On the Nature of Computing

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March16, 2017

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Motivation – The Evolution of Computing

At first, computing was considered rather as the applied technology of math, electrical engineering or science, depending on the observer.

Over the years,

- computing resisted absorption back into the fields of its roots and developed an impressive body of knowledge including : Algorithms, Networks, Operating Systems, Data bases, Compilers, Verification Theory and Semantics, Modeling and Simulation.

- the name of the field has changed several times to keep up with the flux: *Automatic Computation* (in the 40s) , *Information Processing* (in the 50s), *Computer Science* in the U.S. and *Informatics* in Europe (in the 60s), *Computing* (in the 90's)

Today,

- *"Computing is no more about computers than astronomy is about telescopes." (E. Dijksrta)*
- Computing is a great domain of knowledge dealing with the study of Information processing - both what can be computed and how to compute it.

Motivation

- There is currently a lack of recognition of computing as a discipline:
  - does not enjoy the same prestige as natural sciences and mathematics
  - secondary status in K-12 teaching curricula in most countries

- Physics (physicists) have dominated scientific thought until the end of the 20th century

- For decades the importance of Computing and Information have been underestimated or overlooked by a strongly reductionist view of the world: <u>understanding the nature of complex things by reducing them to the interactions of their parts, or to simpler more fundamental things.</u>

- *“My task is to explain elephants and the world of complex things, in terms of the simple things that physicists either understand, or are working on”*
- *“The capacity to do word-processing is an emergent property of computers”*
- *“Brain could exist outside body”*

Motivation – Some Important Questions

What is Computing?

The discipline of computing is the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application. The fundamental question underlying all computing is "What can be (efficiently) automated?“ (ACM 1989)

- Information and knowledge
- Computation - properties and limitations
- Is Computing a New Domain of Knowledge - Science, Engineering or both ?
- How is it related to basic disciplines such as Mathematics, Physics, Biology

Linking Physicality and Computation

- Commonalities between physical and computational processes
- Main differences and limitations
- Physical Computers – Digital Physics

Linking Artificial and Intelligence

- The concept of intelligence
- Commonalities and differences?
- Overcoming current limitations

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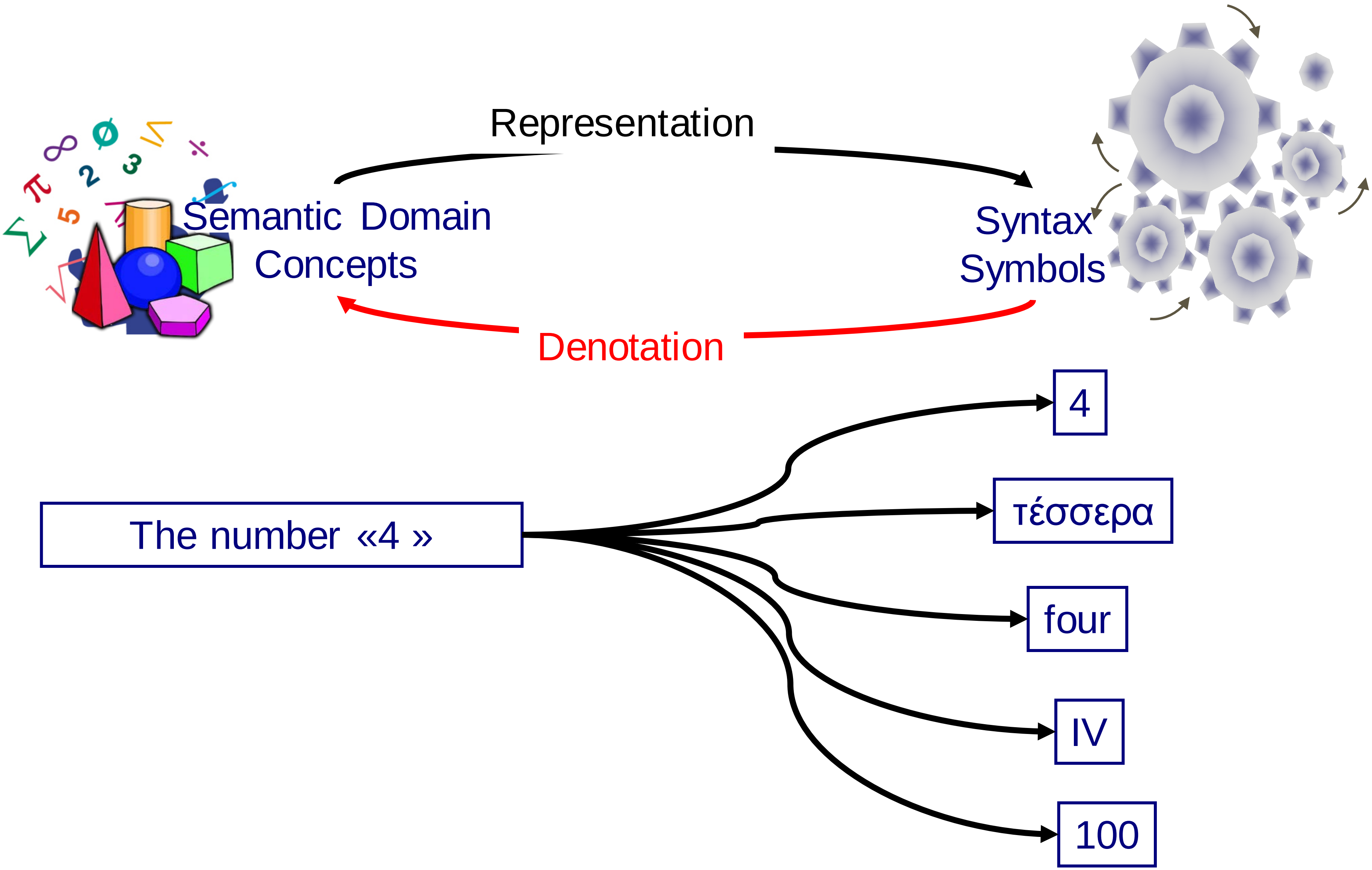
- What is Information
- What is Computing
- Domains of Knowledge
- Linking Physicality and Computation
- Linking Artificial and Natural Intelligence
- Discussion

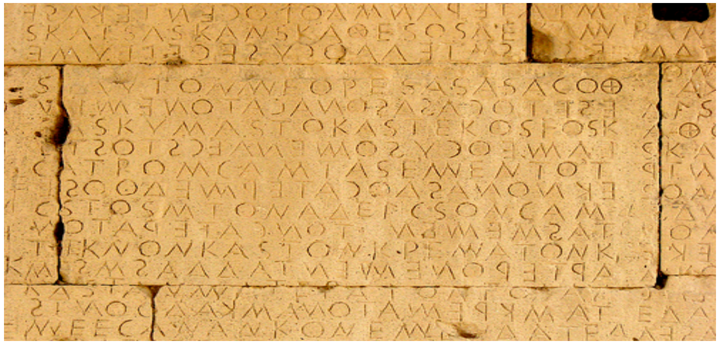
What is Information?

