Wy Computing is Turning the World Upside-Down

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India Habitat Center, New Delhi, November 2nd, 2020

COLLÈGE DE FRANCE 1530

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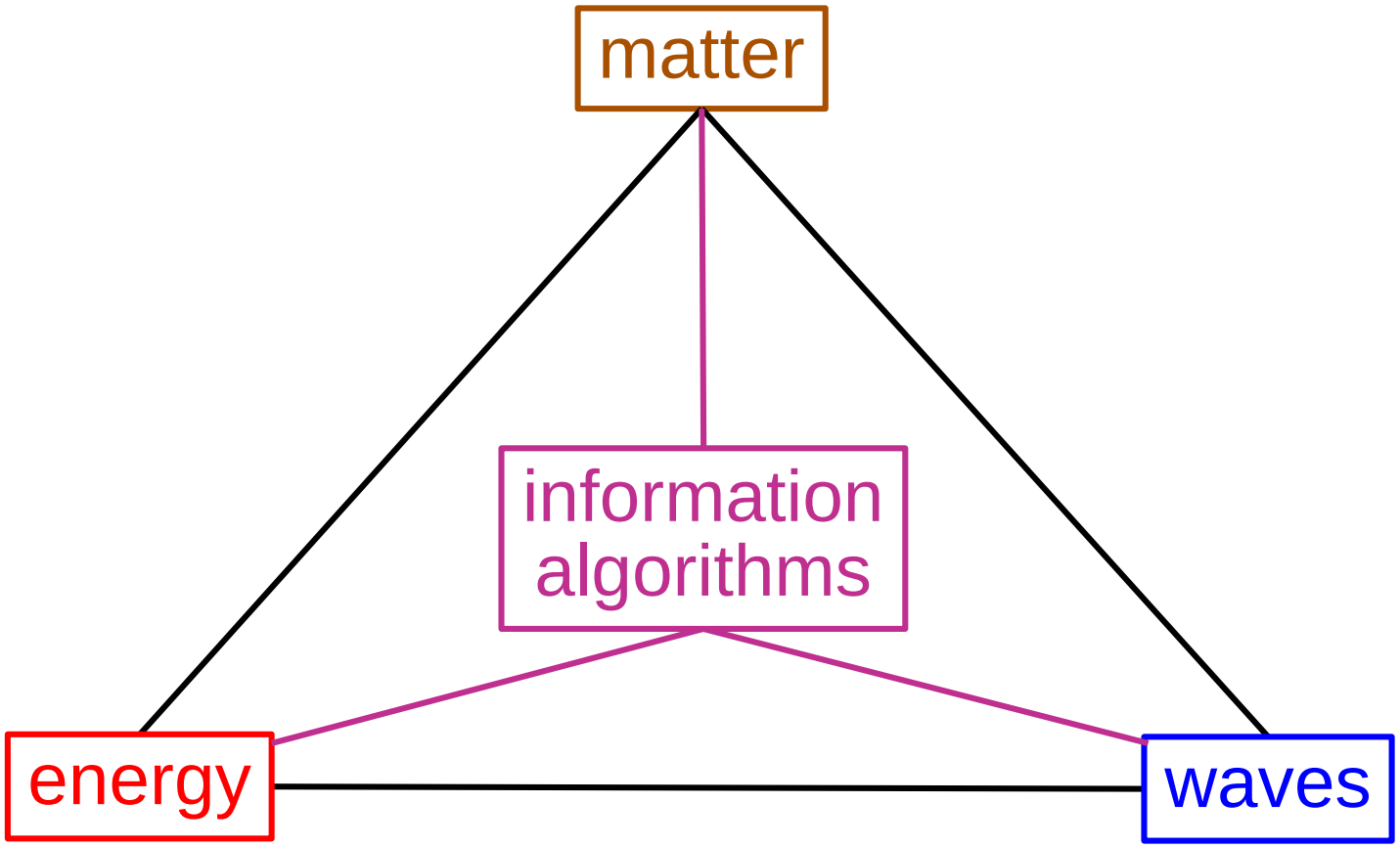
INSTITUT FRANÇAIS INDIA

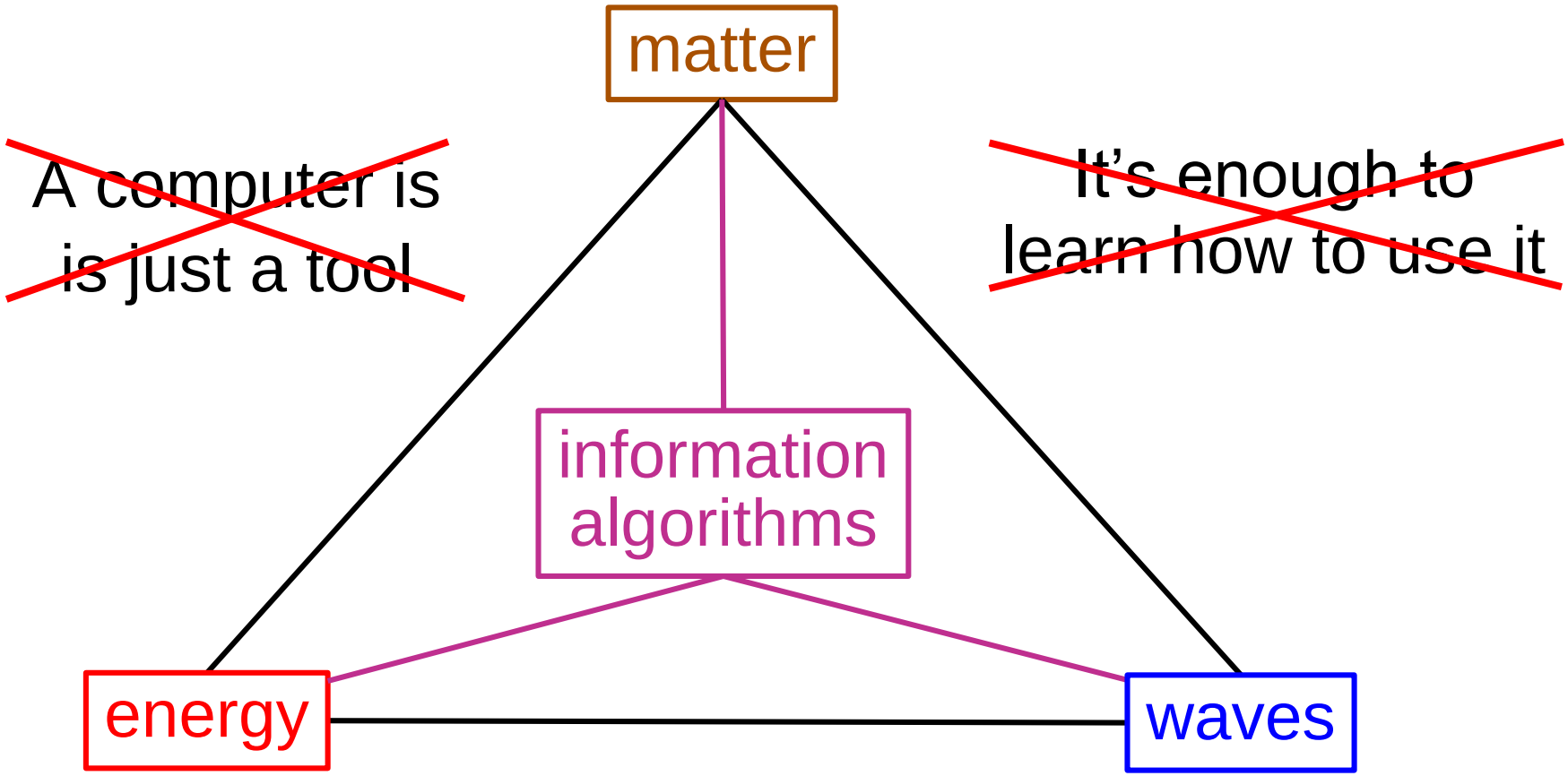
INDIA HABITAT CENTRE

Sciences and techniques, 19e → 21e century



Information has no weight, does smell nor burn, but can be felt (I *know* something). Unlike matter and energy, it can be easily stored, transmitted and duplicated

What makes Informatics essential



Informatics and algorithms lead to
a new way of thinking and acting,
with extremely efficient levers

The power and universality of Informatics

- A unique notion of information for media, telecoms, physics biology, neurology, history, etc.
- A unique notion of algorithm for all domains
- A universal machine, unique in history
- The information lever is hyper-efficient
  - text, music, photos, cars, airplanes control,... → information
  - possessing information >> possessing matter: Booking.com
- But a major mental difficulty
  - Reasoning on and acting with information is very different from reasoning on and acting with matter and energy

Understanding the essence of Informatics has become essential for most activities

