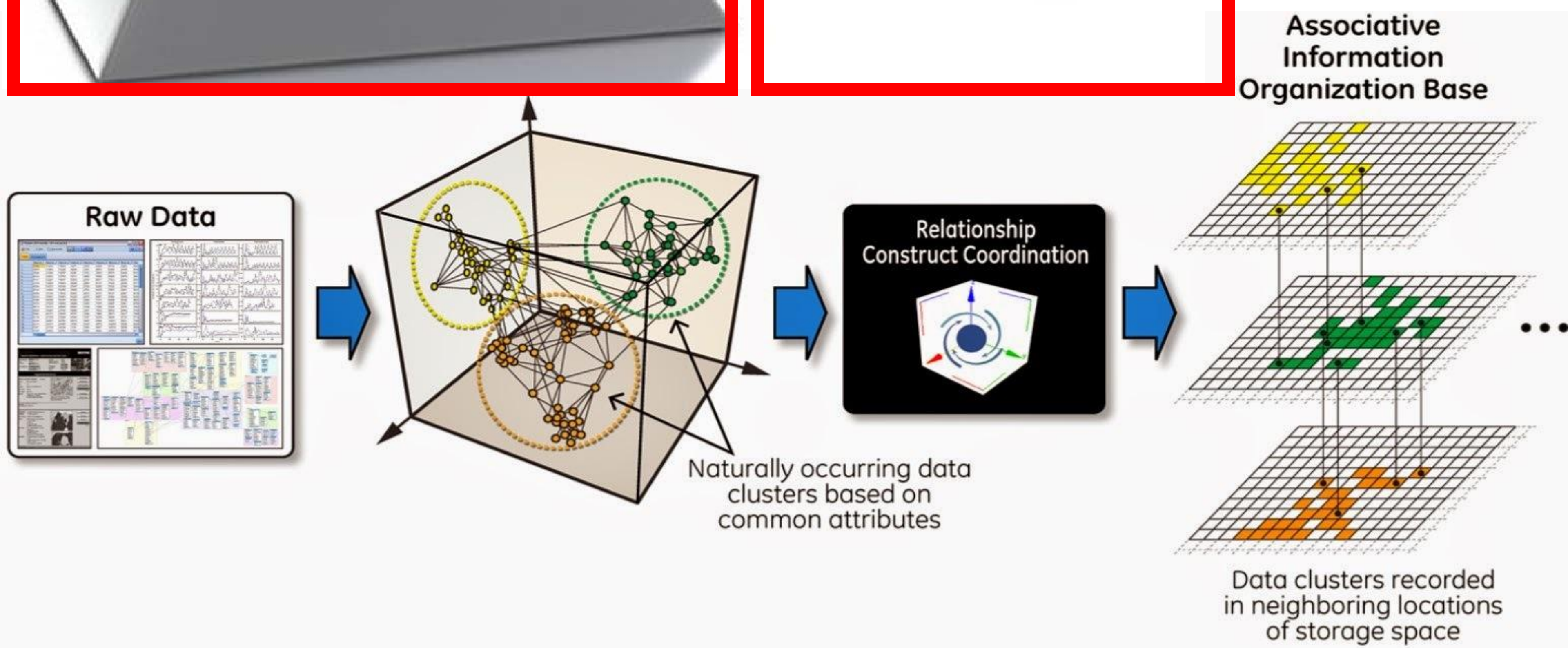

Raw Data
Associative Vector Space
Naturally occurring data clusters based on common attributes
Relationship Construct Coordination
Associative Information Organization Base
Data clusters recorded in neighboring locations of storage space

CURATE

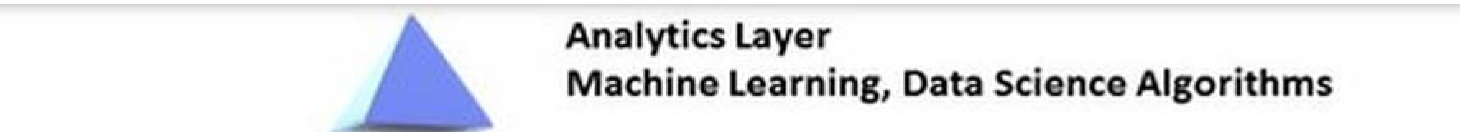

Analytics Layer
Machine Learning, Data Science Algorithms
Cloud Storage and Mobility Layer
Network & Transportation Layer
Security and Context Layer
Perception Layer
Sensors, Actuators, Beacons


Associative Information Organization Base
Raw Data
Relationship Construct Coordination
Naturally occurring data clusters based on common attributes
Data clusters recorded in neighboring locations of storage space

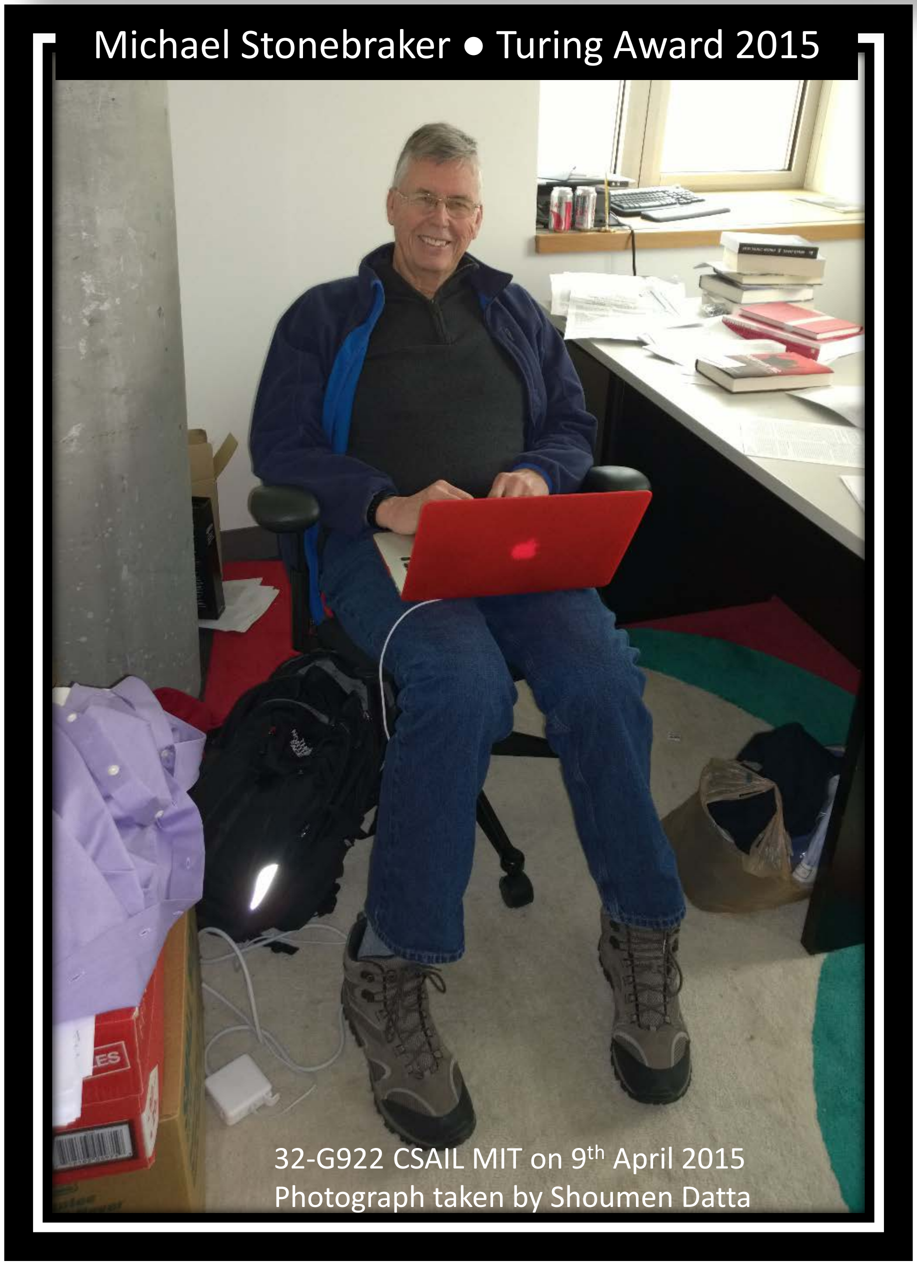
Perception Layer
Sensors, Actuators, Beacons



MONETIZATION



Innovation in Curation Algorithms



Postgres

Introduced the object-relational model, effectively merging DB with abstract complex data types eg CAD, geospatial, so-called big data

www.csail.mit.edu/node/2459

Challenges in Data Curation

- Noise obscures signal
- Data acquired is a blend of noise with signal
- Signal volatility introduces noise which is often proportional to signal

→ How do we correct/reduce the error due to this "noisy channel" factor?

→ Can novel algorithms reduce/deconstruct data to subtract "noise" and reconstruct the signal?

→ What about the application of the principles of (Shannon, Kalman-Bucy) error correcting algorithms?

☑ https://en.wikipedia.org/wiki/Kalman_filter
☑ http://news.mit.edu/2010/explained-shannon-0115
☑ http://www.cs.cmu.edu/~guyb/realworld/errorcorrecting.html
☑ http://www.cs.cmu.edu/~aarti/Class/10704/lec16-shannonnoisythrm.pdf

NOISY CHANNEL ALGORITHM

www.essrl.wustl.edu/~jao/itrg/shannon.pdf

A Mathematical Theory of Communication

By C. E. SHANNON

Introduction

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist[1] and Hartley[2] on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one *selected from a set* of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design.

If the number of messages in the set is finite then this number or any monotonic function of this number can be regarded as a measure of the information produced when one message is chosen from the set, all choices being equally likely. As was pointed out by Hartley the most natural choice is the logarithmic function. Although this definition must be generalized considerably when we consider the influence of the statistics of the message and when we have a continuous range of messages, we will in all cases use an essentially logarithmic measure.

The logarithmic measure is more convenient for various reasons:

1. It is practically more useful. Parameters of engineering importance

[1] Nyquist, H., "Certain Factors Affecting Telegraph Speed," *Bell System Technical Journal*, April 1924, p. 324; "Certain Topics in Telegraph Transmission Theory," *A. I. E. E. Trans.*, v. 47, April 1928, p. 617.
[2] Hartley, R. V. L., "Transmission of Information," *Bell System Technical Journal*, July 1928, p. 535.