Information is a relationship between the syntax and the semantic domain of a given language



What is Information?–Information is in the Mind of the Beholder

No information



Information for a Hellenist

$$\oint \mathbf{E}\cdot d\mathbf{A} = \frac{q_{enc}}{\varepsilon_0}$$

$$\oint \mathbf{B}\cdot d\mathbf{A} = 0$$

$$\oint \mathbf{E}\cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \mathbf{B}\cdot d\mathbf{s} = \mu_0\varepsilon_0\frac{d\Phi_E}{dt} + \mu_0 i_{enc}$$

Information for a Physicist

Information

Information

- is an entity different from matter/energy
- is non-physical although it needs media for its representation.
- is not subject to physical space-time constraints
- is created by minds, <u>not</u> by machines

What is Information – Syntactic Information

Syntactic information is measured as the quantity of symbols, pixels, bits needed for a representation

According to Shannon's Theory, it

- characterizes the content of a message, not its meaning
- is *nlog(b)*, the number of yes/no questions one would have asked to completely resolve ambiguity for a word of length *n* on an alphabet of *b* symbols

g	o	o	d	m	o	r	n	i	n	g
g	d	r	d	o	m	o	n	o	g	i

Syntactic information theory e.g. Shannon, Kolmogorov

- finds application in data compression, channel coding, information representation techniques
- ignores meaning - It is like saying that one kilo of gold and one kilo of lead are equivalent!

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What is Computing – Science vs. Domain of Knowledge

Science is "*a branch of study concerned with the observation and classification of facts, especially with the establishment and quantitative formulation of verifiable general laws.*" (Webster dictionary)

Standard definitions focus on the discovery of facts and laws

- exclude Computing and many other disciplines such as Mathematics, Social Sciences
- overlook the fact that engineering is (or should be) grounded on rigorous methods involving the application of specific knowledge and its ultimate experimental validation

To understand the nature of computing, the most pertinent concept is that of <u>domain of knowledge</u>.

"Knowledge is truthful information that embedded into the right network of conceptual interrelations can be used to <u>understand a subject</u> or <u>solve a problem</u>."

- Scientific theories, but also Mathematics, Engineering, Social Sciences, Medicine, Cooking are domains of knowledge

What is Computing – Knowledge

- A priori knowledge is independent of experience e.g. Mathematics, Logic, Theory of Computing.
- A posteriori knowledge is dependent on experience or empirical evidence e.g. Natural Sciences, Engineering, Economics, Cooking.
  A posteriori knowledge comes in degrees – its validity may differ in testability, degree of abstraction and the way in which it is developed.

- Considering domains of knowledge avoids sterile discussions focusing on the scientific or non scientific nature of disciplines

.

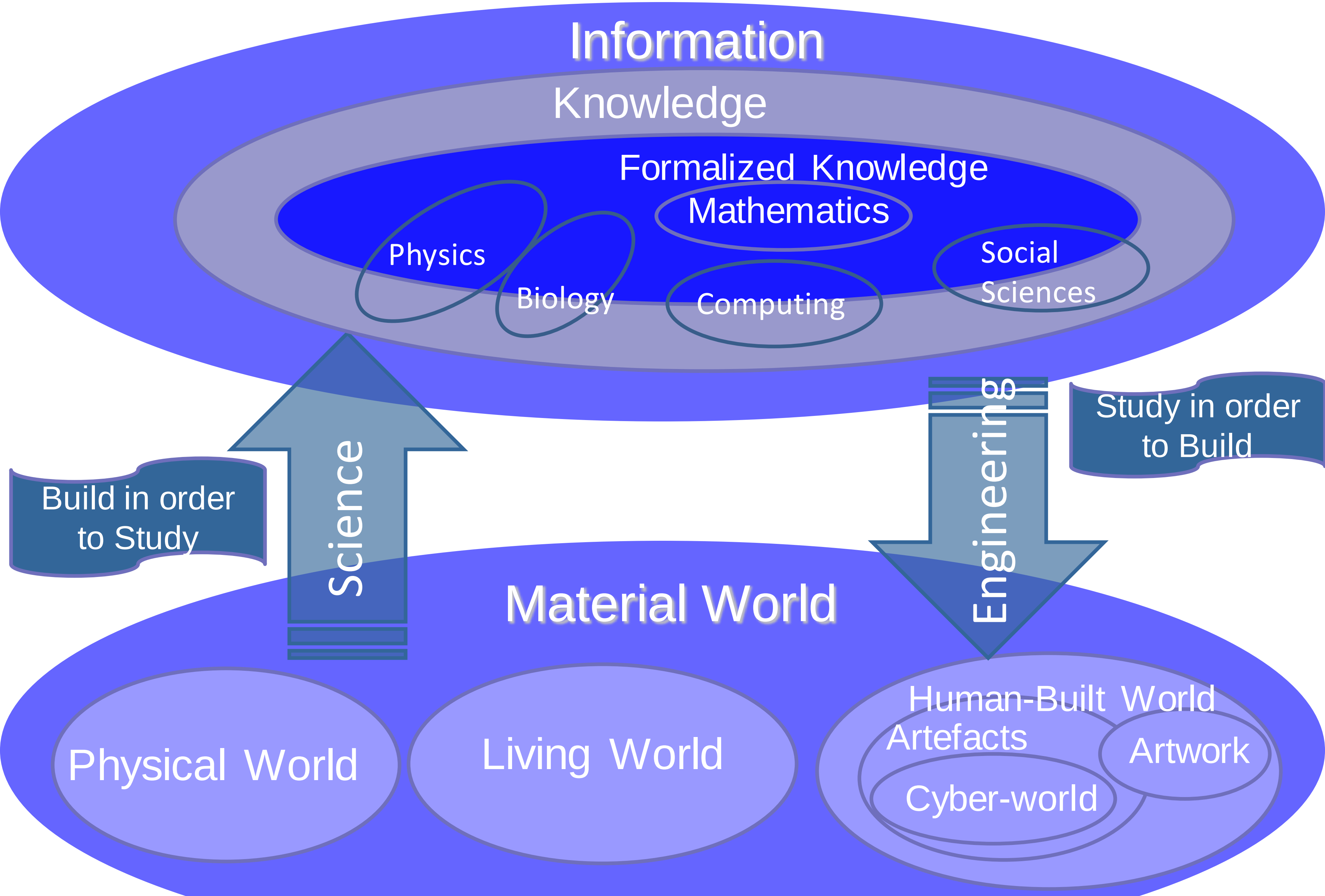
- The starting point in the pursuit of knowledge need not be observation.
  - The Theory of Relativity was motivated by a series of thought experiments rather than direct observation.
  - The development of computing as a discipline started from prior knowledge about computation based on mathematics and logic.
  - If computing had emerged through the study of natural computational processes e.g. quantum computing, neural computing, would it have been deemed as “true” science?