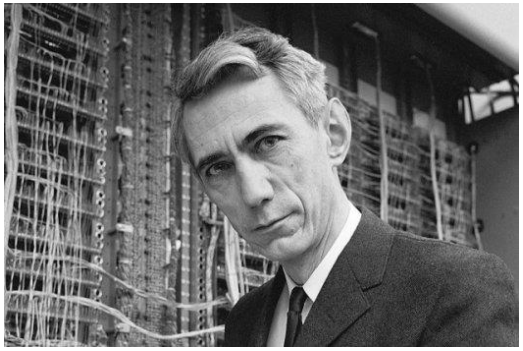
Source Maurice Nivat

Al Khuwārizmī
~ 783 - 850

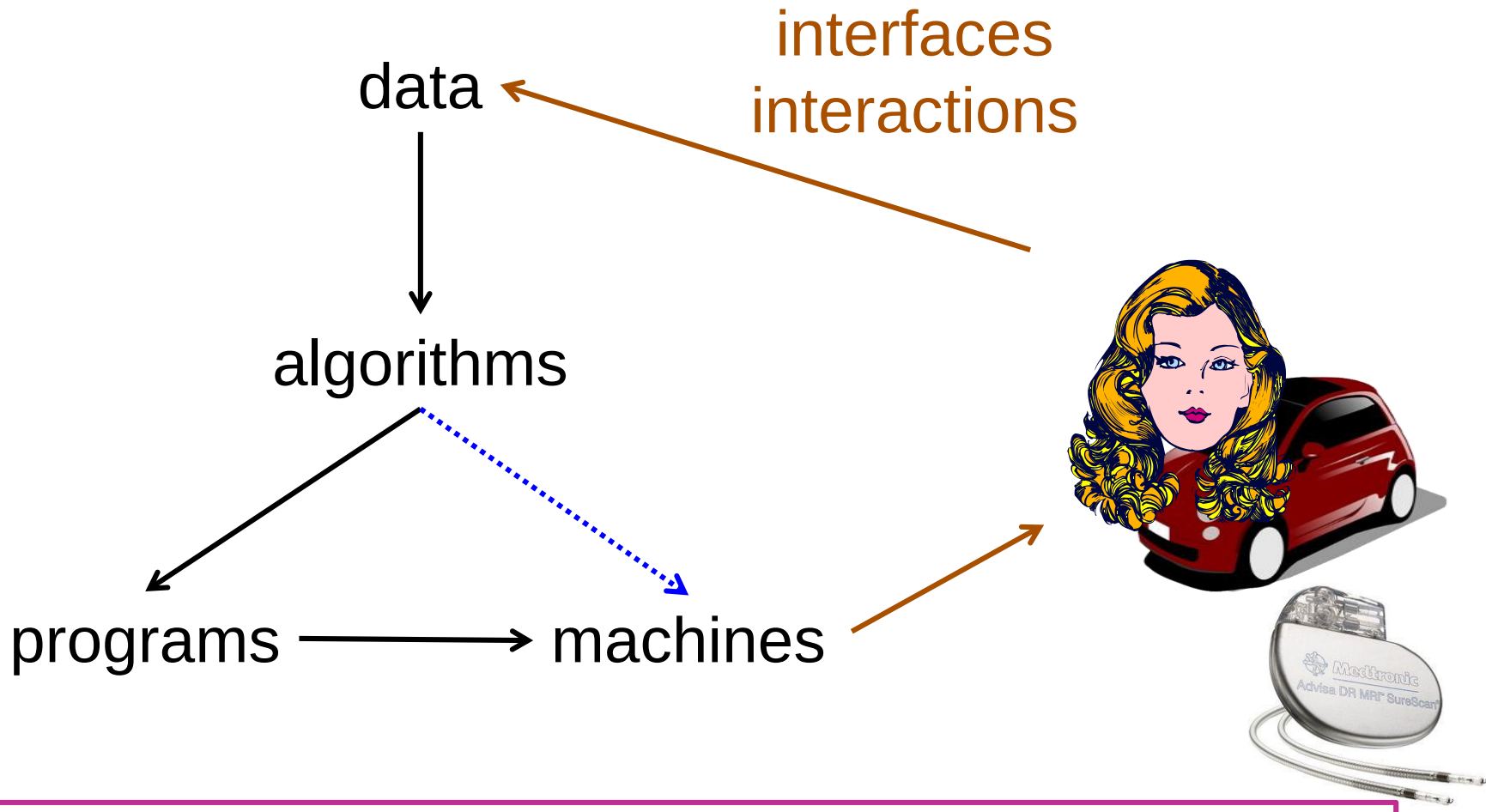
algorithm
"Arabic" numerals (Indian!)
algebra

Turing, 1936
computability
universality

Claude Shannon,
communication,
information



The pillars of Informatics

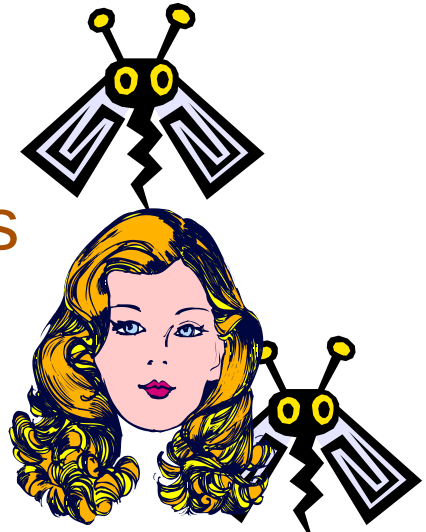


A construction science where we build everything closer to mathematics than to natural sciences

Dangers : bugs and security holes

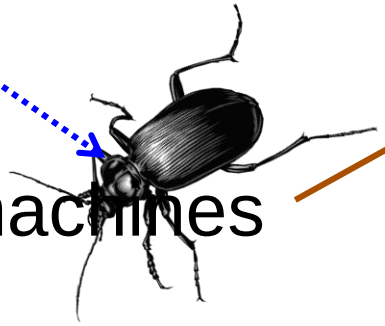
data

interfaces
interactions



algorithms

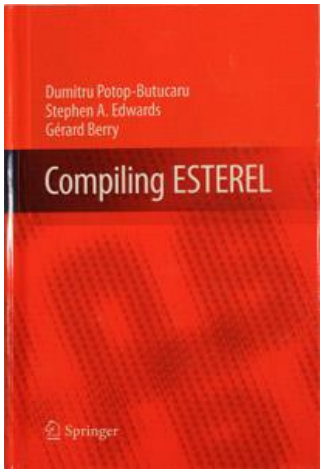
programs → machines

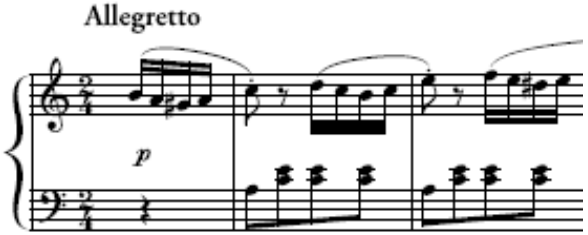


Safety : the right behavior in all execution cases
Security : data and systems protection w.r.t. attacks

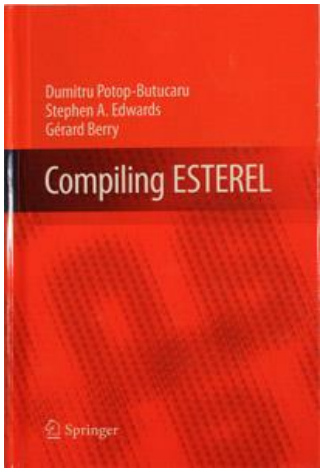
20th Century : Information depends on its support