Published in The Bell System Technical Journal
Vol. 27, pp. 379-423, 623-656, July, October, 1948

MONOGRAPH B-1598
Reissued December, 1957

www.eecs.berkeley.edu/~christos/classics/shannon-report.pdf

www.princeton.edu/~verdu/reprints/IT44.6.2057-2078.pdf

http://web.mit.edu/6.933/www/Fall2001/Shannon1.pdf

http://web.mit.edu/6.933/www/Fall2001/Shannon2.pdf

http://home.ustc.edu.cn/~zhanghan/cs/Gallager01.pdf

www.pnas.org/cgi/doi/10.1073/pnas.1517384113

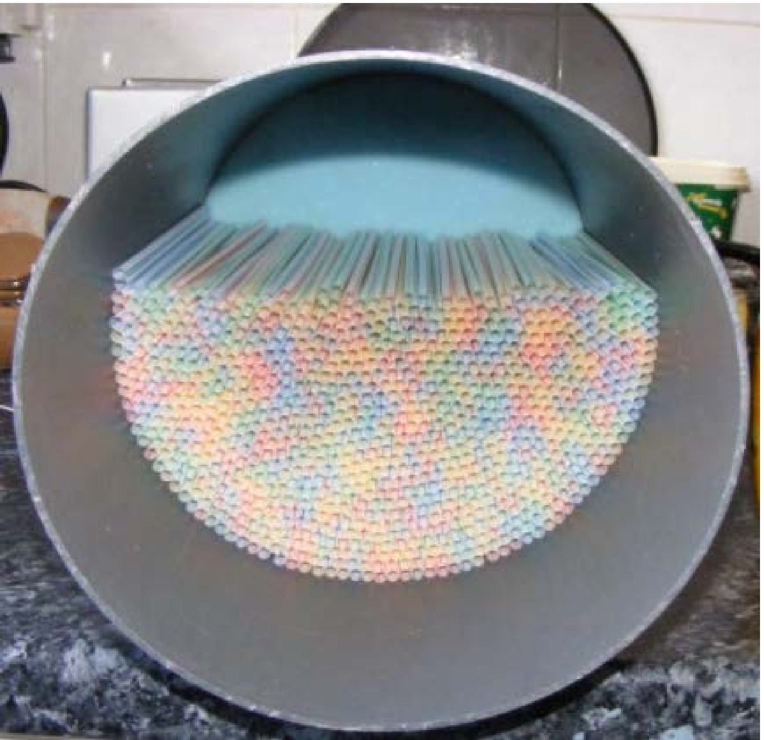
www.pnas.org/cgi/doi/10.1073/pnas.1013529108

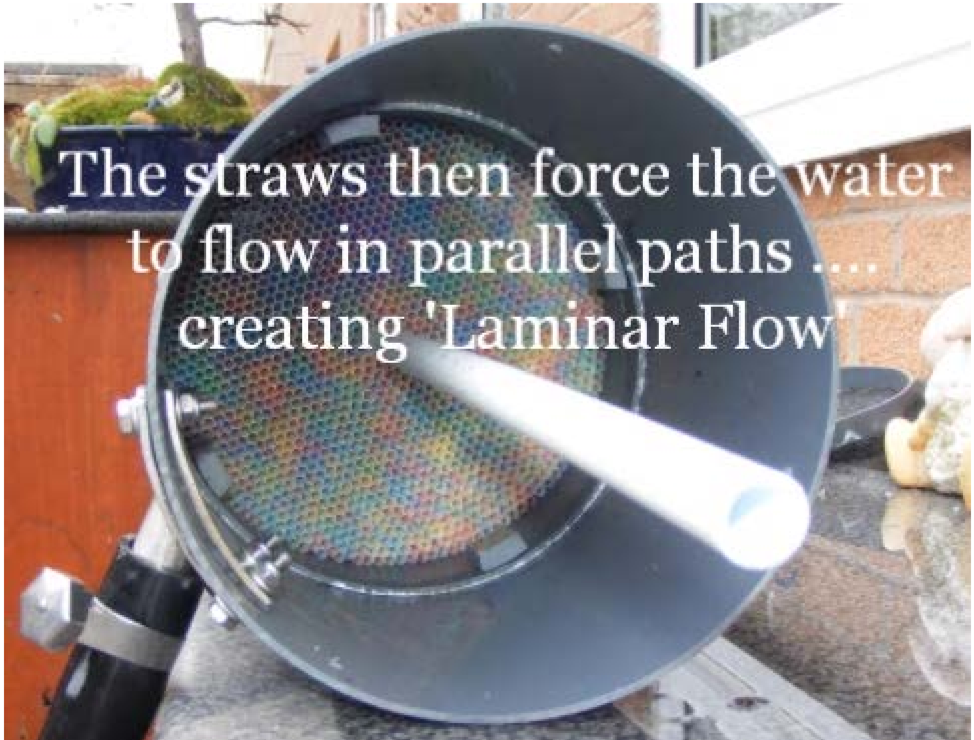
Data Curation Concepts from Laminar Flow

This is applicable across almost all/any data domain where noise is potentially corrupting the data.

This a data curation issue. May unlock related signal/noise problems inherent in (big) data analytics.

http://bit.ly/LAMINAR-FLOW-DATA-CURATION-CONCEPT





Data curation may be rendered useless unless selected for context

The latest US influenza season is more severe and has caused more deaths than usual.

EPIDEMIOLOGY

When Google got flu wrong

US outbreak foxes a leading web-based method for tracking seasonal flu.

BY DECLAN BUTLER

When influenza hit early and hard in the United States this year, it quietly claimed an unacknowledged victim: one of the cutting-edge techniques being used to monitor the outbreak. A comparison with traditional surveillance data showed that Google Flu Trends, which estimates prevalence from flu-related Internet searches, had drastically overestimated peak flu levels. The glitch is no more than a temporary setback for a promising strategy, experts say, and Google is sure to refine its algorithms. But as flu-tracking techniques based on mining of web data and on social media proliferate, the episode is a reminder that they will complement, but not substitute for, traditional epidemiological surveillance networks.

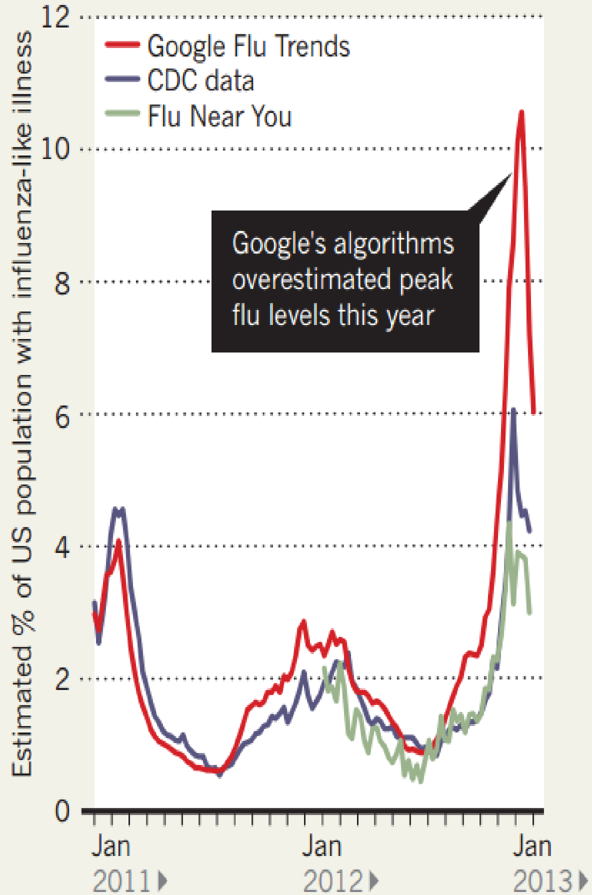
"It is hard to think today that one can provide disease surveillance without existing systems," says Alain-Jacques Valleron, an epidemiologist at the Pierre and Marie Curie University in Paris, and founder of France's Sentinelles monitoring network. "The new systems depend too much on old existing ones to be able to live without them," he adds.

This year's US flu season started around November and seems to have peaked just after Christmas, making it the earliest flu season since 2003. It is also causing more serious illness and deaths than usual, particularly among the elderly, because, just as in 2003, the predominant strain this year is H3N2 — the most

nologies could open the way to easier, faster estimates of ILI, spanning larger populations.

FEVER PEAKS

A comparison of three different methods of measuring the proportion of the US population with an influenza-like illness.



295

Data vs Interpretation – What went wrong? When Google got flu wrong!

http://nautil.us/blog/how-big-data-creates-false-confidence

The temptation (eg Google Ngrams) is to let the sheer volume of data blind us to the ways we can be misled. Google Flu Trends (GFT), released in 2008, would count words (“fever” “cough”) in millions of search queries and use to “nowcast” how many people had flu. With those estimates, public health officials could act 2 weeks before CDC could calculate the true numbers from actual medical reports. Initially, GFT was claimed to be 97% accurate but it was a fluke. First, GFT completely missed the swine flu pandemic in 2009 (turned out that GFT was largely predicting winter.) Then, the system began to over-estimate flu cases and overshot the peak 2013 numbers by 140%. Google scrapped the program. So what went wrong? As with Ngrams, people didn’t carefully consider the sources, context and the interpretation of their data (data source = Google searches = not a static beast). When Google started auto-completing queries, users started just accepting the suggested keywords, distorting the searches GFT saw. On the interpretation side, GFT’s “flu-less” engineers initially let GFT take the data at face value; almost any search term was treated as a potential flu indicator. With millions of search terms, GFT was practically guaranteed to over-interpret seasonal words like “snow” as evidence of flu. On the other hand Jeffrey Shaman (Columbia University) outperformed the flu predictions of both the CDC and GFT by using the former to compensate for the skew of the latter. Shaman tested the model against actual flu activity that had already occurred during the season. By taking the immediate past context into consideration, they fine-tuned their mathematical model to better predict the future. Use BPA?