What is Computing – Science vs. Engineering

Knowledge acquisition and development combine Science and Engineering as well as a priori Knowledge including Mathematics, Logic and Linguistics.

- Science
  - is mainly motivated by the need for understanding the physical world.
  - privileges the analytic approach by connecting phenomena through abstractions to the world of concepts and mathematics.
- Engineering
  - is motivated by the need to master and adapt the physical world.
  - is predominantly synthetic and applies knowledge in order to build trustworthy and optimized artefacts.
- Interaction and cross-fertilization between Science and Engineering is key to the progress of scientific knowledge as shown by numerous examples.
  - A great deal of the foundations of physics and mathematics has been laid by engineers.
  - Today, more than ever, Science and Engineering are involved in an accelerating virtuous cycle of mutual advancement

What is Computing – Science vs. Engineering



What is Computing

- Computing is a domain of knowledge distinct from Physics and Biology. None of those domains is fundamentally concerned with the very nature of information processes and their transformations.

Computing is both a science and associated with engineering disciplines

- Science: study of *information processes* both artificial and natural including the representation, transformation, and transmission of information Phenomena can be interpreted as information process
  - DNA "translation" is an information process;
  - A particle in a uniform gravitational field computes a parabola.

- Engineering: *design* of computing systems as the process leading from requirements to correct artefacts. As such, it studies all aspects from specification to implementation, including tradeoffs between physical resources and performance

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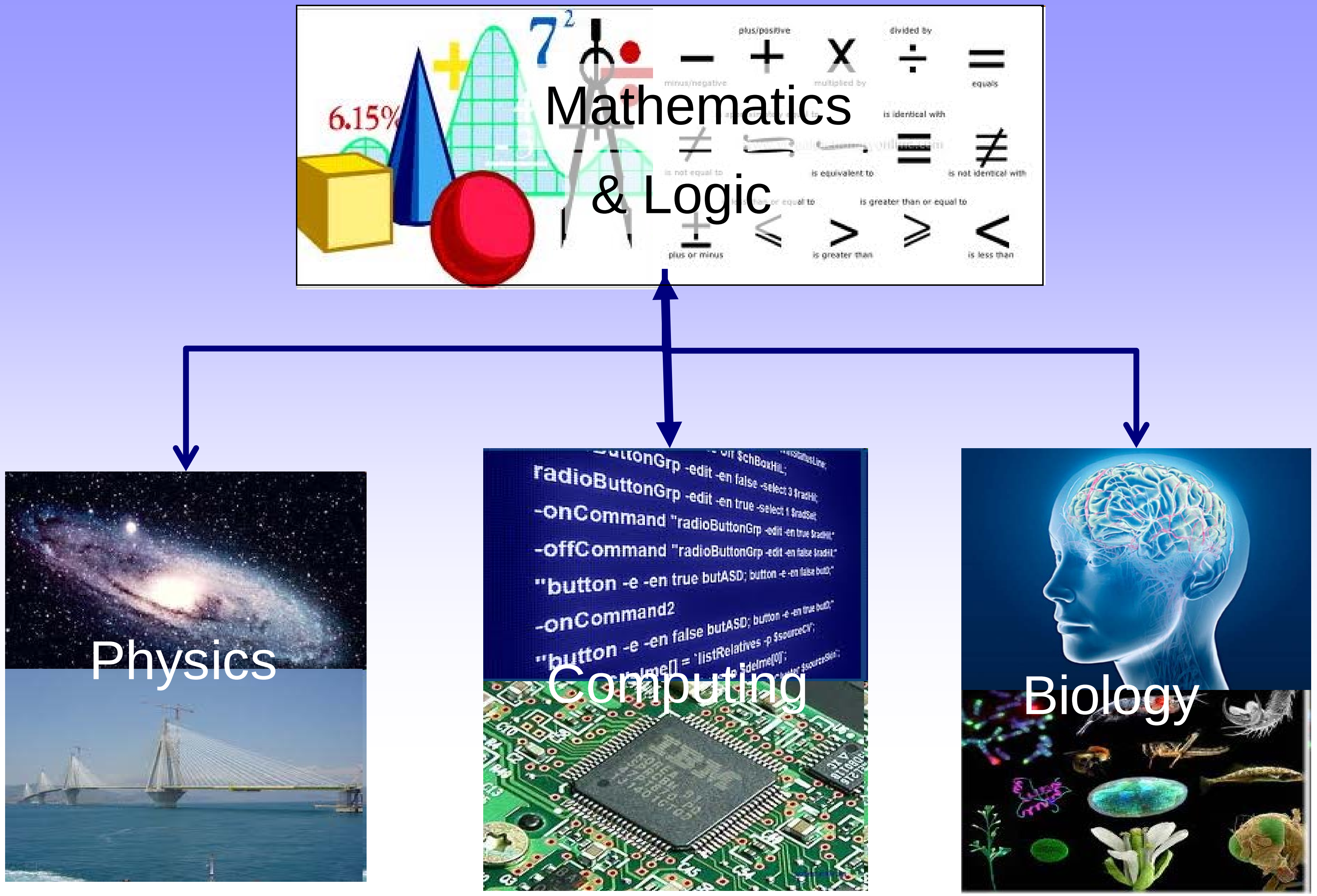
Fundamental Domains of Knowledge



Domains of Knowledge – Abstraction Hierarchies

- To cope with problems of scale we study the physical world at different levels of abstraction. Physical phenomena are studied in scales
  - From 10^{-35}m, the Planck length
  - To 10^{25} m, size of the observed universe

- Abstraction is a holistic way to break complexity by revealing relevant features of the observed reality

  "Being abstract is something profoundly different from being vague … The purpose of abstraction is not to be vague, but to create a new semantic level in which one can be absolutely precise" E.W. Dijsktra

- Abstraction hierarchies are a methodological simplification used to determine successive levels of granularity of observation at which relevant system properties can be studied.
  - The models of the hierarchy should be related through some adequate abstraction relation.
  - The abstraction relation should link the laws and properties at one layer to laws and properties of the upper layers.