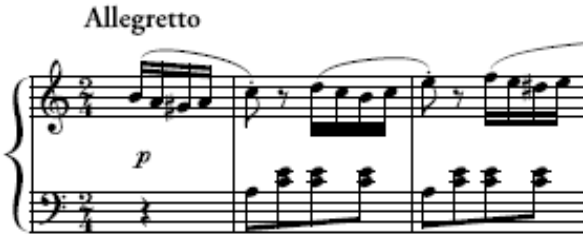
Text, pictures
Formulae





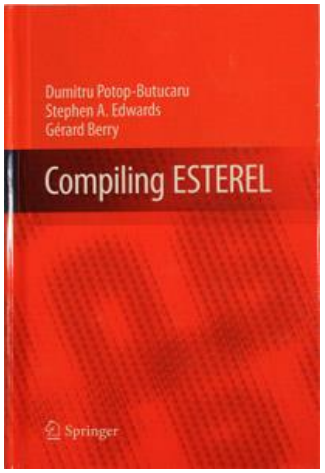
Now : Independence and convergence





01100110111101
10010011101100

… with major improvements



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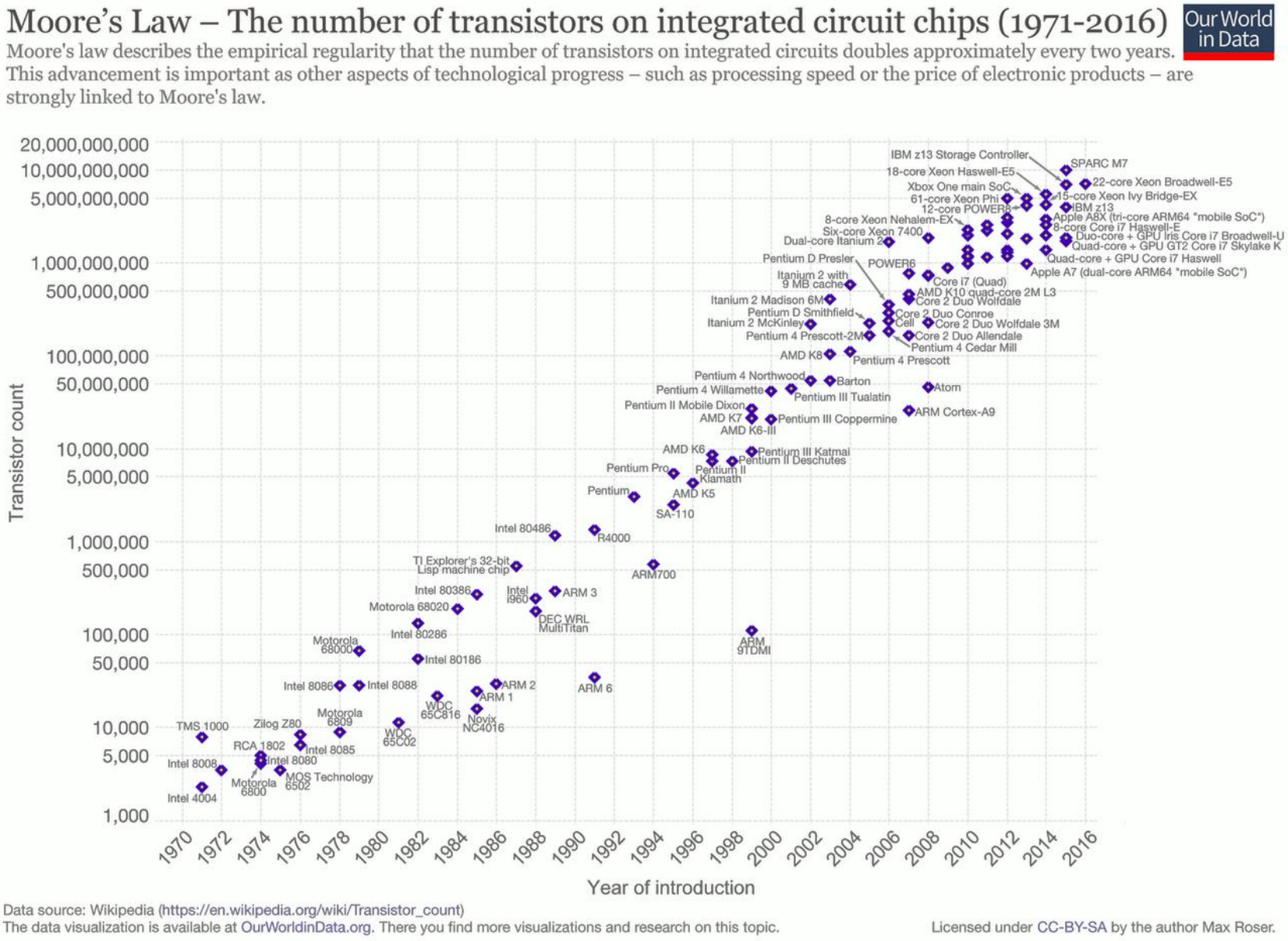
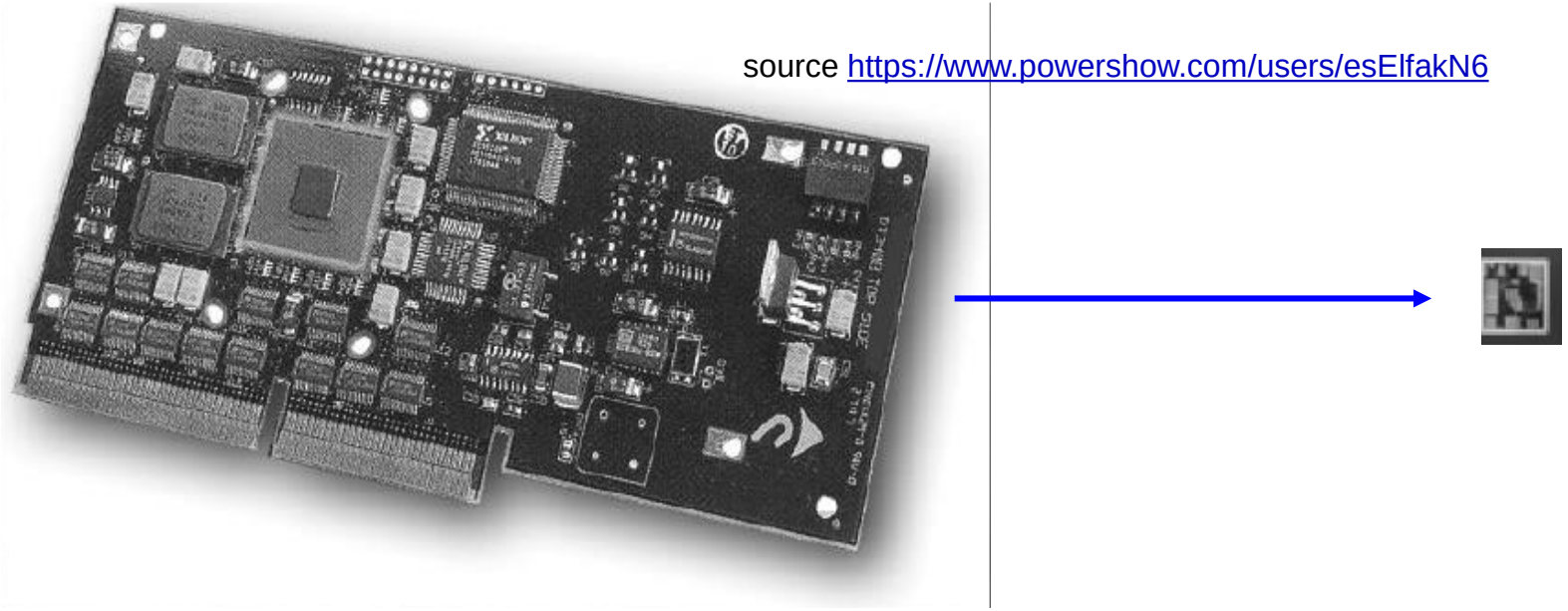
Moore's Law



source Wikipedia

Circuits → Systems on Chips (SoCs)



source https://www.powershow.com/users/esElfakN6

- Built by assembling d'IPs (*Intellectual Properties*)
  - CPUs, GPU, videos, USB, radio, memory controllers, etc.
  - algorithms everywere in design, verification and fabrication !
- Advantages : size, energy consumption, development speed, fabrication, price, etc.

The wide variery of universal machines

CERN, Par Hugovanmeijeren
Travail personnel, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=10282772

data / computation farms (20 MW)

https://commons.wikimedia.org/wiki/User:Raysonho
CC BY 3.0

the same in containers

The incredible invasion by smartphones

source Wikipedia, Francis Flinch

average everywhere

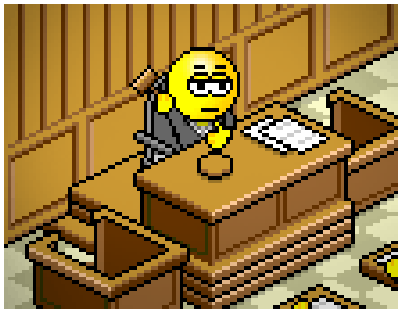
excellent everywhere !

Philipe Geluk, *Le chat pète le feu*, Casterman, 2018

The circuit computes, the software decides what to do

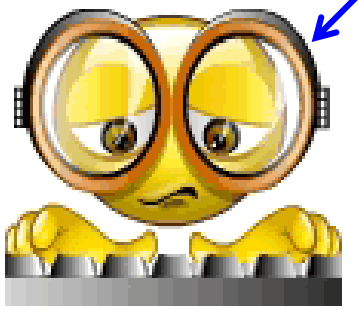
Informatics is so powerful
that it provokes true mental inversions
between the past and the present (future?)

From a computer, one only gets what one has put in



Homo bureaucratus

From the web, I get what the rest of the world has put in



Homo Internetus

Data analysis
Machine Learning

Some mental inversions

- Wired phone → smartphone

  Before : sigh, she is not home…

  Now : where are you ?

  Daddy, why did you put an anti-theft cable ?

- Mam', you told me that when you were my age you had no computer. Then, how did you connect to the Internet ?

- Daddy, the neighbor has an incredible computer ! You hit the keys, and there it prints ! A typewriter…

For kids, computers and smartphone
are no more than standard parts of the exiting nature,
just as the sea, the mountains, the sea, bikes, and cats

Maps

Find your way on a map :

20th century: 1. get the appropriate paper map − which scale?

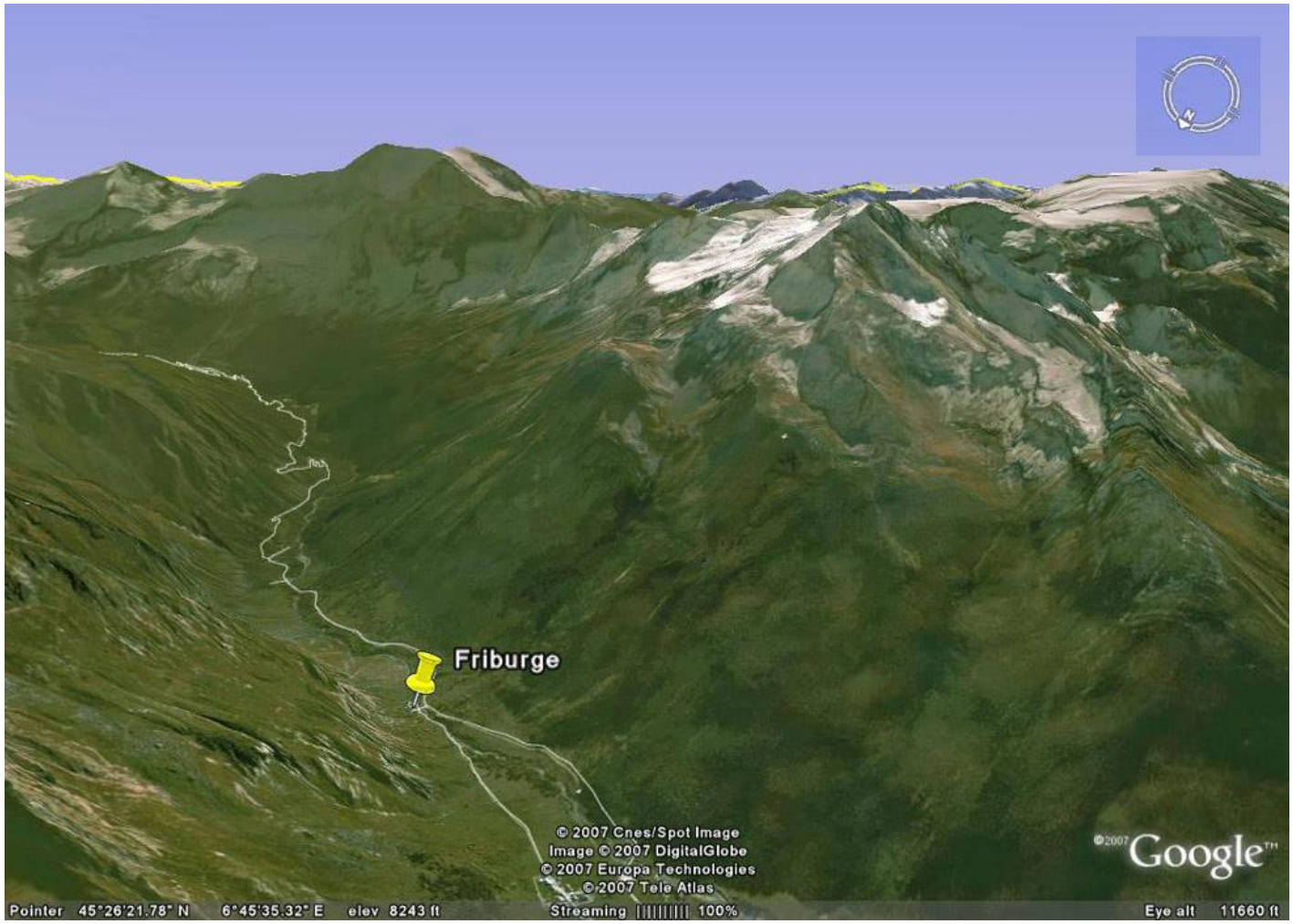
2. find where you are and where you want to go

3. find a way to get there

21th century : turn on the map of the world (all scales)
it tells you where you are
type the destination, it tells you how to get there

A map is an algorithmic device that visualises heterogeneous informations (roads, buidings, forests, geology, aerial photos, weather, annotations, etc.), in 2D or 3D, in a way carefully crafted to satisfy the user needs

3D algorithmic maps



Aerial photography taken by a virtual plane

The progressive digitization of our society

- Commerce, banking, payment on-line
- Reservations : trains, planes, theaters, movie theaters, hotels, …
- Cartography : localization, itineraries, agriculture, teledetection,..
- Culture : radio, TV, podcasts, videos, films, concerts,…
- Information : newspapers (!), blogs, social networks (?)
- Public services : informations, taxes, public data
- Good exchanges: used goods, car pooling,…
- Knowledge exchanges : cooking, reading, sewing, decoration
- …

Explosion of new private actors

Search engines

Social networks

Commerce

Travel

Transports

Music

Video, movies

Simple economic models

- To catch the added value of travels (resp. tranportation), is it essential to possess hotels (resp. taxis) ?