Multi-disciplinarity in Autonomy and Algorithms ▪ Vendors of the Digital Twin Economy

AGENTS

PROFESSIONAL
Howdy!, x.ai, clara, KASISTO, DigitalGenius, OVERLAP.CC, meekan, fuse|machines, PRIMER

PERSONAL
facebook, XIAOICE, large, assistant.ai, nestor, @wesome, Magic

OS INTERFACES
Siri, Cortana, VIV, maluuba, api.ai, COGNEA, Google Now

AUTONOMOUS SYSTEMS

AIR
3DR, dji, PROJECT LOON Google, VERTICAL, DroneDeploy, AIRDOG, SKYCATCH, SKYDIO, Airware, LILY

GROUND
Google, UBER, TESLA, CRUISE, MOBILEYE, COMMA, AdasWorks

SEA
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INDUSTRIAL
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ENTERPRISE

SECURITY / FRAUD
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HR / RECRUITING
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SALES
6sense, infer, people pattern, Preact, Prism, AVISO, Vidora, sentient, salespredict, Gainsight

MARKETING
LiftIgniter, RADIUS, brightfunnel, retention science, AIRPR

CUSTOMER SUPPORT
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INTERNAL INTEL
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MARKET INTEL
Quid, mattermark, DataFox, bottlenose, PREMISE, enigma, CB INSIGHTS

PLATFORMS

RESEARCH / AGI
OpenAI, vicarious, Google DeepMind, Numenta, Cycorp, nnaisense, SCALED INFERENCE, CURIOUS, GEOMETRIC INTELLIGENCE

FULL STACK
context relevant, CognitiveScale, NVIDIA, TERADEEP, QUALCOMM, nervana systems

MACHINE LEARNING
Dato, rapidminer, cortical.io, AYASDI, amazon web services, Azure Machine Learning, naralogics, PredictionIO, SKYTREE, bigml, blue yonder

INDUSTRIAL IOT
ThingWorx, UPTAKE, IMUBIT, Preferred Networks, Alluvium, xively, PLANET OS

AUDIO
Gridspace, TalkIQ, nexidia, vocaliq, NUANCE, Expect Labs, popUp archive

VISION
ORBITAL INSIGHT, Descartes Labs, DEXTRO, cortica, clarifai, PLANET LABS, MetaMind

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FOR GOOD
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HEALTHCARE
deep genomics, 3SCAN, enlitic, Calico, BUTTERFLY, Atomwise, Recombine, color, METABIOTA, GRAND ROUNDS, Google Life Sciences, IBM Watson Health

INDUSTRIES (CONT'D)

EDUCATION
KNEWTON, coursera, turnitin, gradescope, UDACITY, KHANACADEMY

TRANSPORT & LOGISTICS
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MACHINE LEARNING
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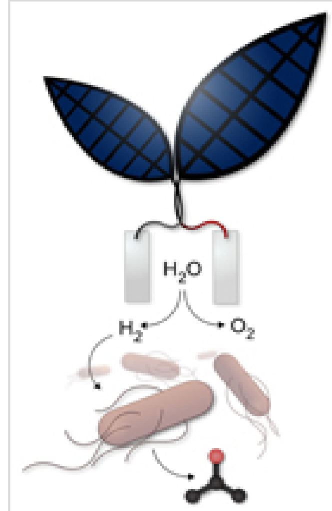
OPEN SOURCE
SKYMIND, TensorFlow, seldon, Caffe, theano, Spark MLlib, Microsoft DMTK, spaCy, DL4J, SciKit, CGT

SHIVONZILIS.COM/MACHINEINTELLIGENCE

Is this possible?



Bohr,

to Pauli and Heisenberg


"We are all agreed that your theory is crazy. The question that divides us is whether it is crazy enough to have a chance of being correct."

All Advantages Are Temporary

www.bbc.com/autos/story/20160421-from-china-a-shot-across-teslas-bow

http://technode.com/2015/09/07/four-hi-tech-car-concepts-from-chinese-tech-companies-youll-see-within-a-year/

Marketing

AIDA Marketing Funnel (1896) by Elias St. Elmo Lewis (Mar 23, 1872 - Mar 18, 1948)

FUNNEL VISION

[3] Monetization

http://bit.ly/MIT-IOT

Monetization

Multi-disciplinary convergence

SCM Data Collaboration (http://bit.ly/SCM-DATA-SHARING)

Economic History of GPT (http://bit.ly/PAUL-DAVID-GPT)

Information Asymmetry (Akerlof, Spence, Stiglitz)

The Nature of the Firm (Ronald Coase)

Role of Technology (Robert Solow)

(The Actual) Metcalfe's Law

Trust in Social Networks

Systems Science

Graph Theory

Platforms

Analytics

SCM Data Collaboration (http://bit.ly/SCM-DATA-SHARING)

Economic History of GPT (http://bit.ly/PAUL-DAVID-GPT)

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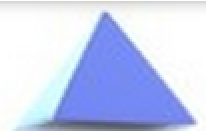
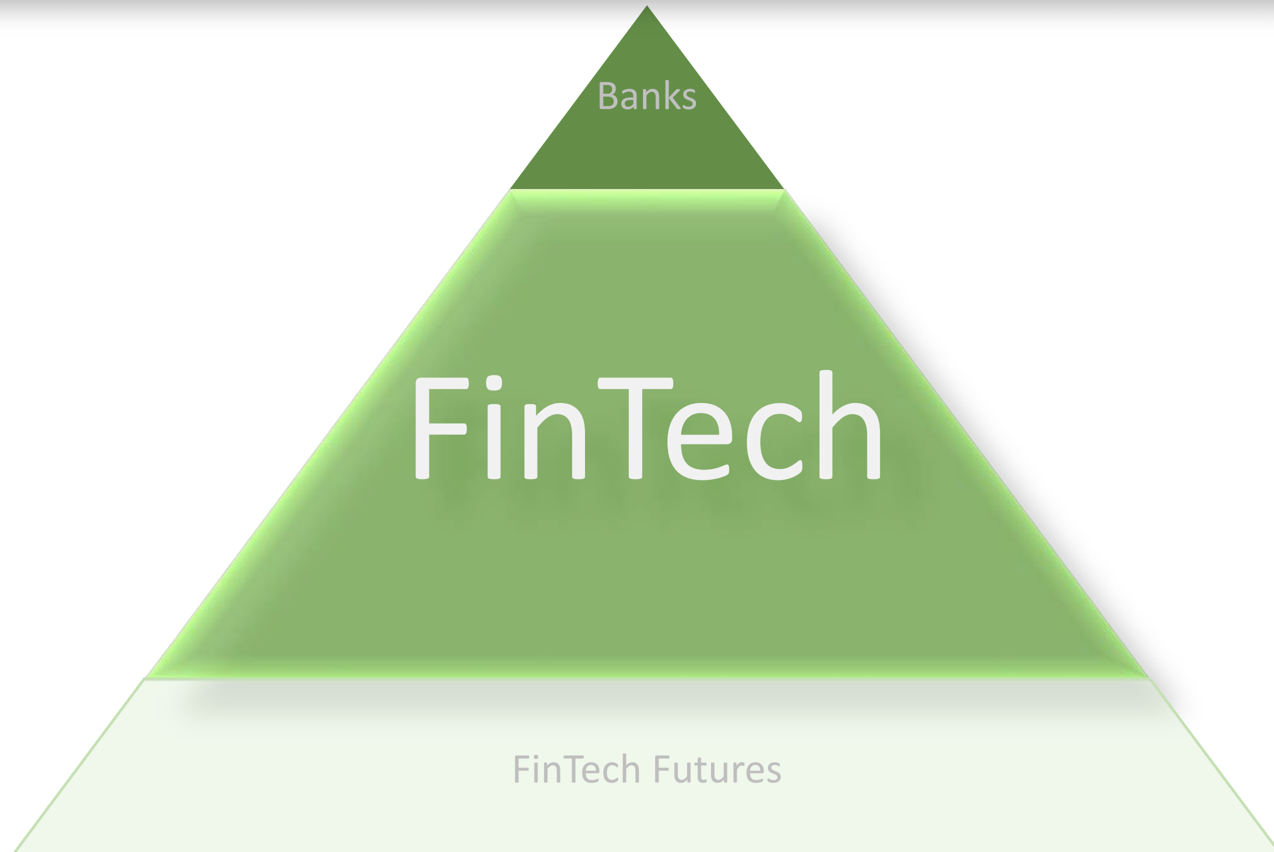


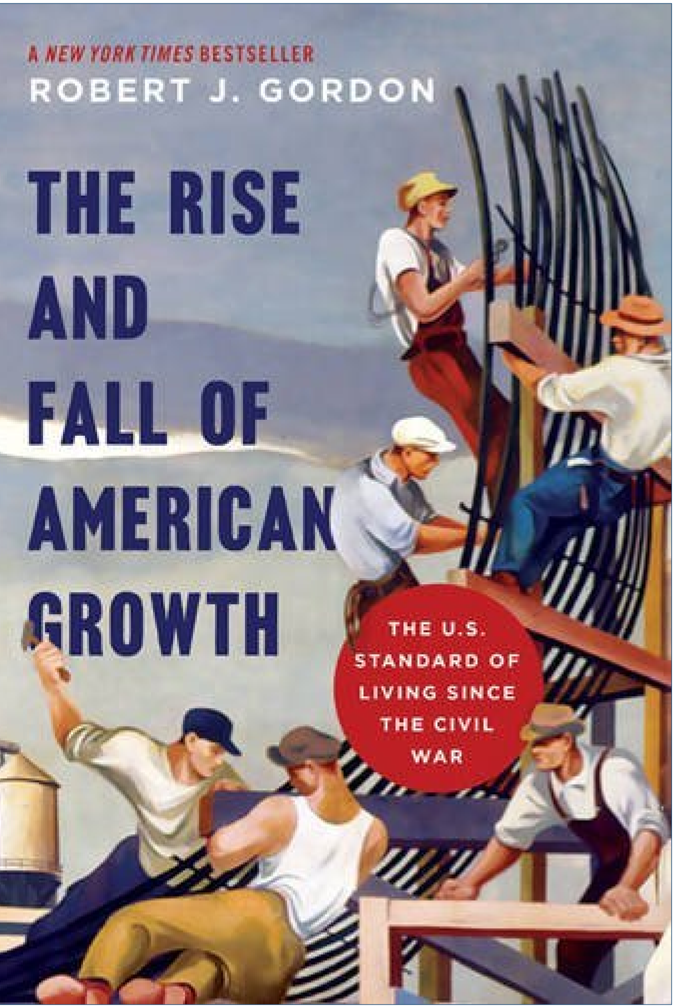
- Analytics
- Platforms
- Graph Theory
- Systems Science
- Trust in Social Networks
- (The Actual) Metcalfe's Law
- Role of Technology (Robert Solow)
- The Nature of the Firm (Ronald Coase)
- Information Asymmetry (Akerlof, Spence, Stiglitz)
- Economic History of GPT (http://bit.ly/PAUL-DAVID-GPT)
- SCM Data Collaboration (http://bit.ly/SCM-DATA-SHARING)