Domains of Knowledge – Abstraction Hierarchies

The Physical Hierarchy	The Computing Hierarchy	The Bio-Hierarchy
The Universe	The Cyber-world	Ecosystem
Galaxy	Networked System	Organism
Solar System	Reactive System	Organ
Electro-mechanical System	Virtual Machine	Tissue
Crystals-Fluids-Gases	Instruction Set Architecture	Cell
Molecules	Integrated Circuit	Protein and RNA networks
Atoms	Logical Gate	Protein and RNA
Particles	Transistor	Genes

We need theory, methods and tools for climbing up-and-down abstraction hierarchies

Domains of Knowledge – Modularity

- Modularity: Complex systems can be built from a relatively small number of types of components (bricks, atomic elements) and glue (mortar) that can be considered as a composition operator.

  Basic assumptions:

  1. Any system of the considered domain can be built as the composition of a finite set of predefined types of components;
  2. The behavior of each component can be studied separately.
  3. The behavior of a composite component can be inferred by composing the behavior of its constituents.
  4. The behavior of the components is not altered or changes in a predictable manner when they are composed

     This assumption is valid in classical Physics but fails for bio-systems, linguistic systems, etc.

- A specific problem for computing systems is *component heterogeneity* - This is a key limitation to mastering component-based construction of software

Domains of Knowledge – Emergence of Properties

- Is it possible to unify knowledge in a domain using a compositionality principle: knowing the properties of components at one layer, is it possible to infer global properties of composite components at a higher level?
  - *properties of water from properties of the atoms of hydrogen and oxygen and rules for their composition?*
  - *properties of an application software from behavioral properties of the components of the HW platform on which it is running*?
  - *properties of mental processes from behavioral properties of components of the brain*

These questions are of the same nature, and will probably find no answers!

"*<u>The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe</u>. In fact, the more the elementary particle physicists tell us about the nature of the fundamental laws, the less relevance they seem to have to the very real problems of the rest of science, much less to those of society.*"

"More is Different", Philip Anderson, Science 1972.

Domains of Knowledge – Predictability

Laws of Physics

- are just models that do not disagree with experiment and observation.
  By their nature they are different from laws promulgated by humans. Nature is not liable for not respecting its "laws".
- are the result of a (logically arbitrary) generalization by *natural induction*: from a finite sample of observations we make an absolutely arbitrary generalization that should not contradict experiment.

<ins>Bertrand Russell's Inductivist Turkey</ins>: A turkey, in a turkey farm, decides to shape its vision of the world scientifically well founded.

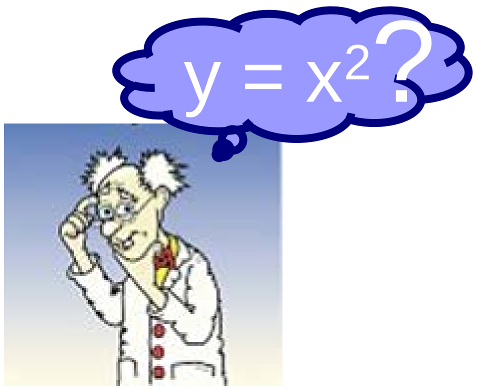
1. He found that, on his first morning, he was fed at 9 a.m.
2. He waited until he collected a large number of observations that he was fed at 9 a.m. under a wide range of circumstances: on Wednesdays, on Thursdays, on cold days, on warm days.
3. Finally, he was satisfied that he had collected a sufficient number of observation statements to inductively infer that "**I am always fed at 9 a.m.**".
4. However on the morning of Christmas eve he was not fed but instead had his throat cut.

Domains of Knowledge – Predictability

Laws of Physics

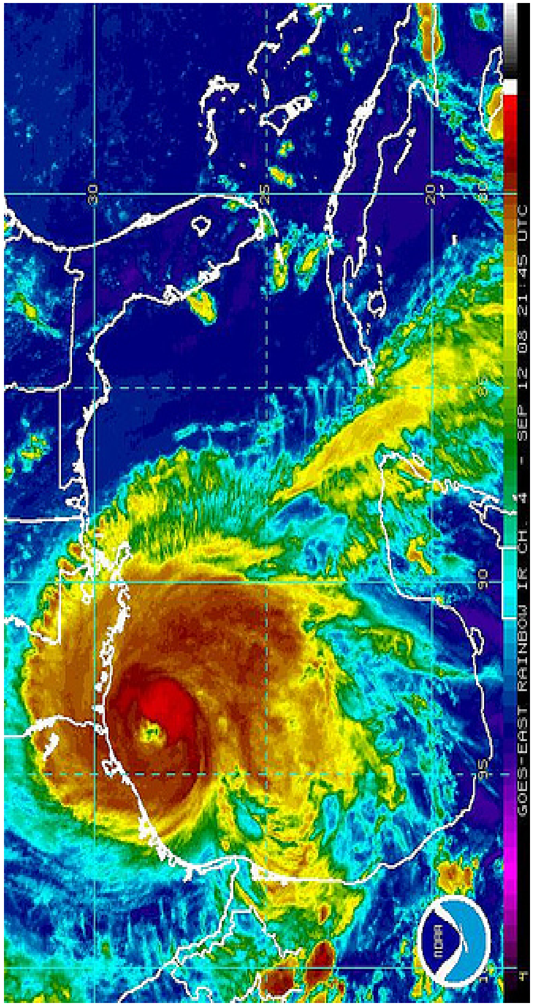
- are designed by human minds – they are rather “invented” than “discovered”.
- their invention depends on the available toolbox of concepts and languages e.g. Thales who can understand and formalize only laws of proportionality, cannot understand a phenomenon involving exponential growth of some physical quantity
- depend on our ability to observe the reality, here and now - the idea that the same laws hold everywhere and forever is completely arbitrary.