  No, what matters nost is to know who wants to go where and when, and to collect this data plus the users ids and advices!

  XXX.com's moto : *one for all, all for one, and my 18% !*

- Since music and video are pure information, why bothering by keeping physical supports ?

  Still true for ultimate quality, but this is also changing fast

  (but LP lovers remain respectable…)

… but with serious problems

- The invasion of advertisement
  - isn’it stupid to pay to get none ?
- The danger of overexposition to screens
  - aready true for TV – kids or parents problem?
- The dangers of immediate propagation of any info
  - fake news as fast as real news
- …

No hope to improve this situtation if not trying to understand its fundamental causes

USA, Asia : « We act first, Europe regulates next »

The importance of non-commercial actors

- Wikipedia, the huge encyclopedy
- Free software, developed in a collaborative way
  - Linux, NTP, programming languages, verification systems
- Internet Archive, the web backup (volontary)
  - 15 Petabytes, 330 10^9 pages, 2 10^6 books, 10^7 texts
- Software Heritage, the big memory of software
  - 4,5 10^9 source files, 83 10^6 projects
- Open and collaborative sciences
  - physics, astronomy, computer security

All based on algorithmic thinking
And building a huge world-wide culture !

A major mental inversion

By coupling Informatics and Physics,
we can do many things that are
inaccessible to Physics only
(It becomes the same for Biology and Medicine)

Photography, a perfect example

- 20th century : 1. take the picture
  2. when film is full, bring it to the lab
  3. the next day, get the prints and send them by *snail mail* (post office)
- 21st century : taken, sent, received!

Facebook receives 2 billion pictures per day

Digital photography

Siver halide: clic, its done → print or project

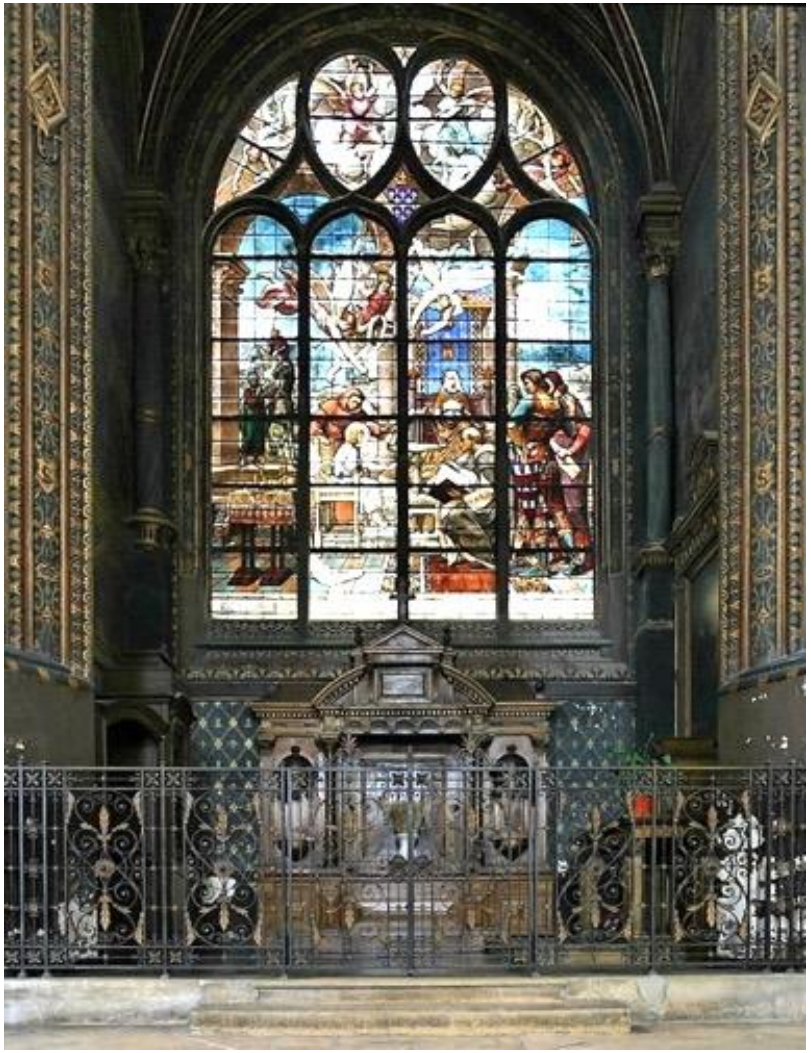
Digital : clic, it starts → algorithms !

Digital Photography

Automatic correction of optical distorsions

Algorithmic transformation of light : ~~Physics?~~

And with one more click (if you want it)



Doable with Physics, but difficult

algorithms helps shooting

Focus, exposition, faces and eyes detection, stabilization., etc.

Focus peaking

Source phototrend.fr

Now : joint algorithmic design of lenses and correction of their defaults

=> simpler and lighter lenses (cf. smartphones)

2019 : image fusion

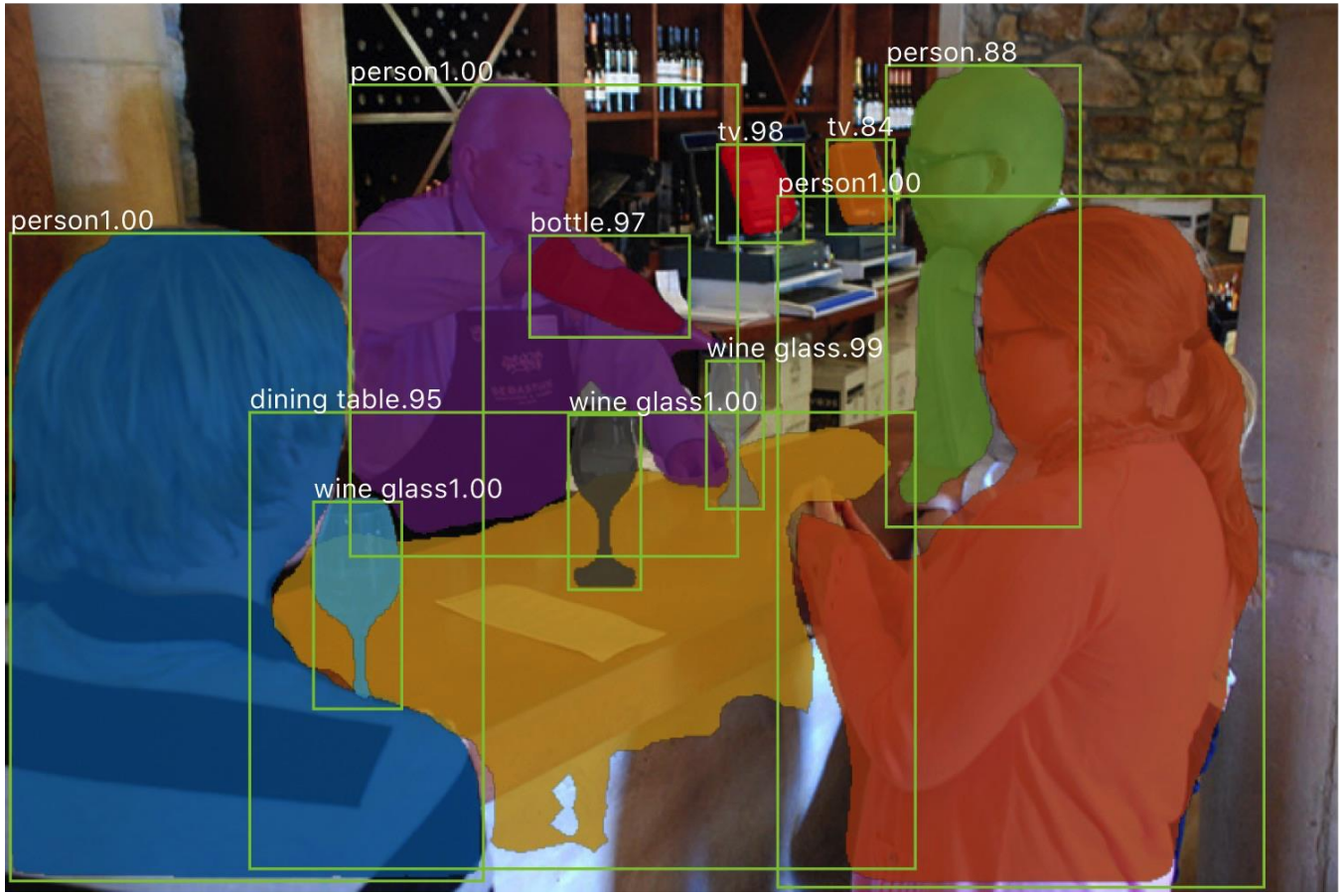
fusion of 6 successive images
with sh,ifted focus

final image

Impossible by physics only

This is why tiny phone cameras take good pictures!