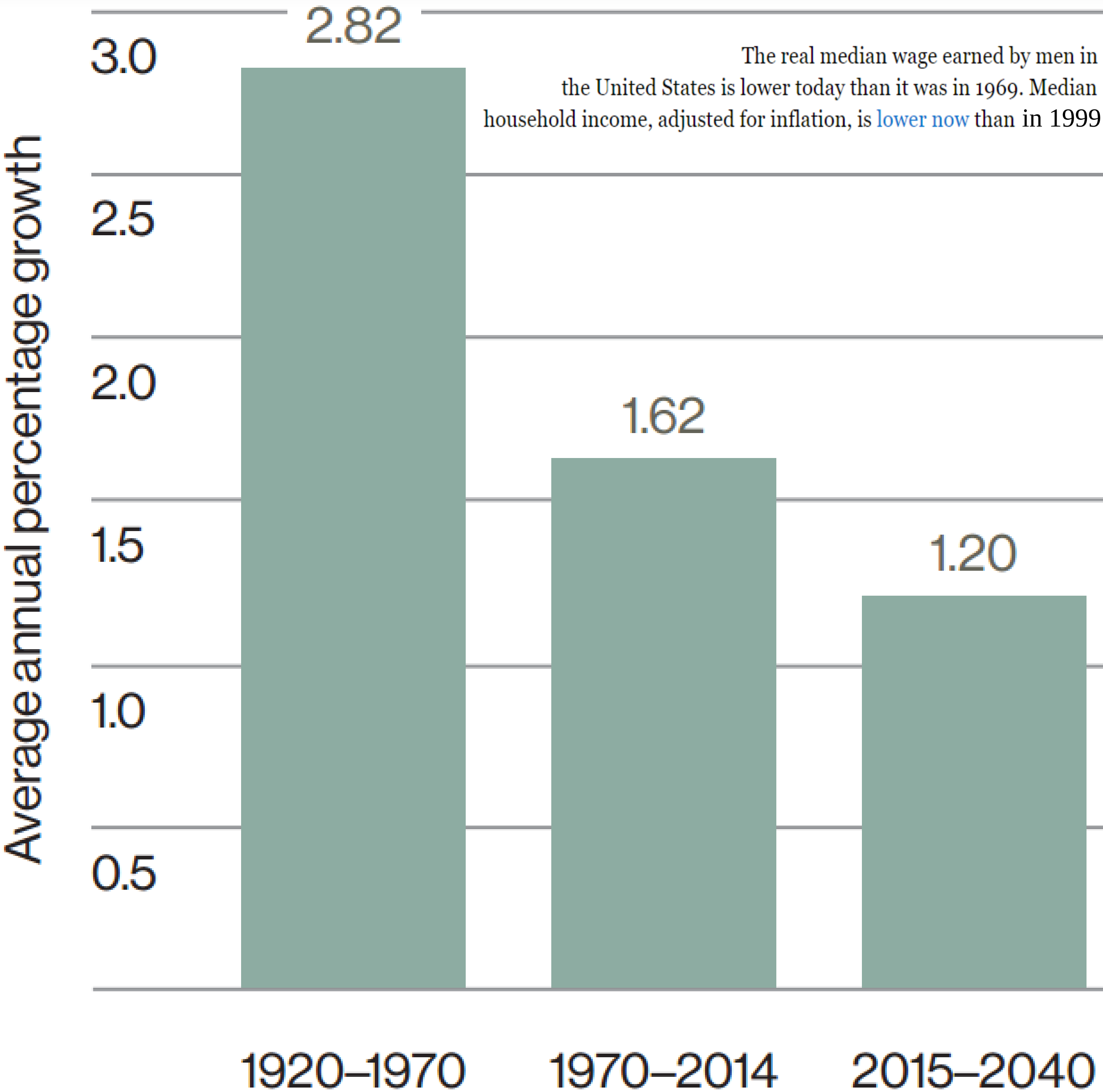
MONETIZATION



Alipay (Ant Financial) has >400 million users, about 100 million transactions per day (70% share of the Chinese payments market). Ant Financial also owns Yu'ebao, money-market fund with 200 million users and managed nearly $100 billion in assets (2014). Now add Huawei to Alibaba!
http://hweblog.com/the-age-banking-revolution ● www.statista.com/statistics/478527/paypal-mobile-tpv-share-quarter/ ● Don’t forget India.

Is productivity a suitable indicator of progress?



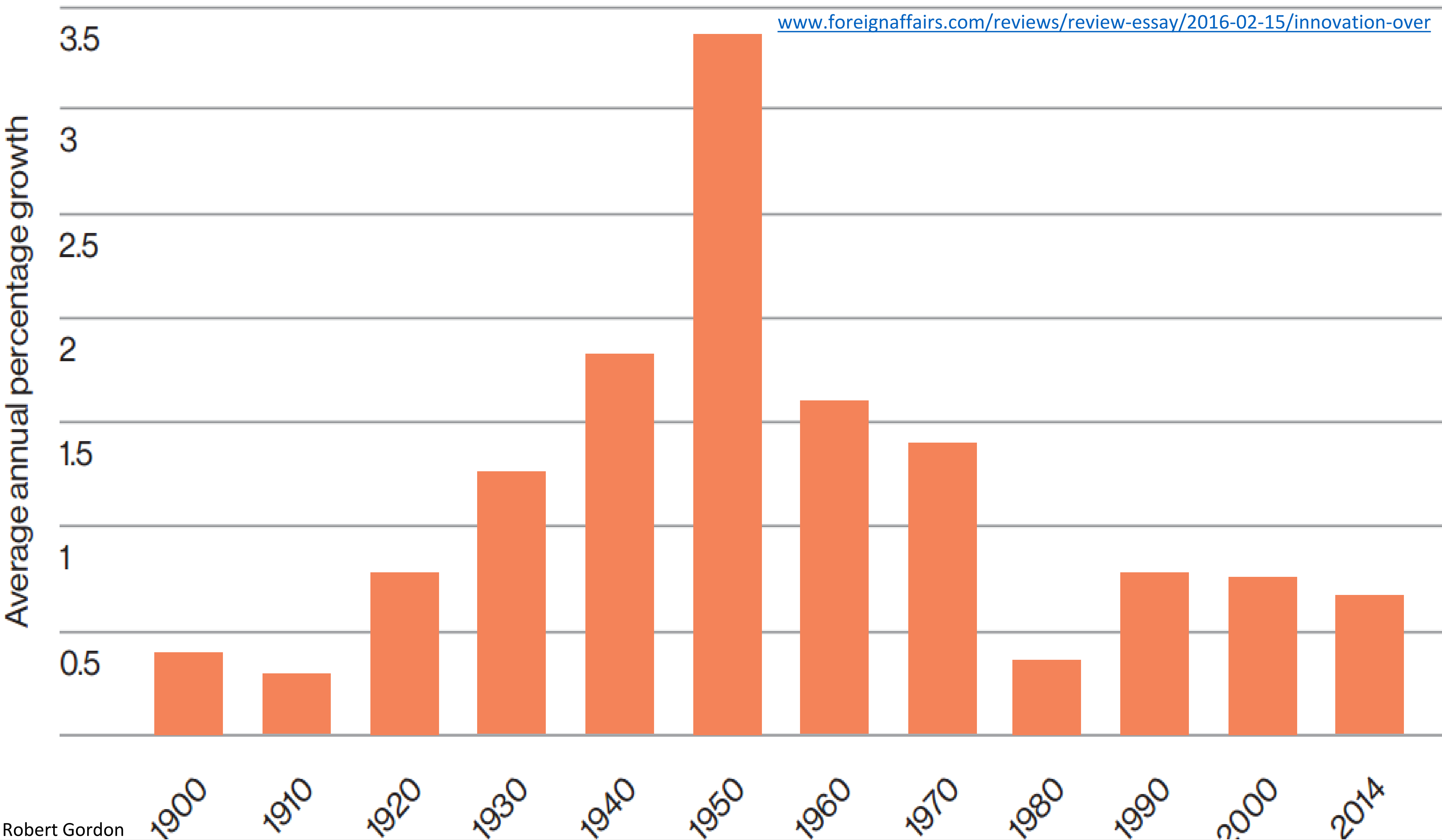


The real median wage earned by men in the United States is lower today than it was in 1969. Median household income, adjusted for inflation, is lower now than in 1999