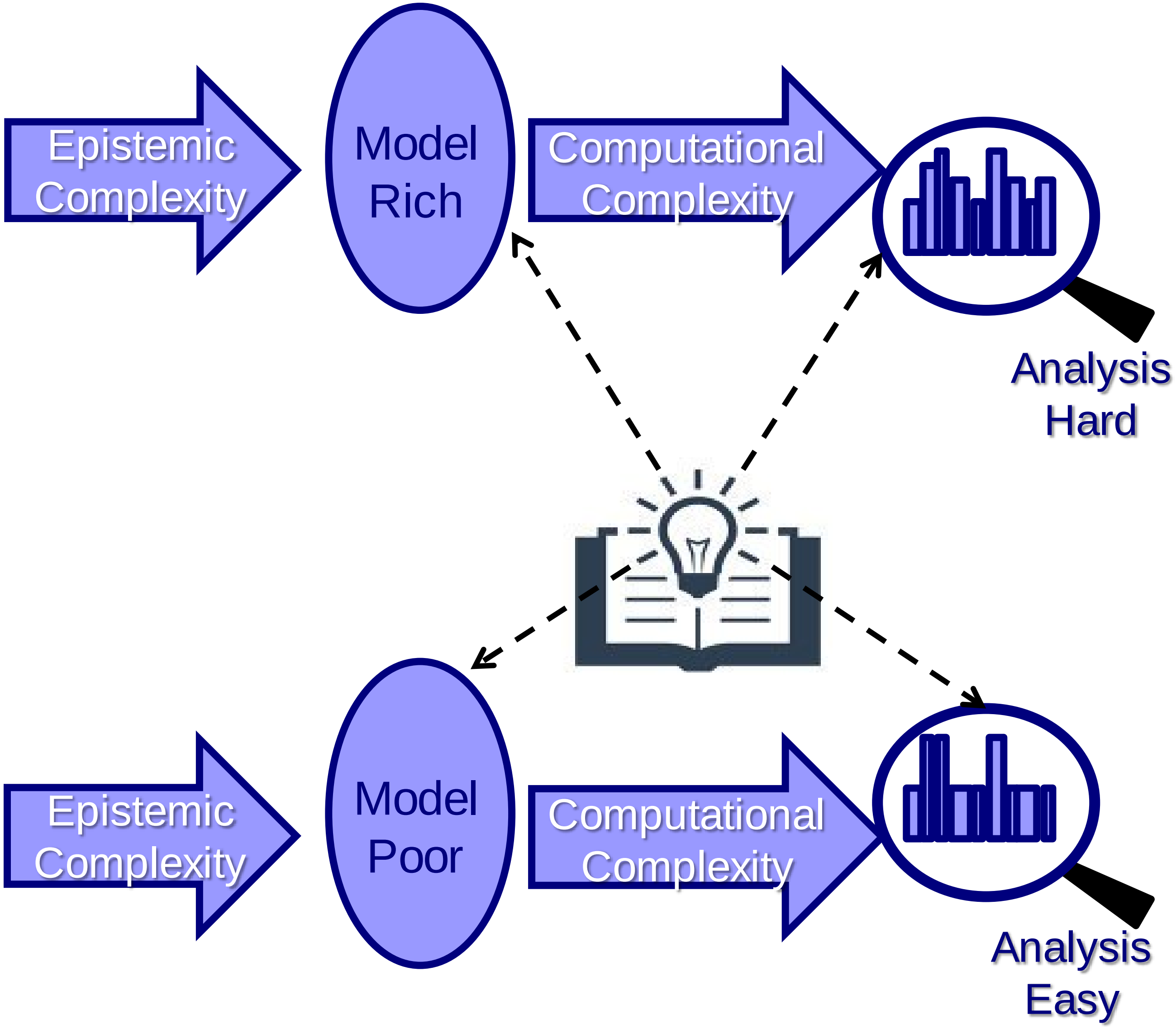
Some physicists claim that *the laws of physics could have created the universe* from nothing e.g. Krauss, Hawking.
Although the idea sounds utterly unreasonable, it should be recognized that physical laws at our level of observation, are remarkably simple, and robust.



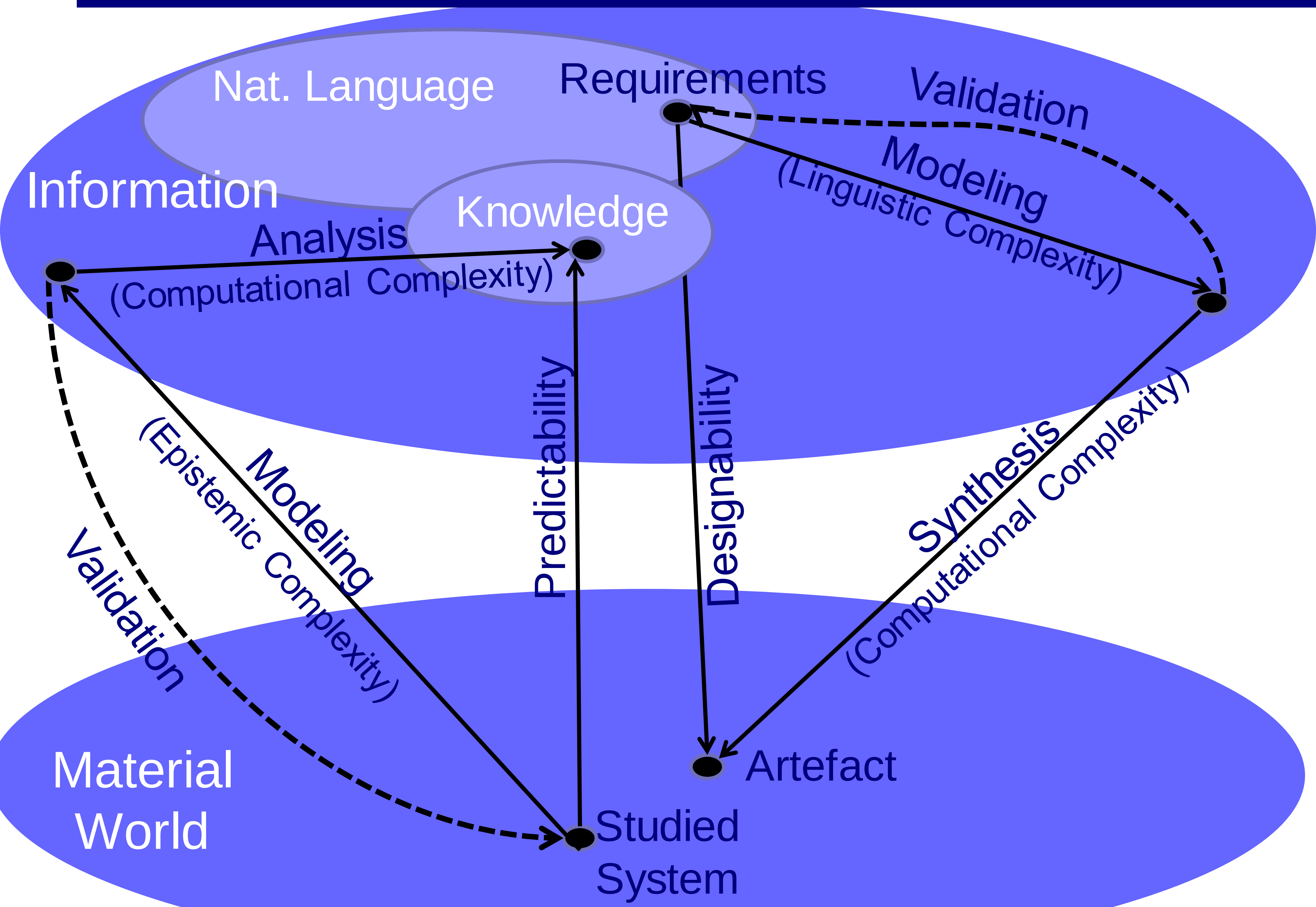
“The most incomprehensible thing about the universe is that it is comprehensible“ (Einstein)