Deep Learning-based object recognition



Mask-RCNN Results on COCO dataset, 2017 (Thanks to Yann Le Cun)

The same for tumors in X-ray, scanner et MRI images, themselves built algorithmically from physical measurements

All natural sciences get computerized

Modern high field clinical MRI scanner.

(3T Achieva, the product of Philips
at Best, the Netherlands.)

DNA Sequencer

By Flickr user jurvetson — Flickr, CC BY 2.0,
https://commons.wikimedia.org/w/index.php?curid=1552252

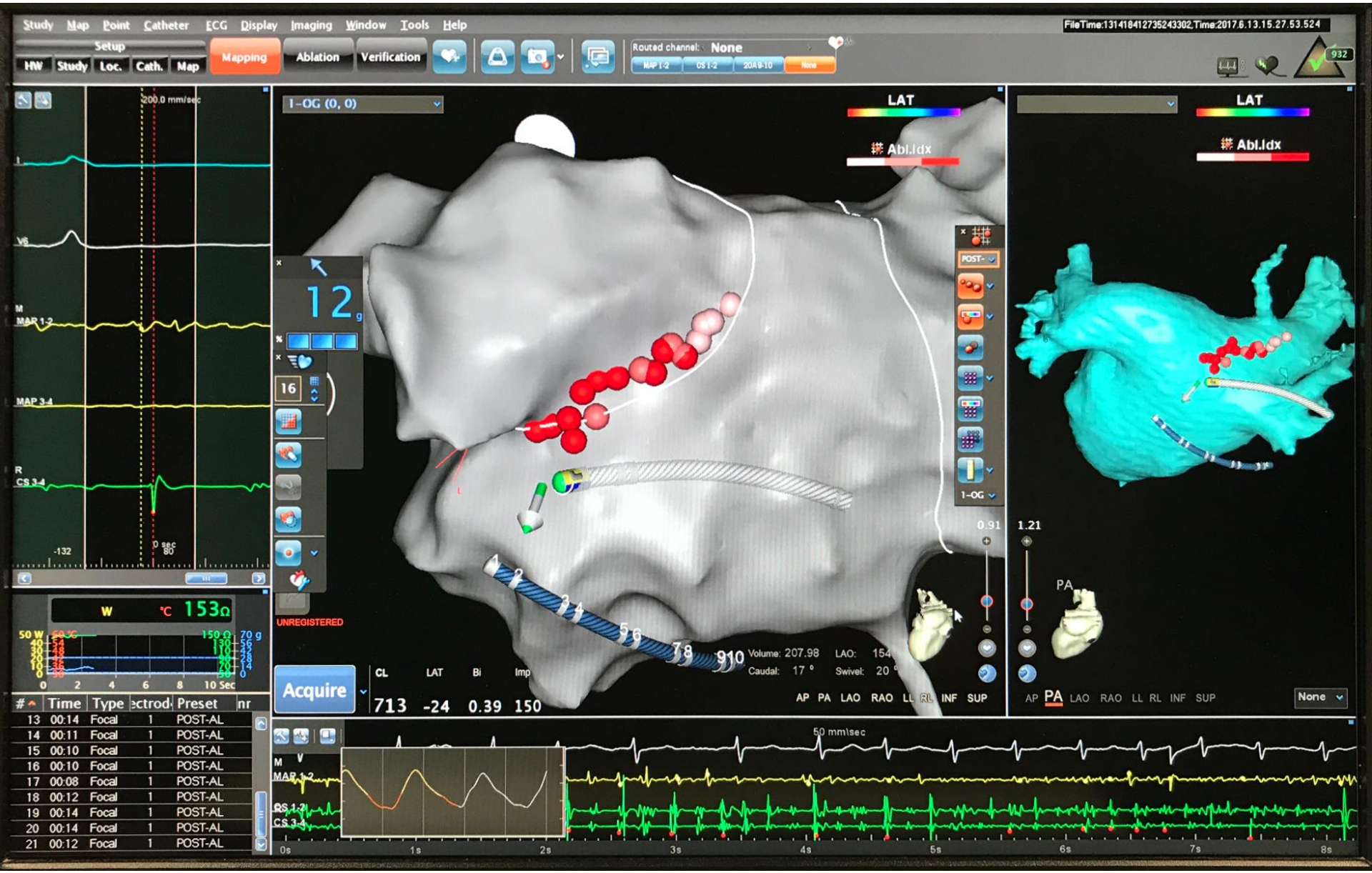
Curiosity (Mars)

VLT (Chile)

Interventional Radiology

Source F. Besse, Centre de Cardiologie du Nord

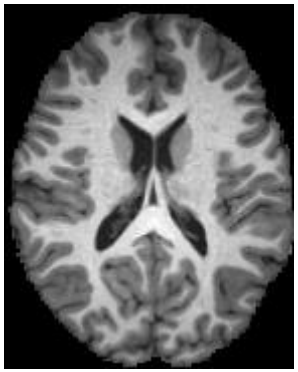
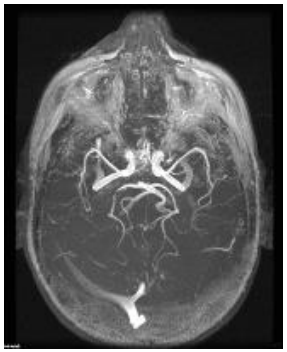
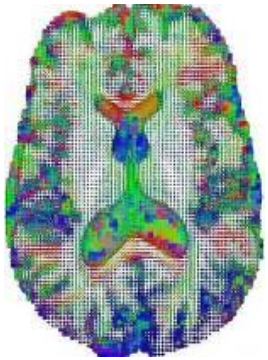
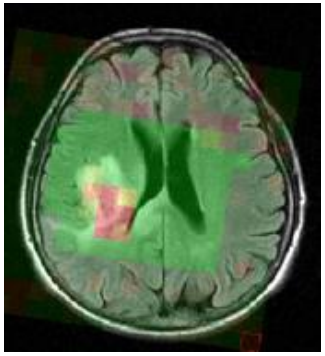
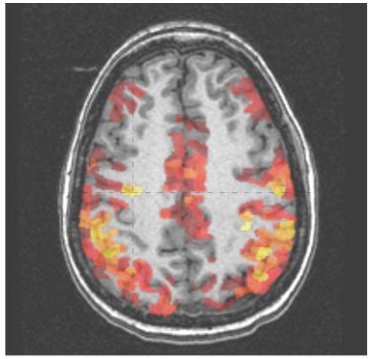
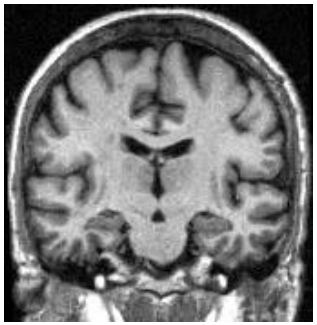
3D augmented reality

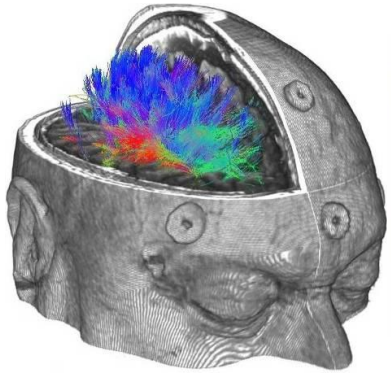
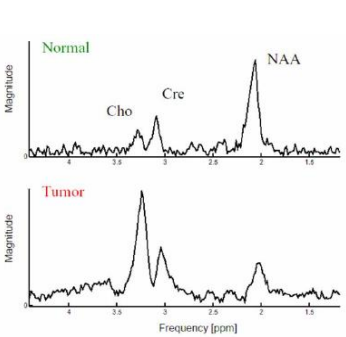


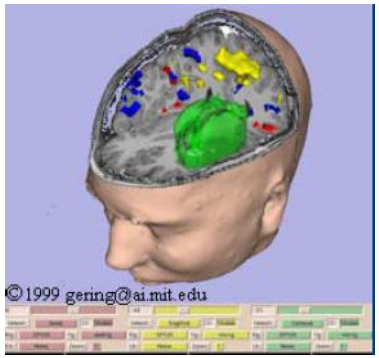
Source F. Besse, Centre de Cardiologie du Nord