www.nytimes.com/2016/01/31/books/review/the-powers-that-were.html?_r=0

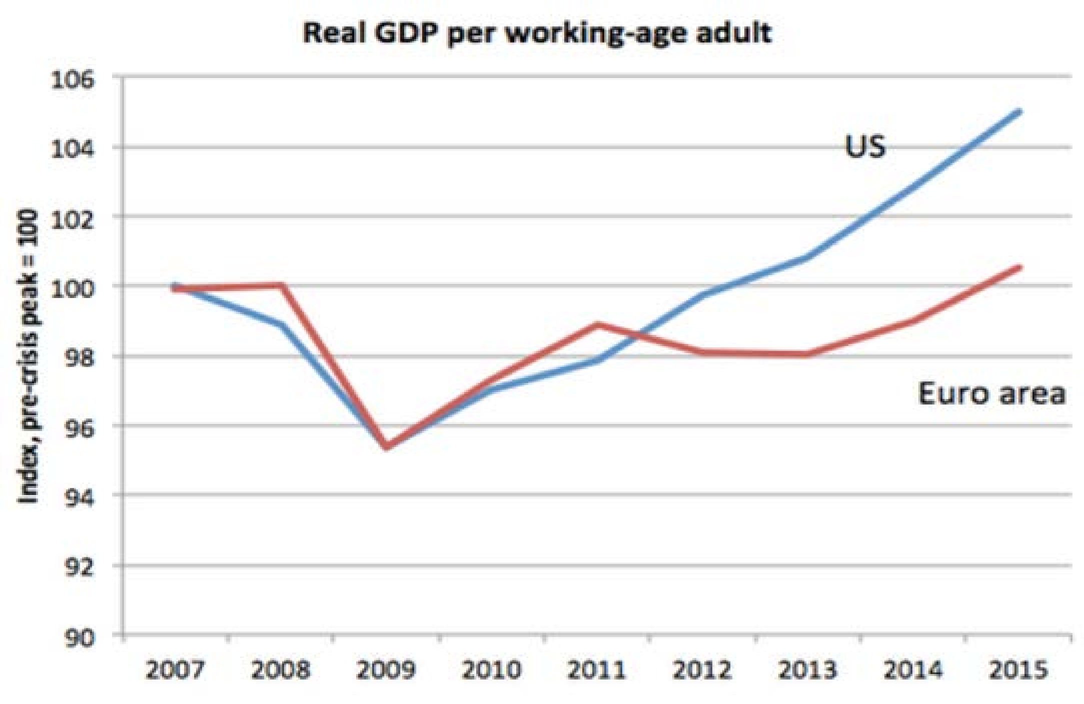
US incomes shrank between 1972 and 2013

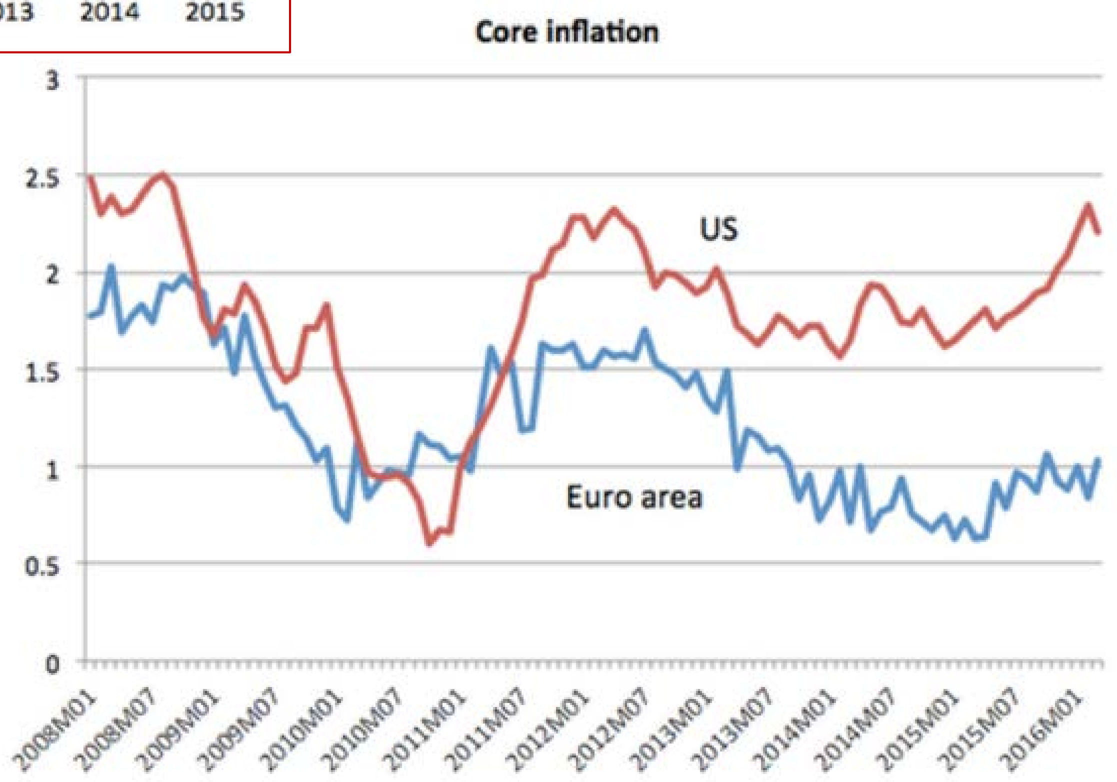
Each bar shows a 10-year average prior to the year shown (2014 bar is for 2001–2014).



Robert Gordon

EU vs US

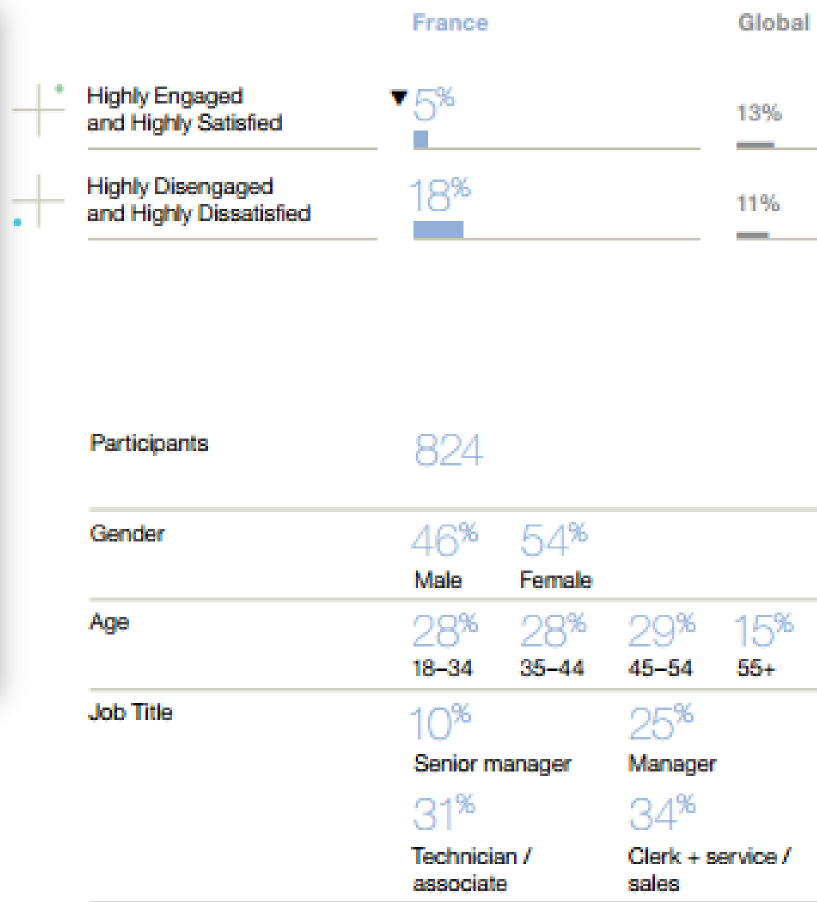


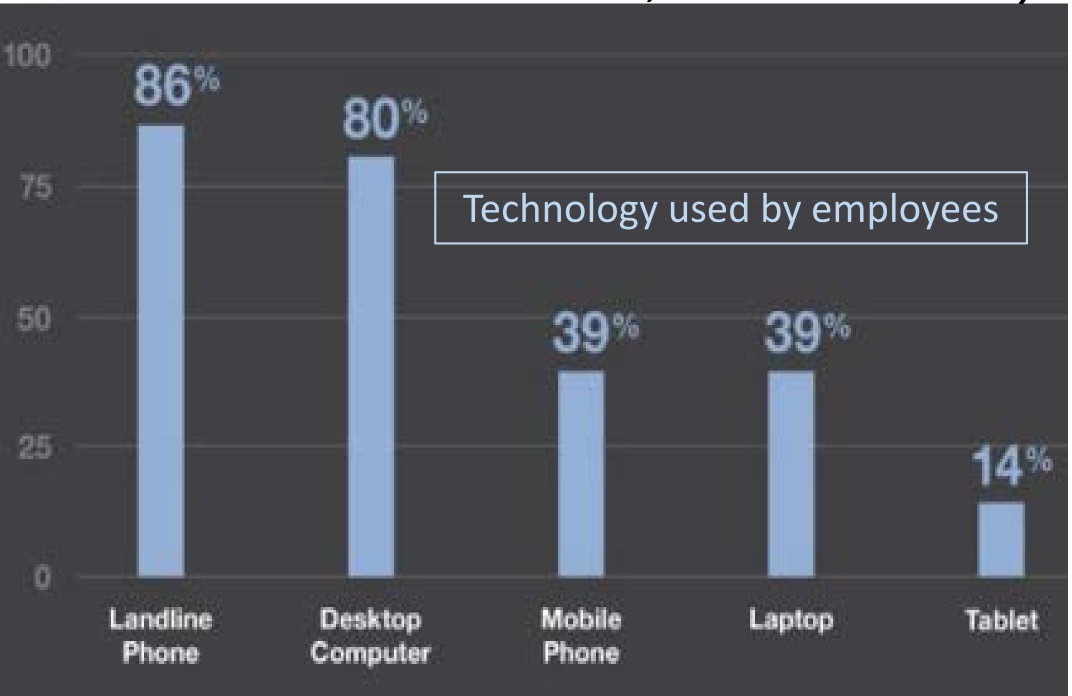


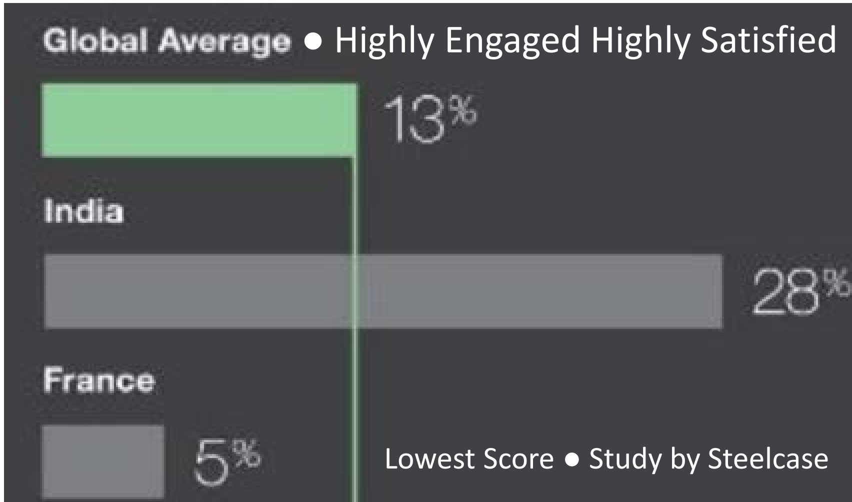
http://krugman.blogs.nytimes.com/2016/04/30/when-europe-stumbled/