Domains of Knowledge – Predictability

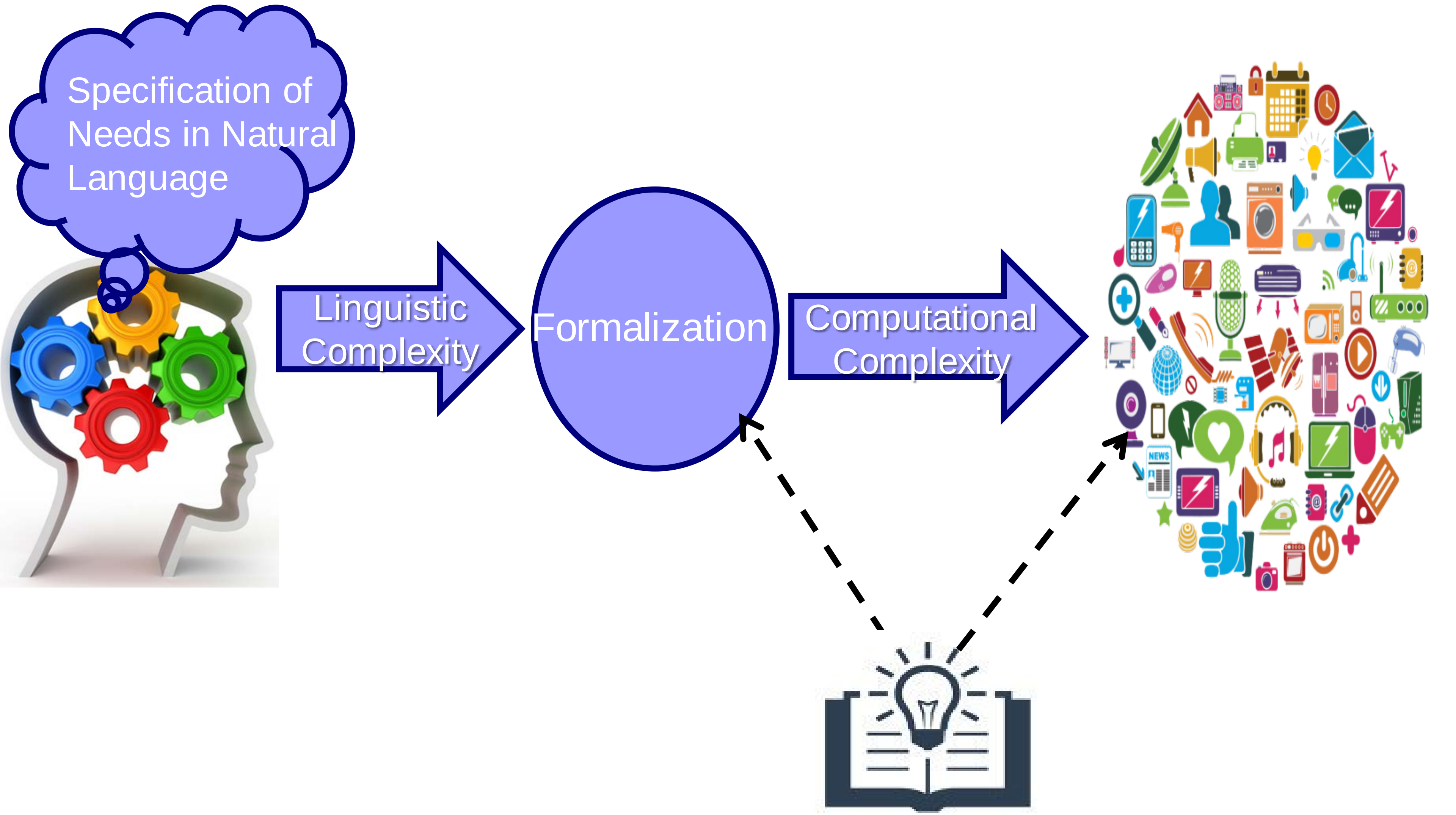




Domains of Knowledge – Predictability and Designability



Domains of Knowledge – Designability



OVERVIEW

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Linking Physicality and Computation – Commonalities

Physical phenomena

- are conveniently modeled using continuous mathematics - regardless of the very nature of the physical world
- cannot be understood without the concepts of time and space - time is a common parameter of the observed physical quantities.
- are intrinsically parallel and synchronous