3D-fusion of multiple imaging modalities

anatomy angio diffusion spectro functional

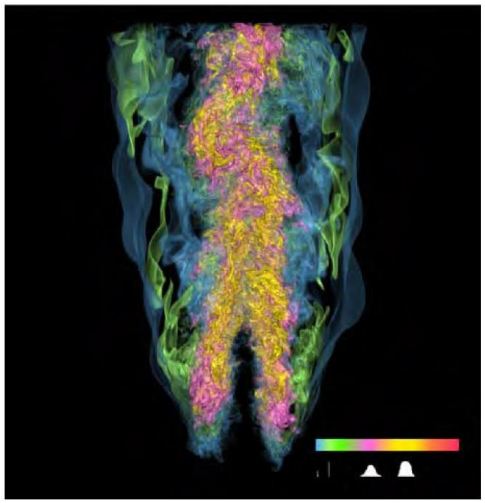





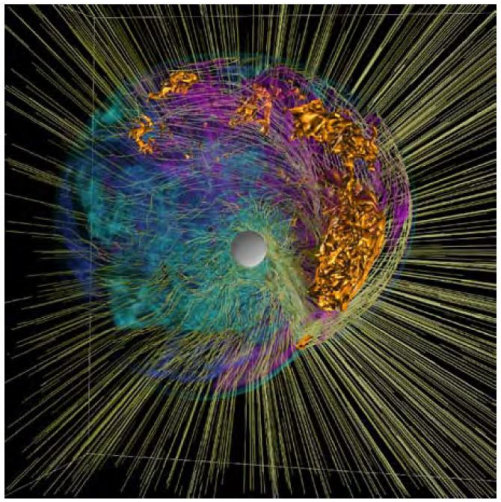
Le Bihan, Le cerveau de cristal, 2013

Infeasible by Physics only

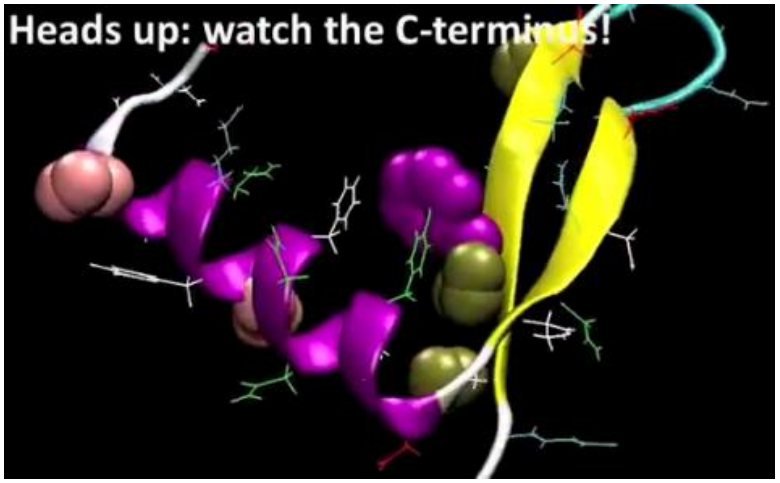
Digital simulation and modeling



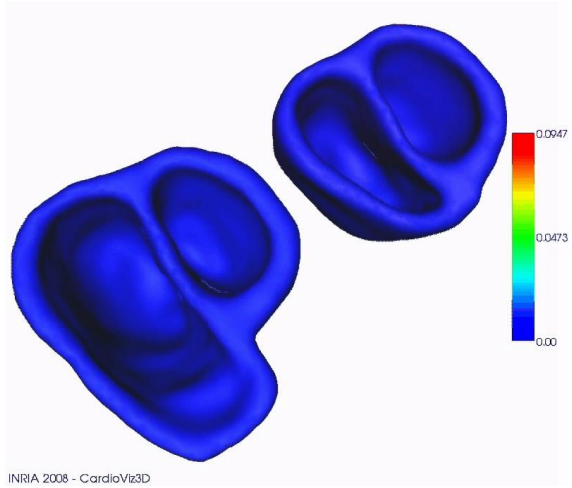
Ariane 5



Supernova



protein folding (foldingathome.org)



Surgery preparation

What is simulation really doing?

- It replaces matter, energy and waves by pure information
- It replaces the equational laws of nature by algorithmic laws
- It replaces physical time by computation time
  - fast simulation of slow phenomena (astronomy)
  - slow simulation of fast phenomena (physics, biology)
  - real-time simulation (airplane pilots or surgeons training)

Matter, energy and waves are needed
to run the simulations, but these are universal,
without any relation to the simulated phenomenon

Limit: You won't find oil by drilling the map…

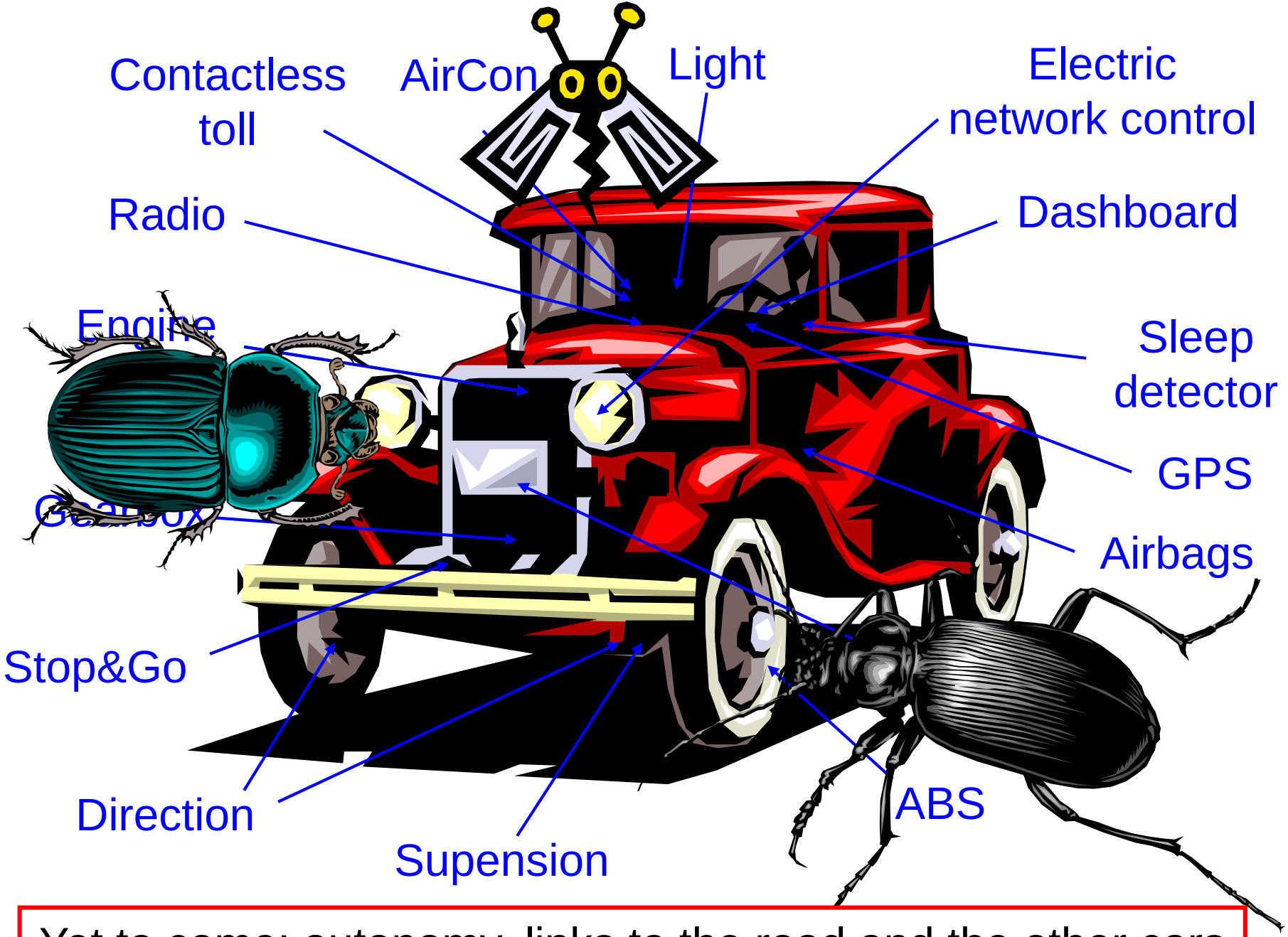
Algorithmic modeling vs. Data analysis

- Modeling
  - by mathematical and algorithmic laws, ex. the heart avove
  - leads to explanation, simulation, and prediction
  - but models are hard to build and must be validated by experiments
- Bigdata analysis
  - Deep learning : big success, but when and why it works is yet unknown and the results are not yet explainable – huge research field in mathematics !
  - correlation is neither explanation nor causality
  - risk : reinforcing existing biases

A major goal: coupling modeling and data crunching

Towars the Internet of Objects (IoT)

Massive infestation par Systems on Chips & software
Not only smartphones, wacthes and personal assistants
But mostly 20th century everday's standard objects!



Yet to come: autonomy, links to the road and the other cars

Toyota Camry Engine Control: 89 casualties

There are a large number of functions that are overly complex. By the standard industry metrics some of them are untestable, meaning that it is so complicated a recipe that there is no way to develop a reliable test suite or test methodology to test all the possible things that can happen in it. Some of them are even so complex that they are what is called unmaintainable, which means that if you go in to fix a bug or to make a change, you're likely to create a new bug in the process. Just because your car has the latest version of the firmware -- that is what we call embedded software -- doesn't mean it is safer necessarily than the older one….And that conclusion is that the failsafes are inadequate. The failsafes that they have contain defects or gaps. But on the whole, the safety architecture is a house of cards. It is possible for a large percentage of the failsafes to be disabled at the same time that the throttle control is lost.

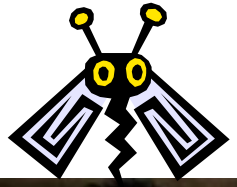
Michael Barr, American specialist and justice expert
750+ pages report, secret (but enough info on the web)

Remotely controlling Jeep Cherokee

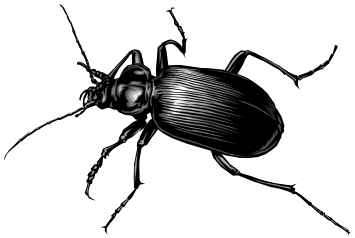
https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/

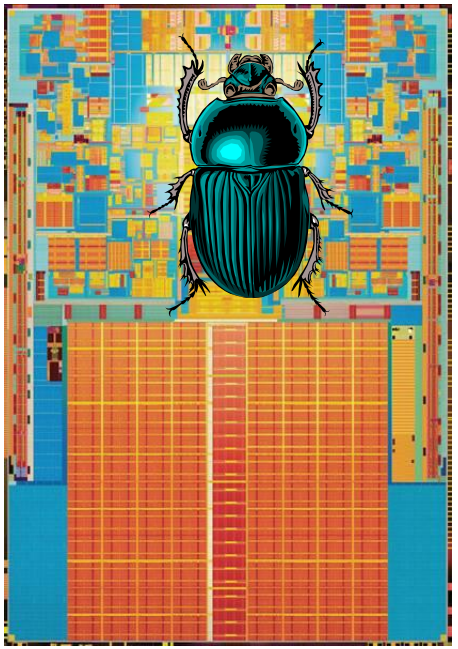
Their code is an automaker's nightmare: software that lets hackers send commands through the Jeep’s entertainment system to its dashboard functions, steering, brakes, and transmission, all from a laptop that may be across the country.

Beware of the bugs !



Mastering ?