Deep Divisive Denominators

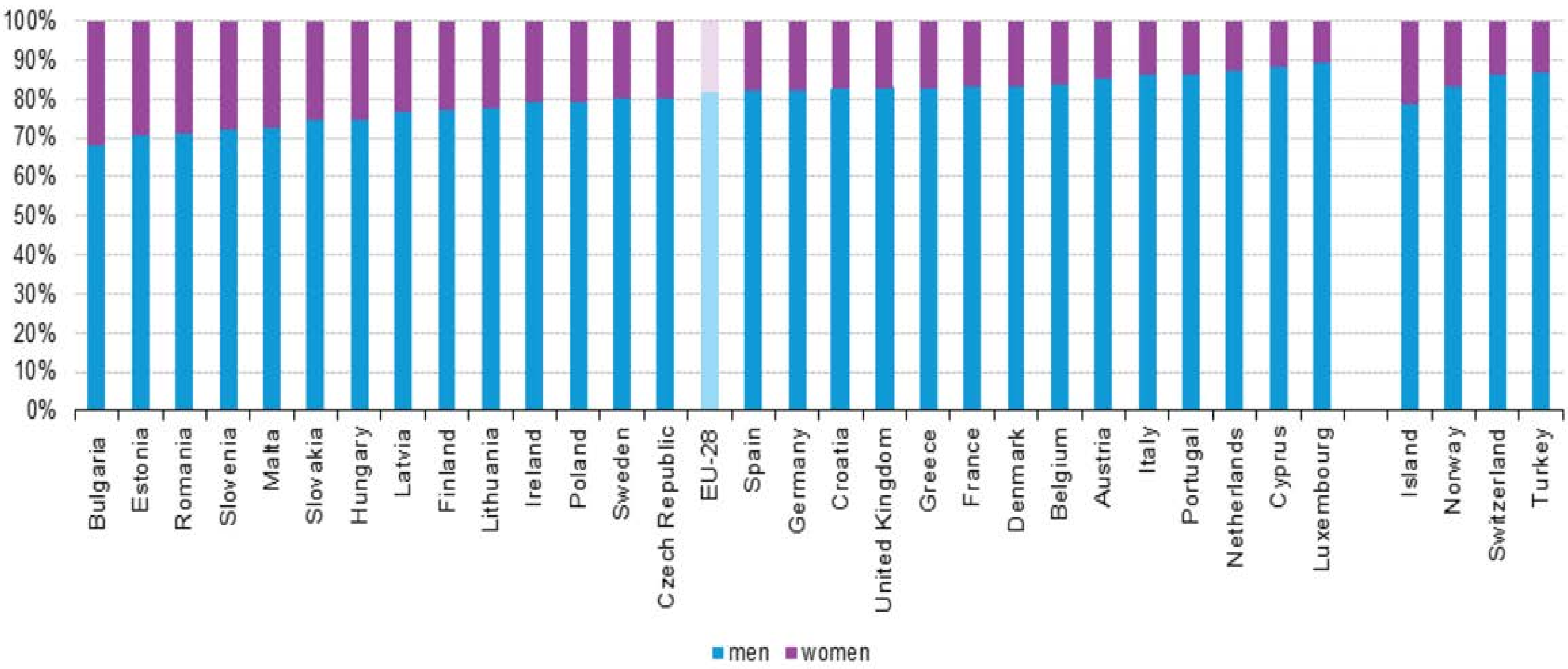
A wide chasm between ideas, vision and reality.





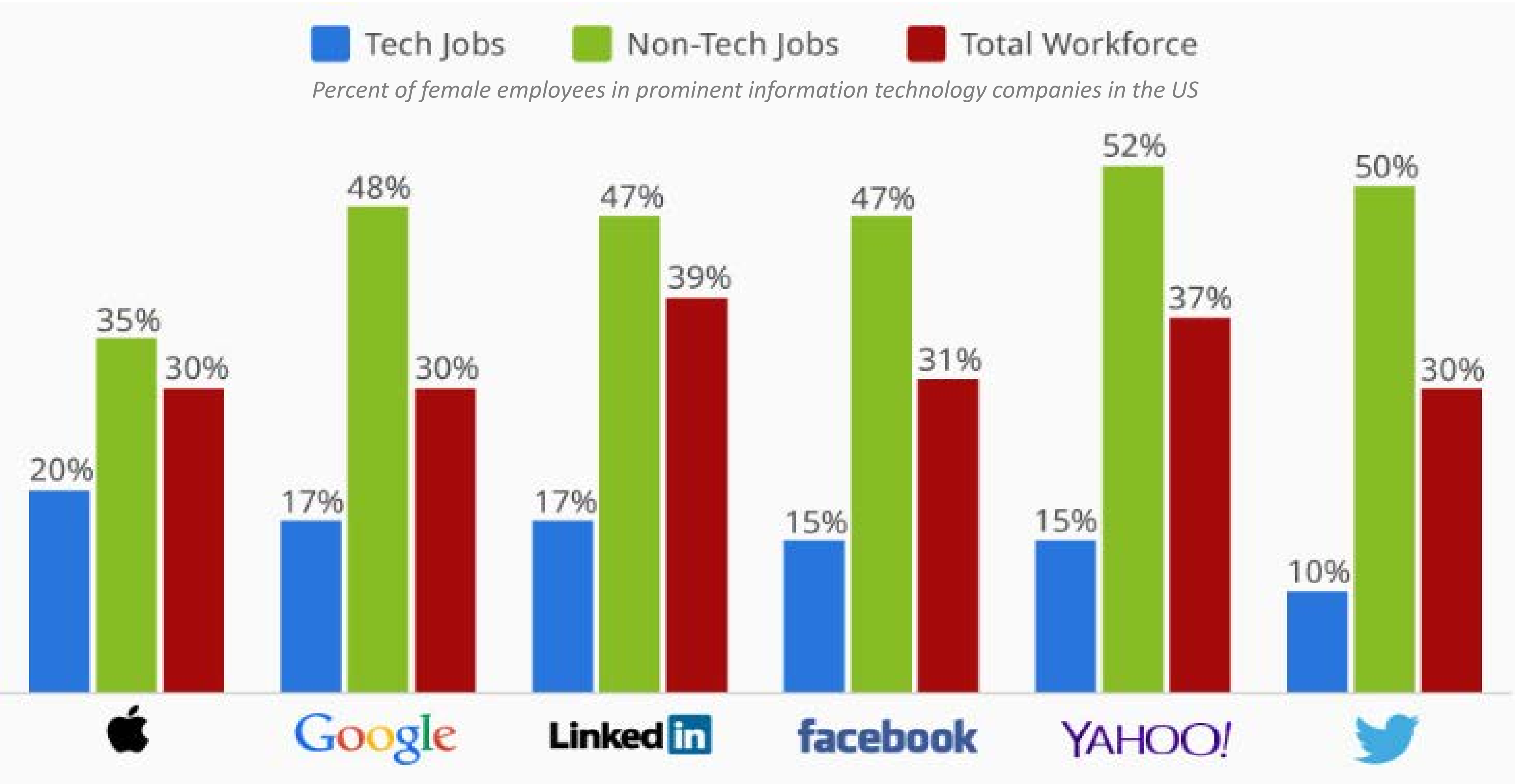


Gender of ICT Experts



2014 Eurostat

TWO.MEN = WOMEN

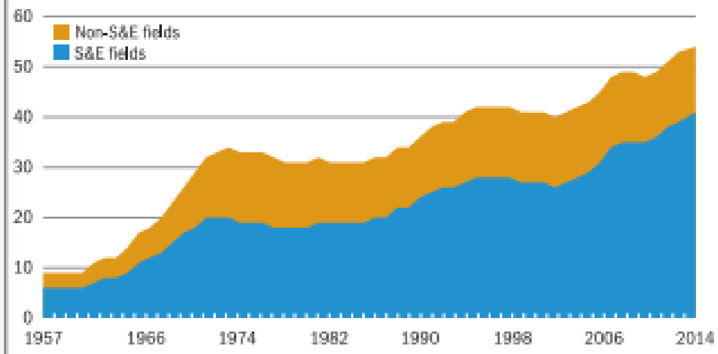


N U M E R A T O R

A

Doctorates awarded by U.S. colleges and universities: 1957–2014

Doctorate recipients (thousands)

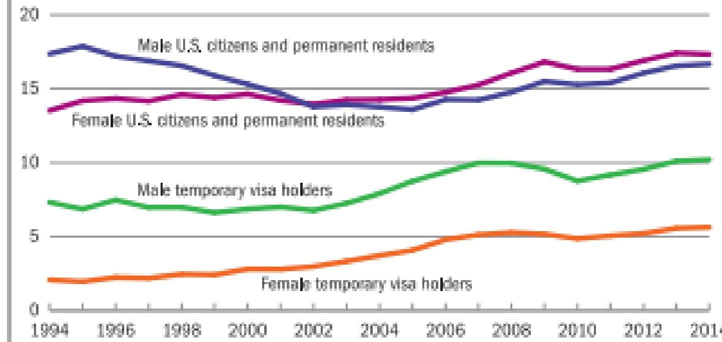


SOURCE: *Doctorate Recipients from U.S. Universities 2014.*

D

Sex and citizenship of U.S. doctorate recipients: 1994–2014

Doctorate recipients (thousands)



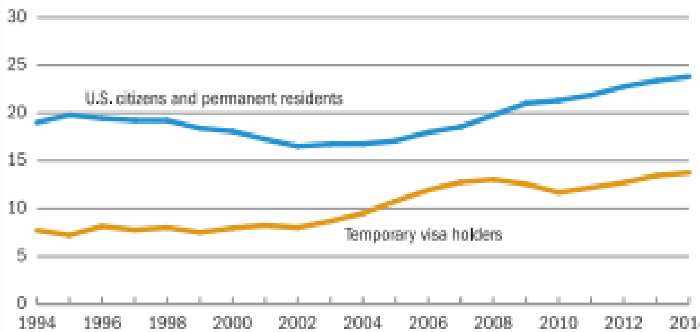
SOURCE: *Doctorate Recipients from U.S. Universities 2014.* Related detailed data: tables 20, 21.

http://bit.do/NSF-2014-DOC

B

Doctorates awarded in science and engineering fields, by citizenship: 1994–2014

S&E doctorate recipients (thousands)

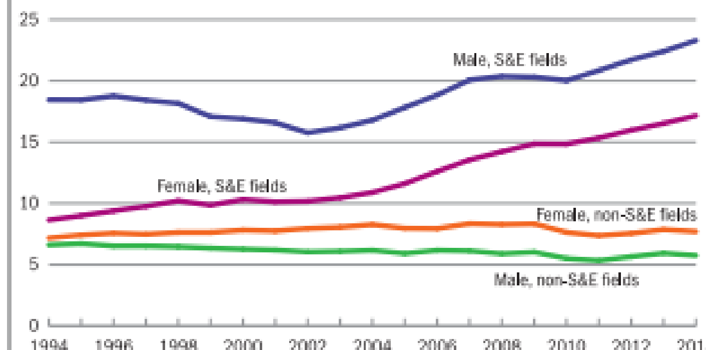


SOURCE: *Doctorate Recipients from U.S. Universities 2014.* Related detailed data: tables 17, 18.