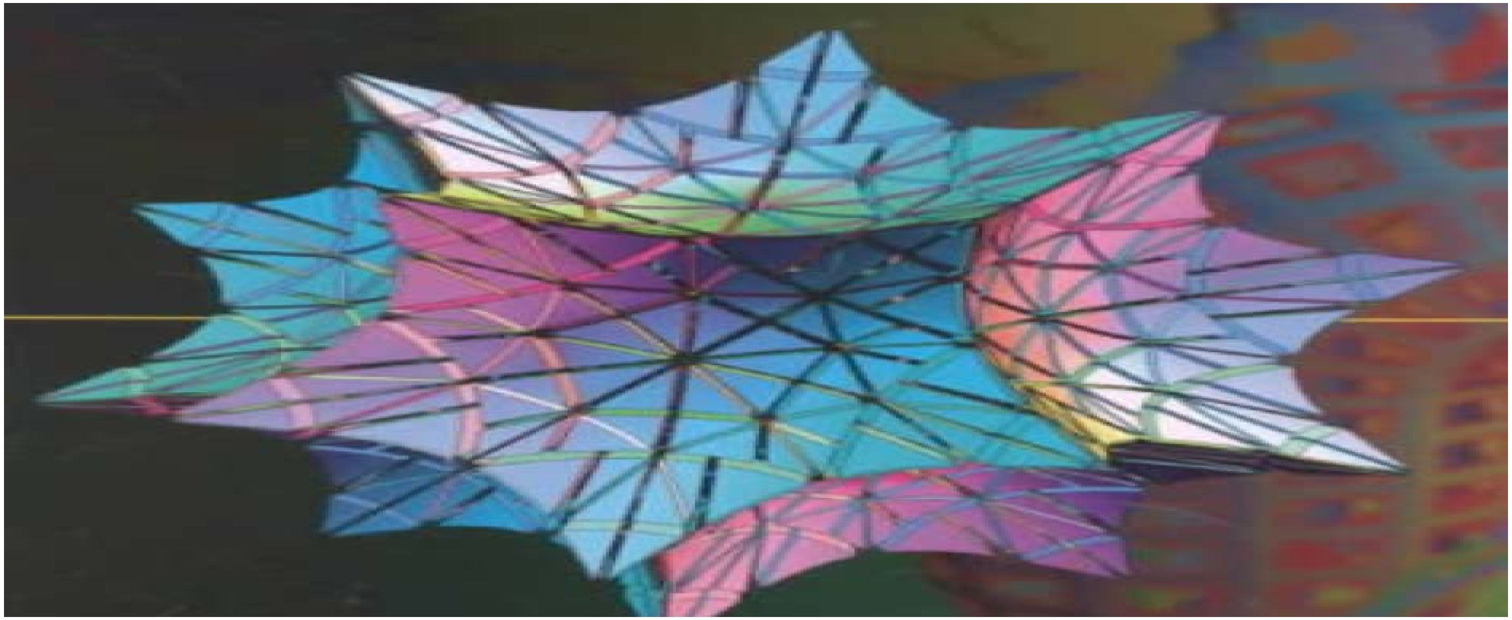
Computation

- is discrete as is founded on arithmetic and logic.
- is sequential – algorithms involve a finite number of execution steps
- has no built-in notion of time and ignores physical resources

Nonetheless they can be both modeled as dynamic systems !

Linking Physicality and Computation – Two Approaches

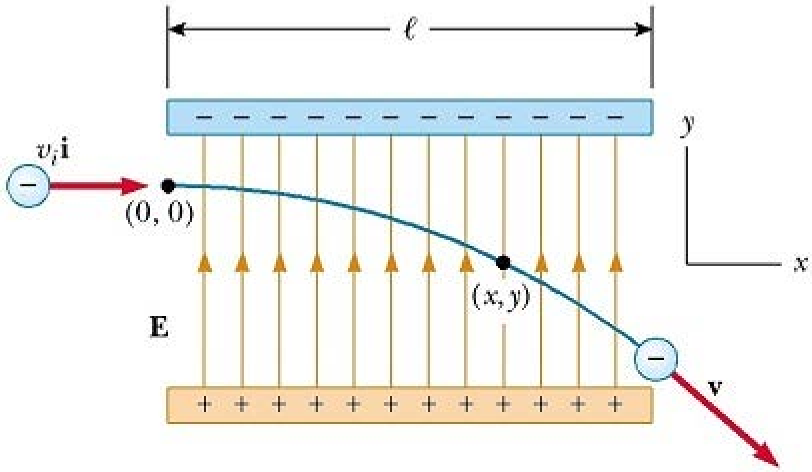
Digital physics: considers the universe is a huge computer (discrete dynamic system) and that phenomena are manifestations of its computation.



"The Universe is like a parallel computer, a computer with no master program, a company filled with self-modifying code and autonomous processes – a space of computation" (Douglas Rushkoff)

Linking Physicality and Computation – Two Approaches

<u>Natural Computers</u>: each well-understood physical phenomenon involves a computation described by the underlying physical law.



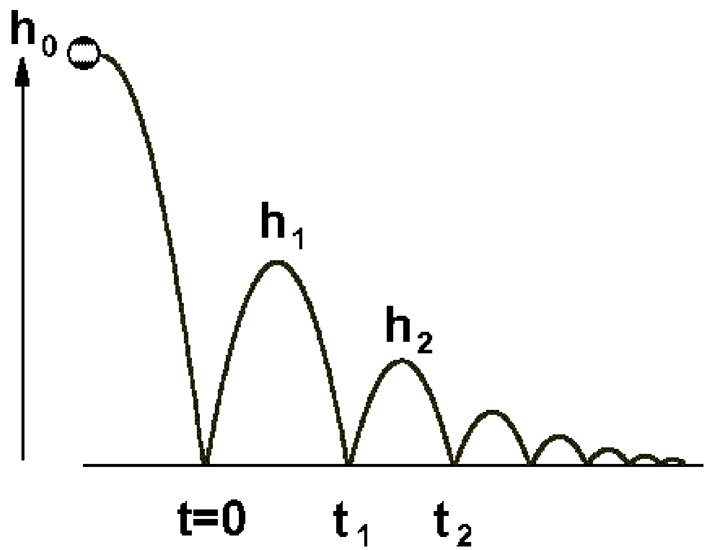
An electron projected horizontally into a uniform electric field "computes" a parabola

We need to extend Turing machines to account for basic properties of analytic models used in Physics, in two directions:

- First, by considering machines that do not terminate, to model natural phenomena involving endless change.
- Second, by investigating how the concept of parallelism inherent to time-space and natural phenomena can be adequately modeled by concurrency of computation.

Linking Physicality and Computation – Modular Simulation

Limitations of Computing appear when we try to faithfully simulate physical processes such as



- Simulators cannot faithfully simulate processes involving an infinite number of converging discrete events
- Finding $\lim_{n\to\infty} (t_n - t_0)$ requires discovery and application of an induction hypothesis - cannot bbe automated

Natural computing e.g. quantum, bio, analog computing is a promising research avenue that may lead to the invention of new models of computation overcoming current limitations due to the discrete and sequential nature of computing

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Artificial vs. Natural Intelligence – The Myth of AI

29 January 2015 Last updated at 18:05 GMT

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Microsoft's Bill Gates insists AI is a threat

By Kevin Rawlinson
BBC News

Bill Gates said he could not understand why people were not concerned by AI

Humans should be worried about the threat posed by artificial Intelligence, Bill Gates has said.

The Microsoft founder said he didn't understand people who were not troubled by the possibility that AI could grow too strong for people to control.

Mr Gates **contradicted one of Microsoft Research's chiefs, Eric Horvitz**, who has said he "fundamentally" did not see AI as a threat.

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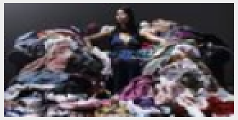

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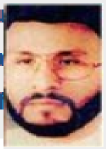

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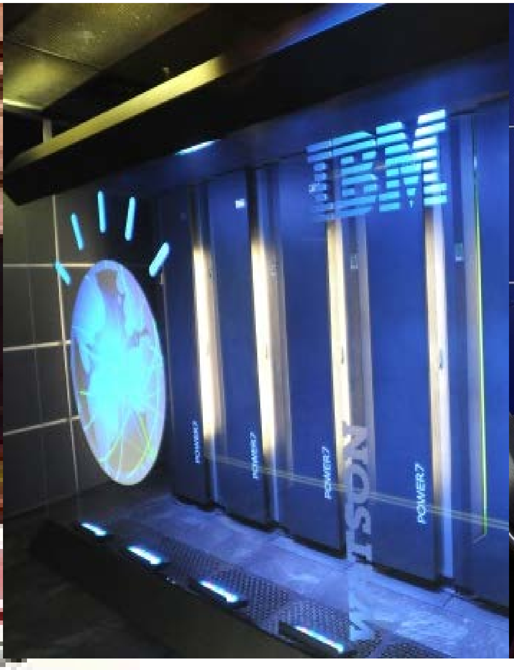
Artificial vs. Natural Intelligence – Commonalities

- Computers surpass conscious human thinking in that they compute extremely much faster and with extremely much higher precision.
- This confers them the ability to successfully compete with humans in solving problems that involve the exploration of large spaces of solutions or the combination of predefined knowledge.