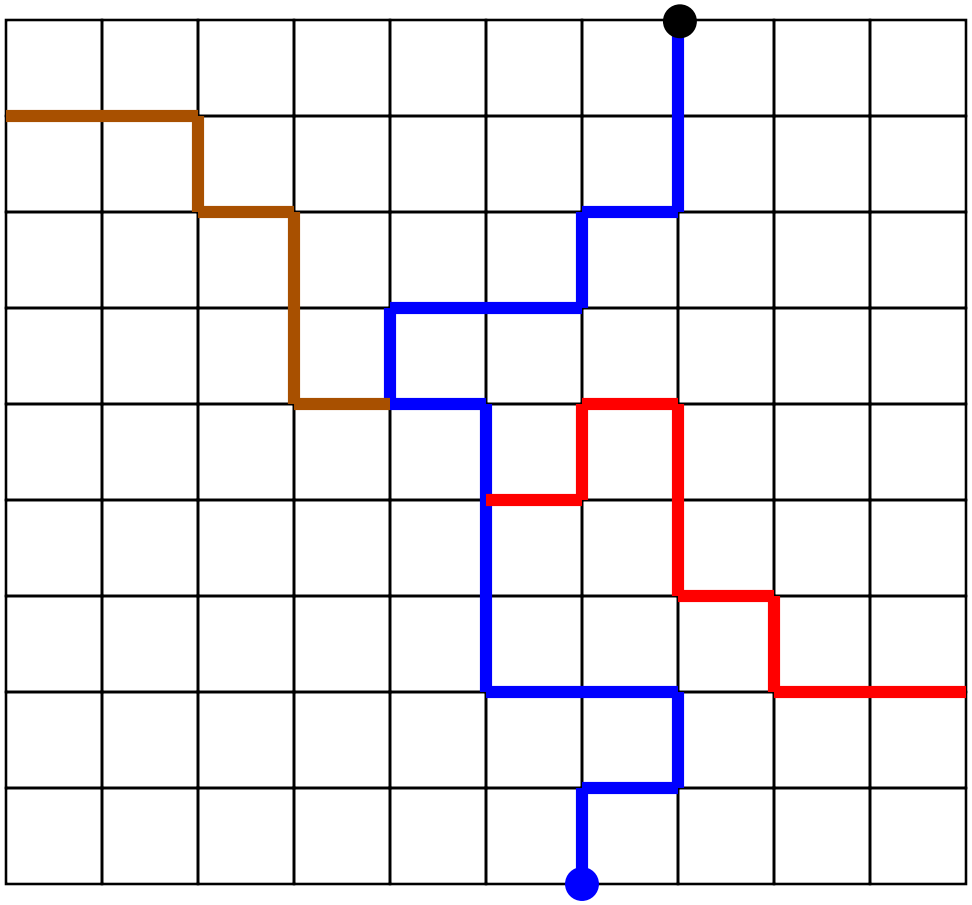


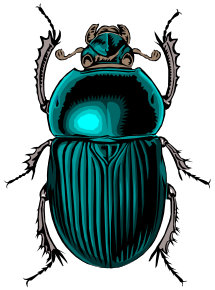


Intuitive
Rigorous
Slow

100% Stupid
100% Exact
Ultra-fast

The widest gap possible !





SRLLSRSSLRRSLRLS

SRLLSRSRLRRSLRLS

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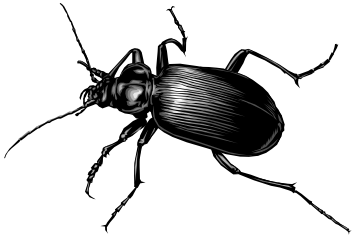
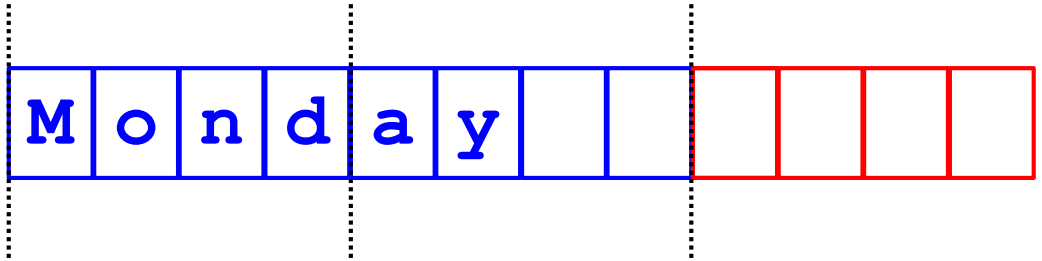
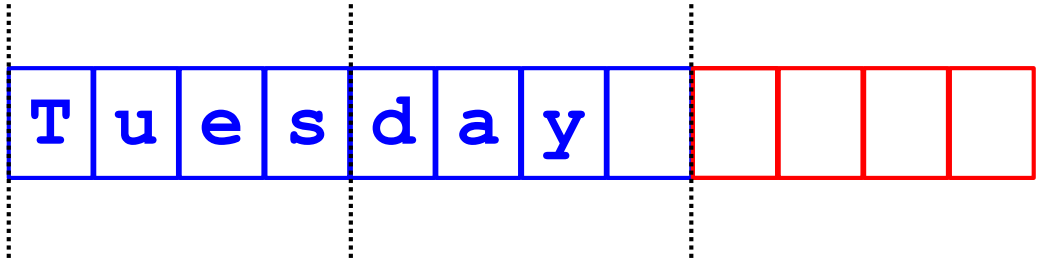
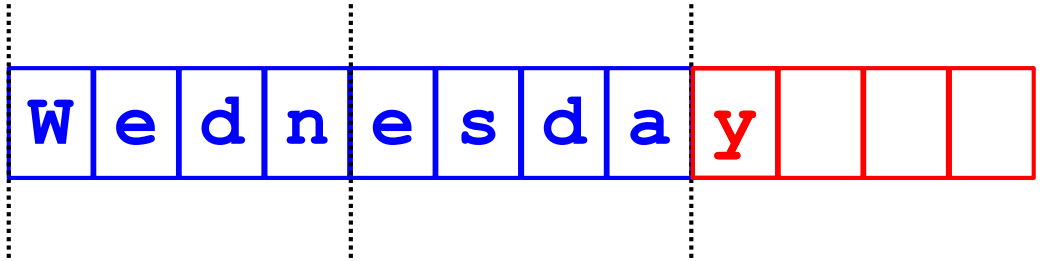