E

Sex and field of study of U.S. doctorate recipients: 1994–2014

Doctorate recipients (thousands)



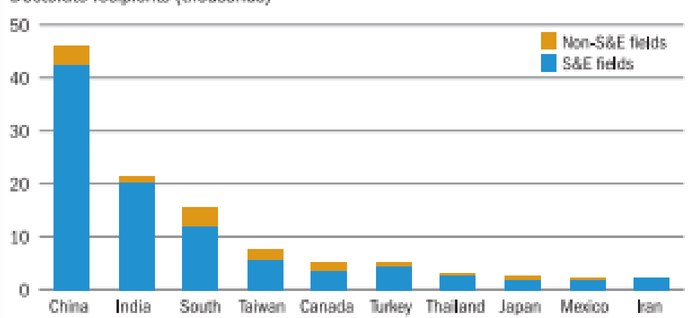
SOURCE: *Doctorate Recipients from U.S. Universities 2014.* Related detailed data: tables 14, 15, 16.

http://bit.do/NSF-2014-DOC

C

Top 10 countries or economies of foreign citizenship for U.S. doctorate recipients: Total, 2004–14

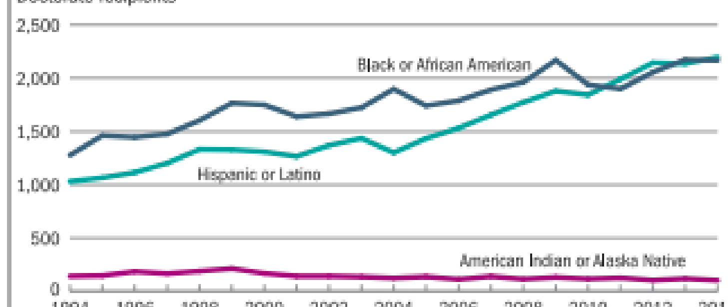
Doctorate recipients (thousands)



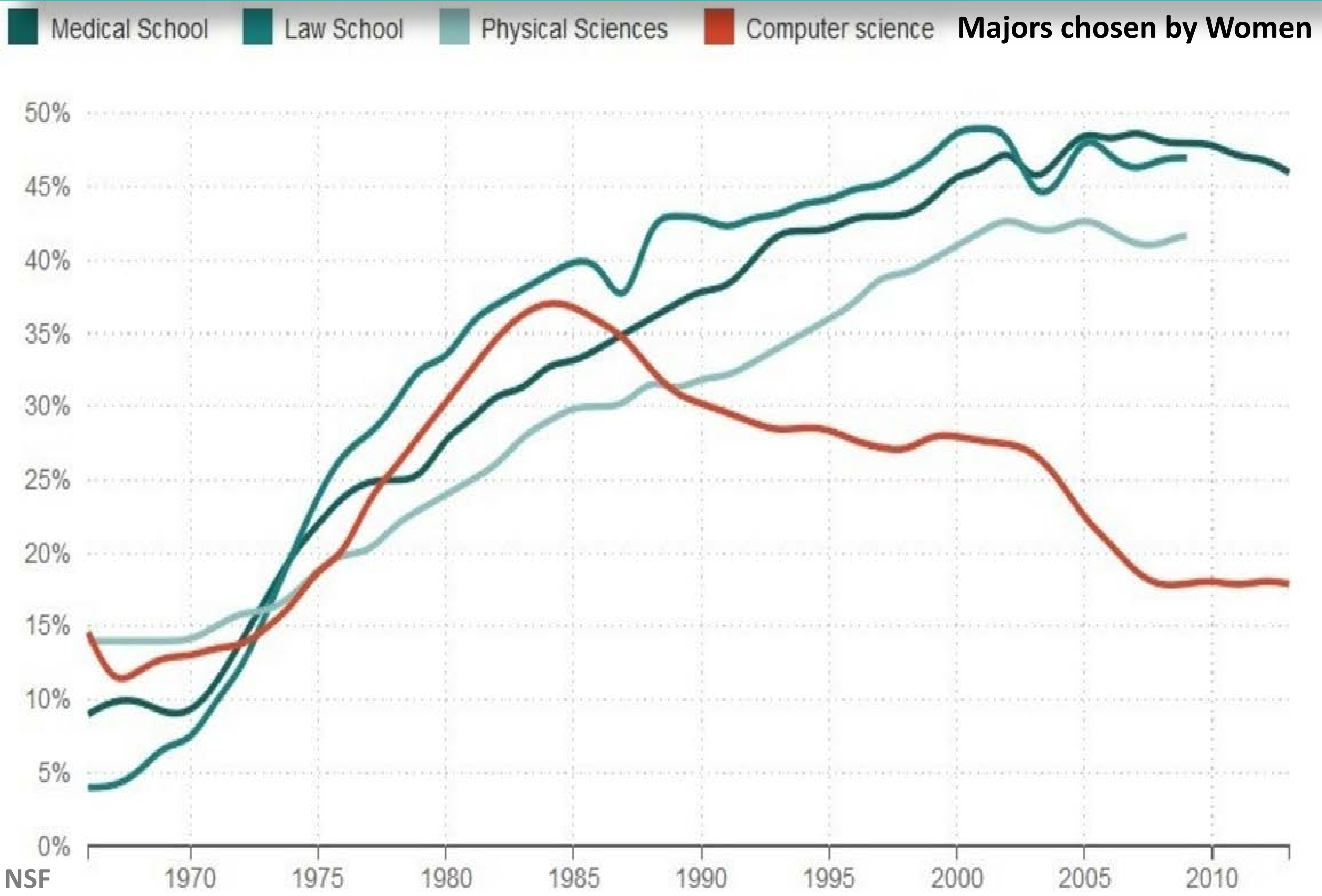
F

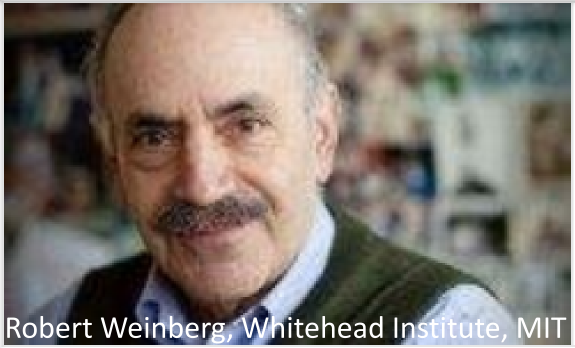
Doctorates earned by members of U.S. underrepresented minorities: 1994–2014

Doctorate recipients



Is this the impact of math-phobia spread by female teachers in US elementary schools?



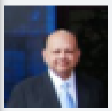


Robert Weinberg, Whitehead Institute, MIT

Cancer Pioneer Laments 'Marginalization' of Basic Research

medpagetoday.com • Is the bench forgotten?

Like • Comment • Share • 1



Shoumen Datta Pandering to the hype of the "app" generation, even the august institutions are being converted to proselytizing agencies and marketing machines evangelizing that you can download an app to cure cancer from Google Play only if we fish out the "disruptive" data from the "big data lake" (Loch Ness). show less

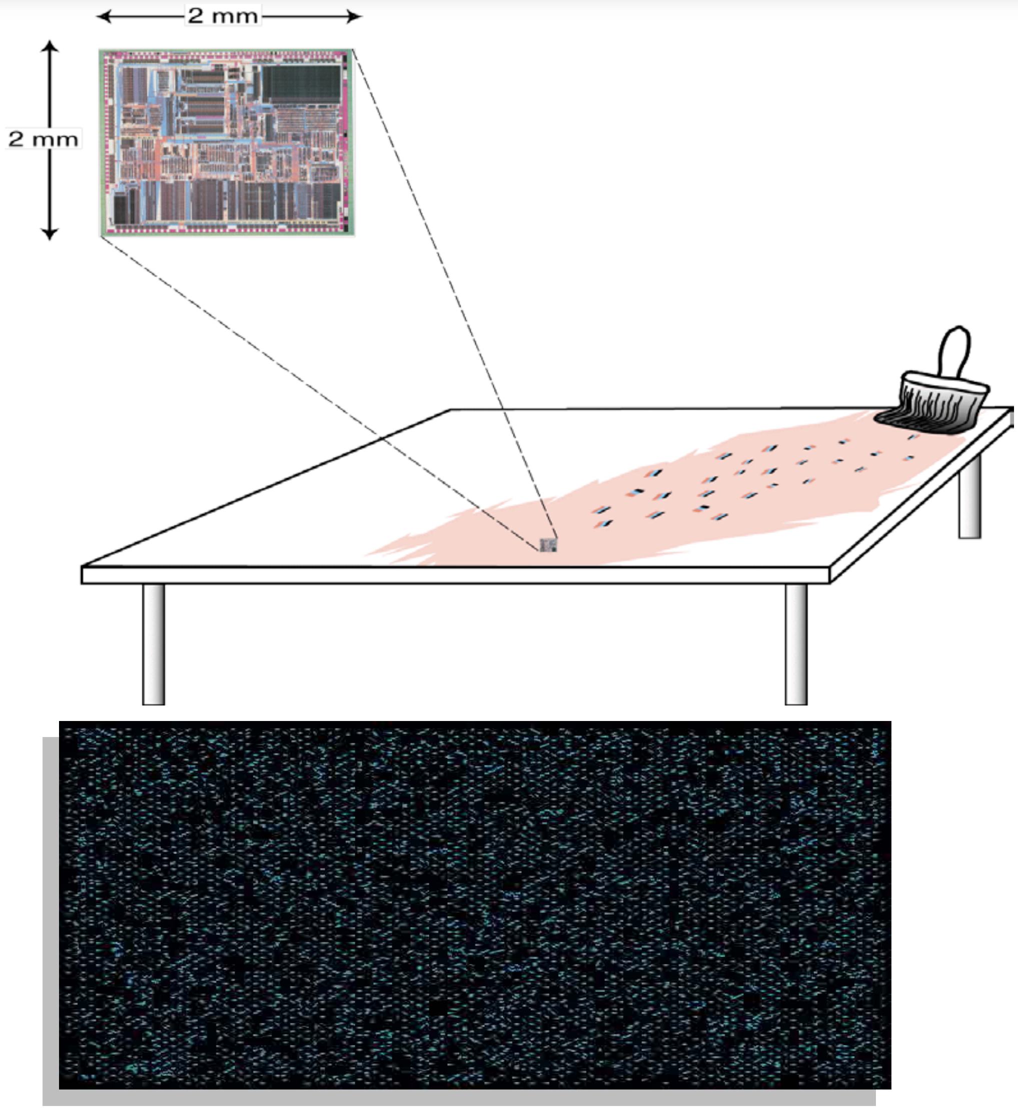
WeChat Transforms China's School Days

How teachers, parents, and students in some schools in China are using the messaging app to perpetuate round-the-clock pressure.