Memory corruption, a major danger

A program that doesn’t work one day per week



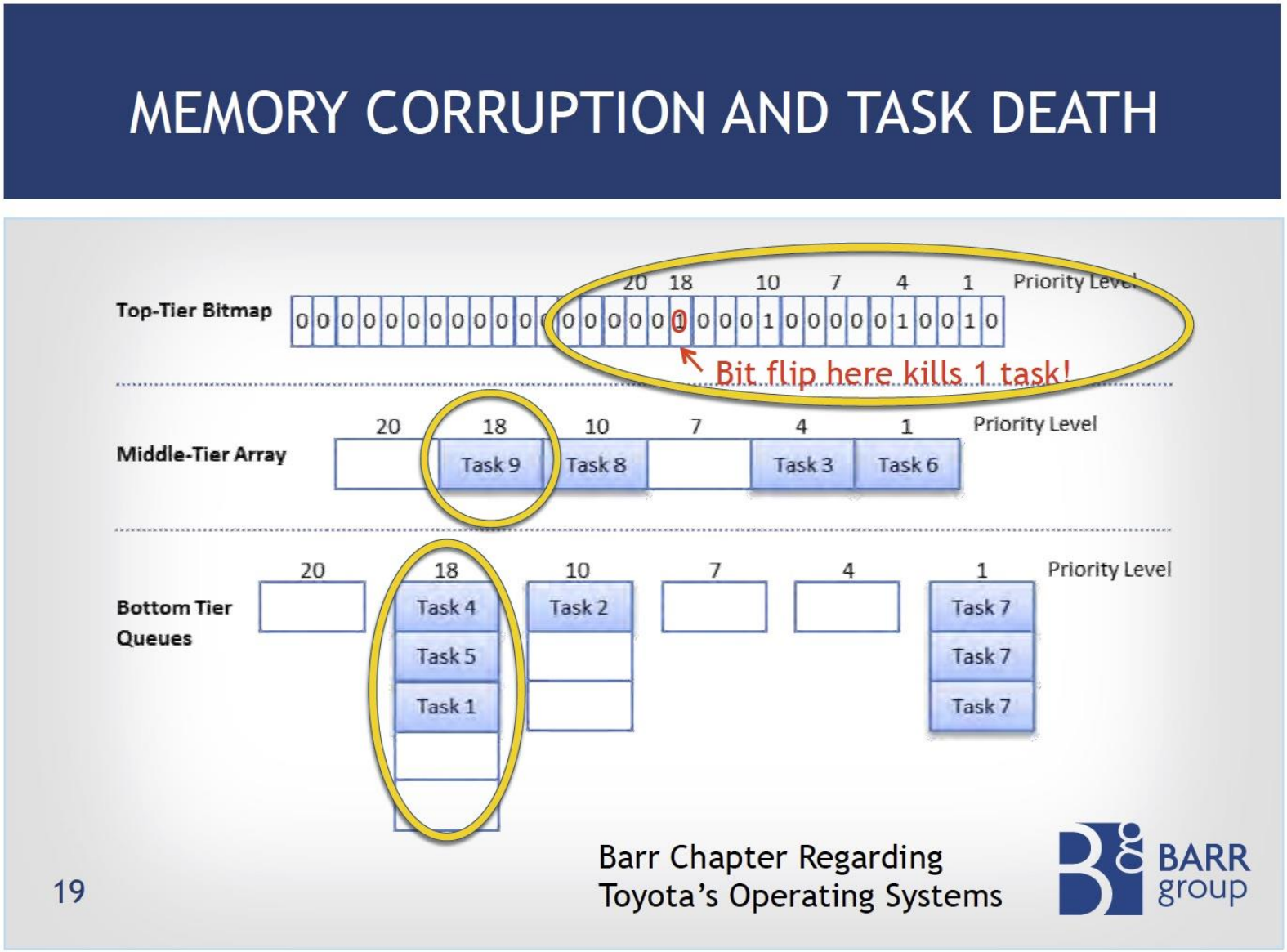




Conclusion

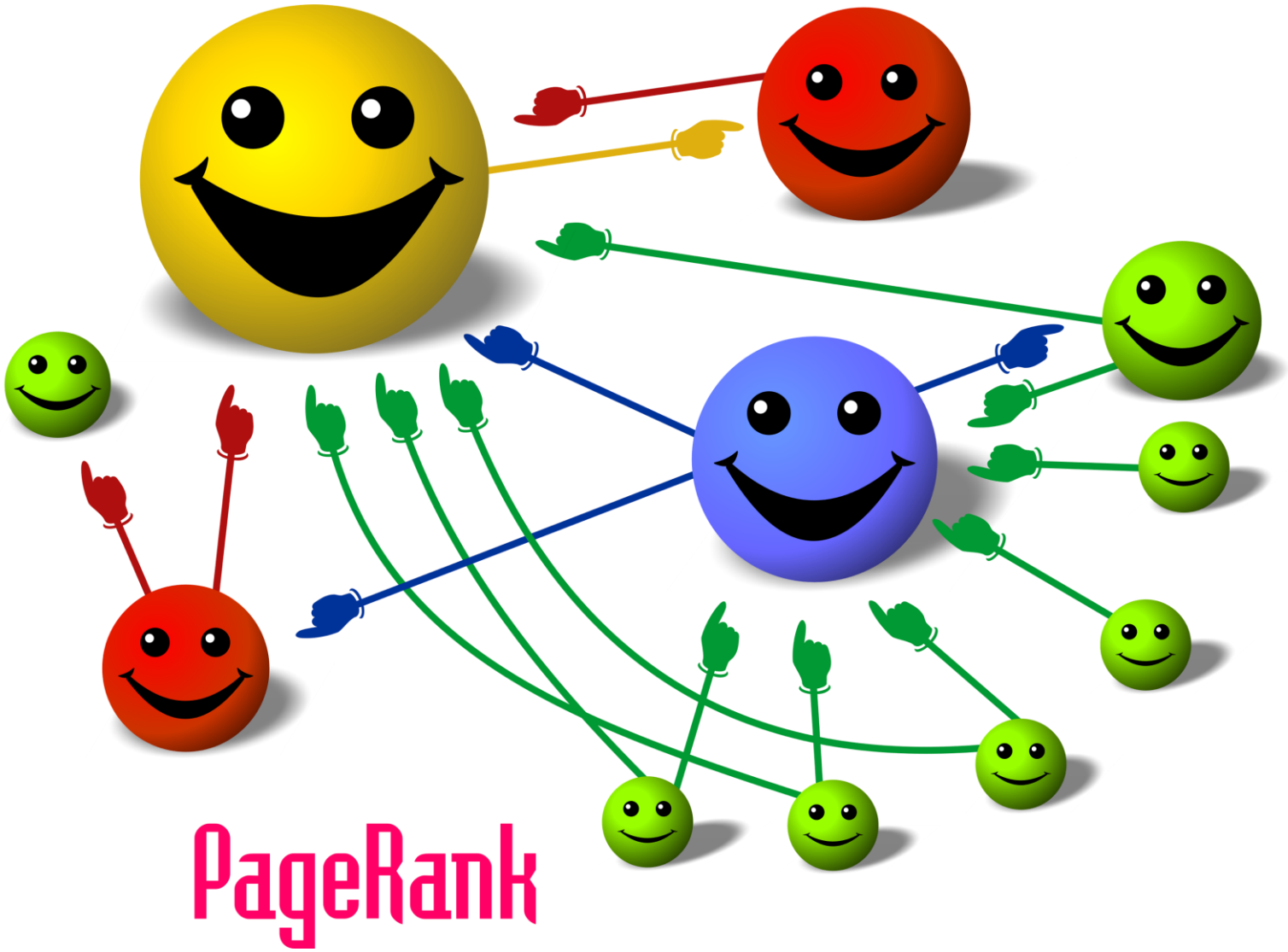
- Informatics is hyperpowerful : not a tool, but a new way of thinking and acting
- When well-done, it is extremely useful
- Otherwise, it can lead to disasters
- The ways of failing are well-known
- The ways of succeeding also, but they are much more difficult
- The big system will consolidate, probably with many more stunning novelties
- Safety and security are hard to get to an will limit the expansion, in particular for the IoT (currently very weak)
- A major problem remains (at least in Europe) : the persistent ignorance of the public, politicians, CEOs, etc.

Mort d'une tâche de contrôle… et du conducteur

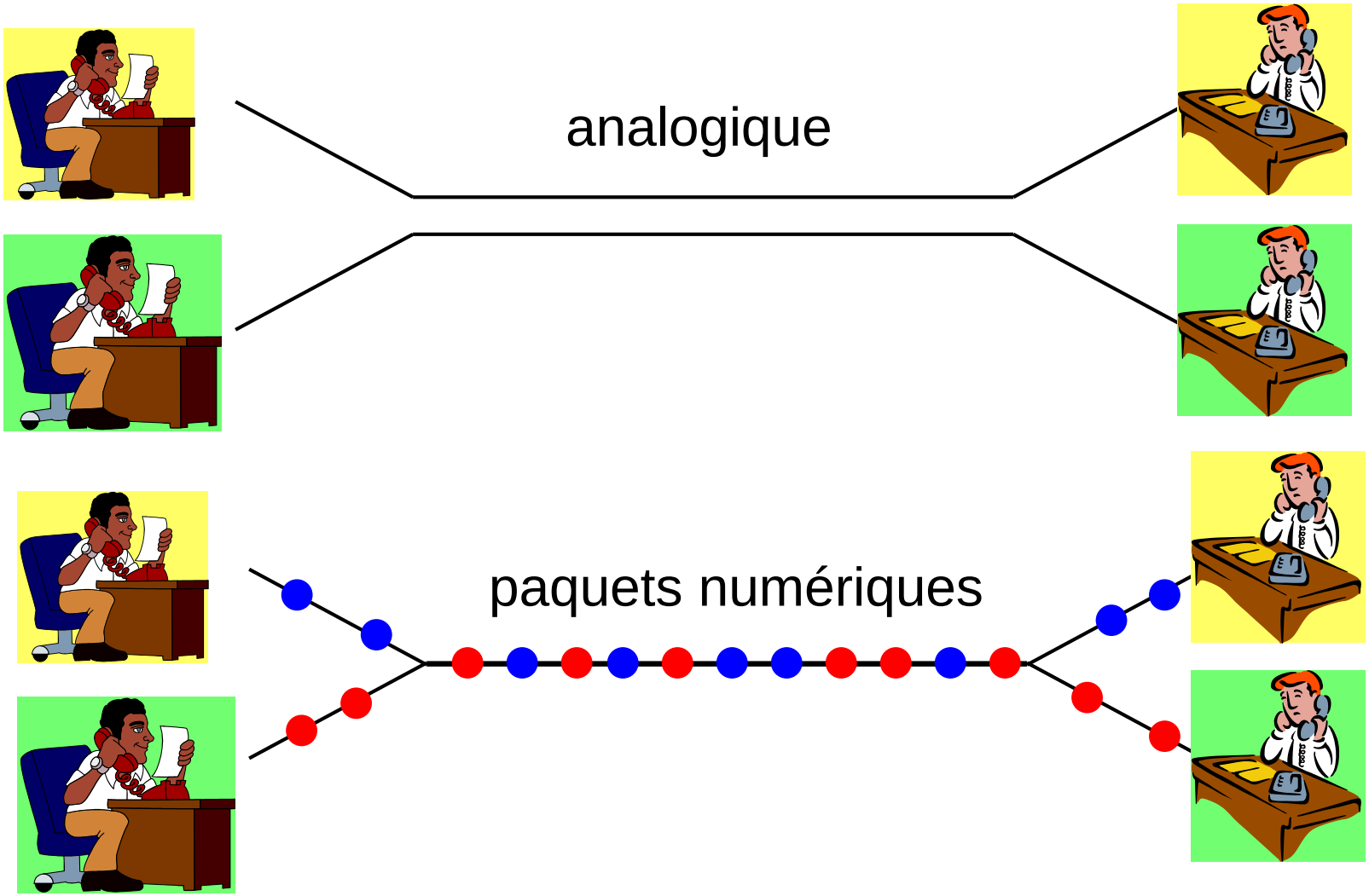


http://www.safetyresearch.net/Library/BarrSlides_FINAL_SCRUBBED.pdf

Moteurs de recherche : popularité des pages

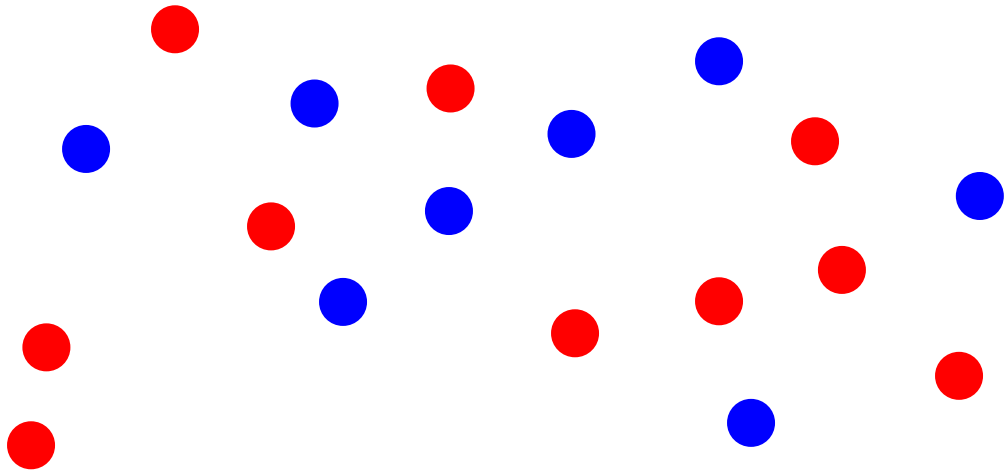


La communication, du 20e au 21e siècle



La communication, du 20e au 21e siècle

analogique



sans fil