On a recent Thursday evening, Zhang Zehao, a seventh grader in Tianjin, China, braced himself for extra math assignments posted by his teacher on WeChat, a messaging app. At 7 P.M., his mother received a picture on her phone: a piece of paper with three handwritten geometry problems concerning parallel lines. He

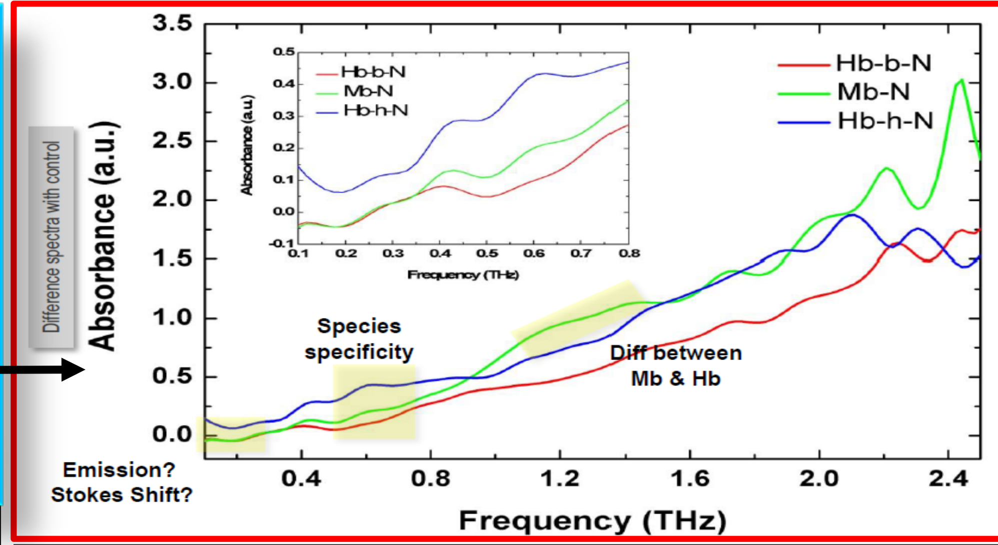
Li Guibin checks WeChat to see what his math homework assignments are.

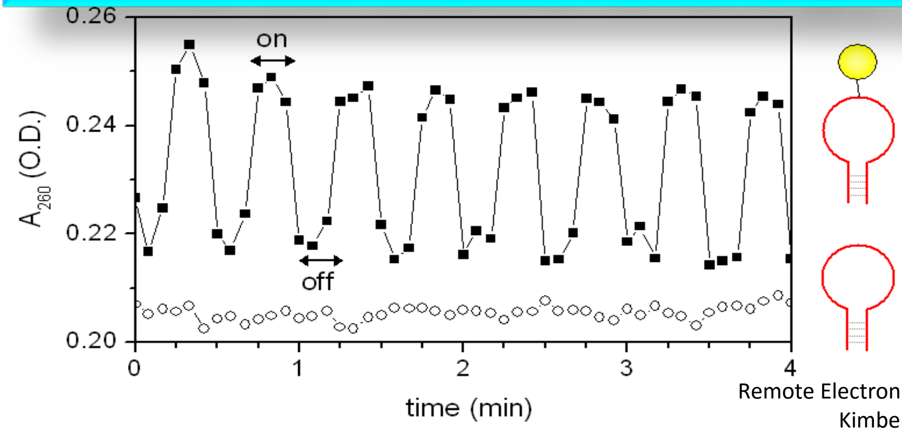
Can we paint a self-organizing computing surface agnostic of material?

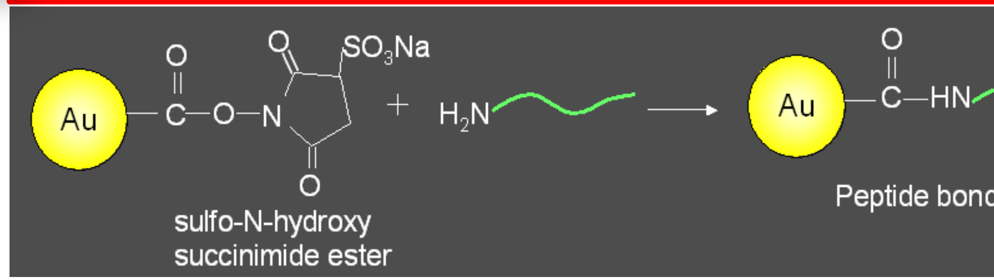


http://bit.ly/BILL-BUTERA-MIT-PhD-THESIS ● Programming a Paintable Computer (Bill Butera, PhD Thesis, MIT 2001)

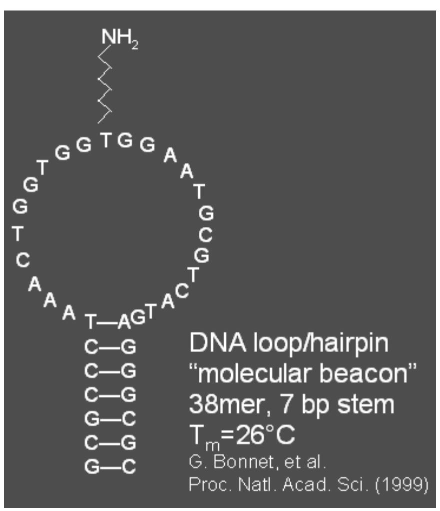
Convergence (?) of TeraHertz Medicine (proteins are radios) and RF Nano Biology

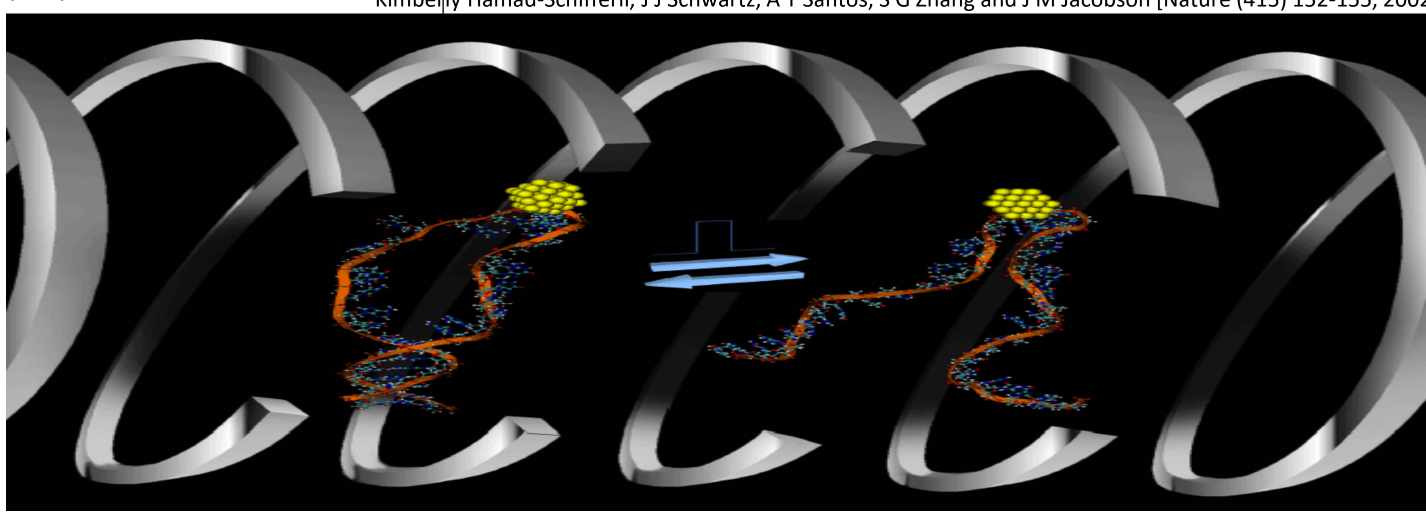






Remote Electronic Control of DNA Hybridization Through Inductive Coupling to an Attached Metal Nanocrystal Antenna
Kimberly Hamad-Schifferli, J J Schwartz, A T Santos, S G Zhang and J M Jacobson [Nature (415) 152-155, 2002]





"Did not entail being right all the time.
It was rather to dare, to propose new
ideas, and then to verify them and to
know how to admit errors."

Professor Pierre-Gilles de Gennes[*] (1932-2007)
after receiving the 1991 Nobel Prize for Physics

In Praise of Imperfection

Gerald Santucci
Head of Unit "Knowledge Sharing" at European Commission

Dear Shoumen,

Thank you so much! This is the BEST report I ever read on the IoT, Industrial Internet, whatever it's called. I like the evidence-based analysis, the notion of "impotence" of II without data and data analytics, the description of II around the dimensions of Technology, Strategy and Organisation (with an emphasis on culture change), the detailed analysis and predictions about application fields, etc. So well done!

To explore the collection of ideas – REVIEW IOT http://bit.ly/MIT-IOT

I hope I didn't bore you to sleep …

Thank you

Shoumen Datta