IBM Deep Blue (1997)



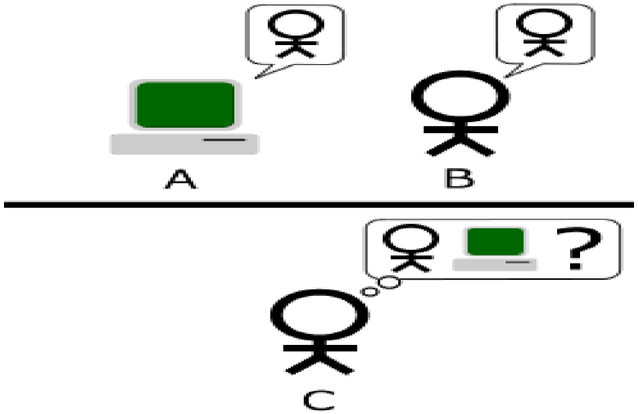
IBM "WATSON" (2011)
The Jeopardy!

AlphaGo (2016)
Google DeepMind

By defeating so human intelligence make people believe that computers exhibit intelligence and are even superior to humans in that respect.

Artificial vs. Natural Intelligence – The Turing Test

"If you were talking online with a Computer A and a Person B, could you distinguish which was the computer?"



Behavioral tests may be criticized for several reasons:

- Searle's Chinese Room Argument is a thought experiment which shows that understanding the meanings of symbols or words – what we will call semantic understanding – cannot simply amount to the processing of information.
- The Test may be diverted from its original purpose if the experimenter asks questions such as "compute a digital expansion of length 100 for π" - Computers are faster than humans in performing any well-defined computation!
- Even if the Computer passes the Turing test, all I can conclude is that it was programmed by a *genius programmer*

Artificial vs. Natural Intelligence – General Intelligence

We need systems that *exhibit general intelligence* - The route may start with a better understanding of human intelligence (perception and reasoning)

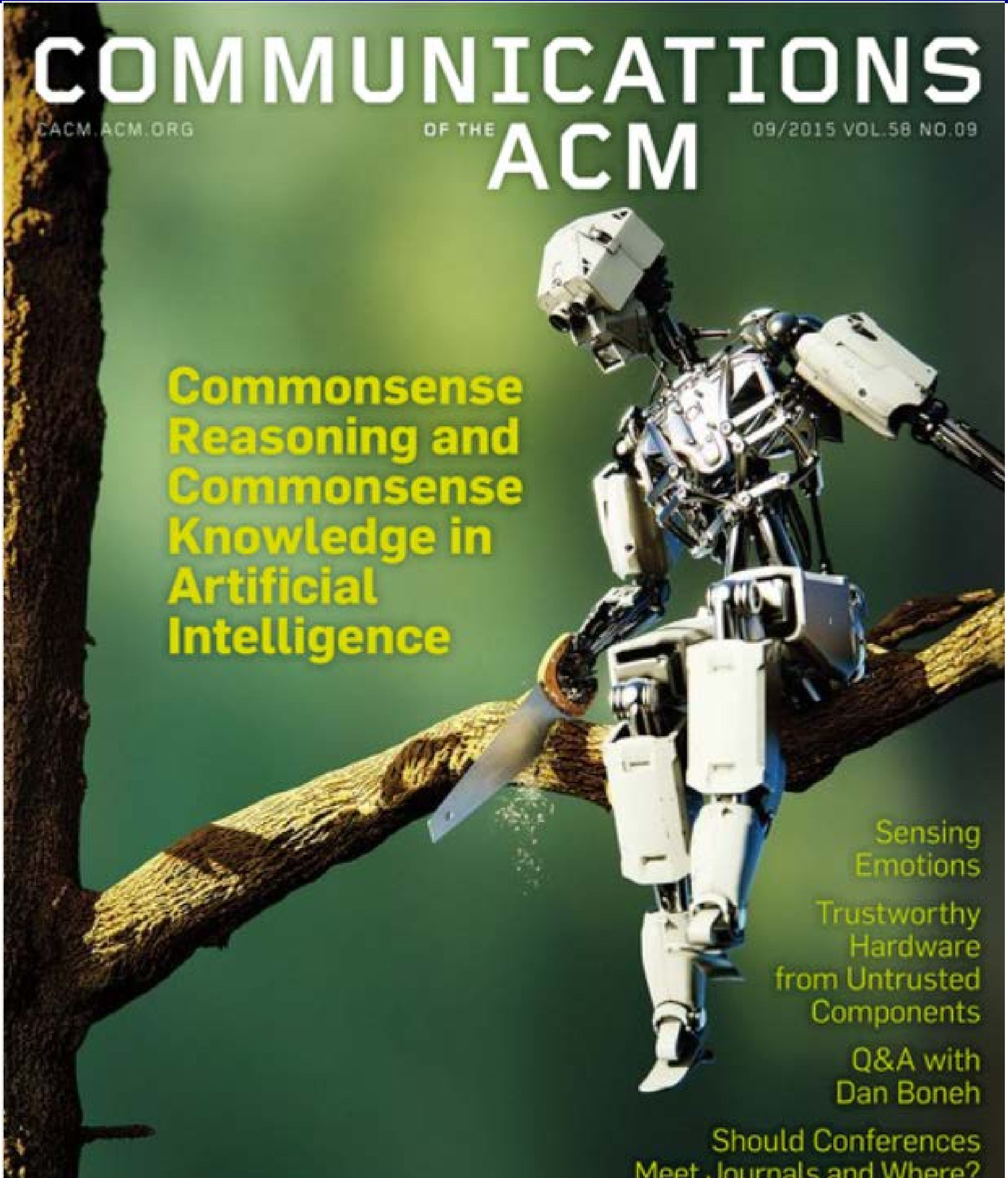
- Human reasoning uses a *semantic model* of the external world that has been progressively built in the mind though learning and by consistently integrating knowledge acquired along lifespan.
- *Consciousness* is the ability to “see” the Self interact with the semantic model contemplating possible choices and evaluating the consequences of actions.

- To build semantic models we need
  - to analyze natural language and create semantic networks involving hierarchies of disjoint categories (concepts) representing knowledge about the world.
  - to define rules for updating and enriching the knowledge used by the model.

Very little progress has been accomplished so far !

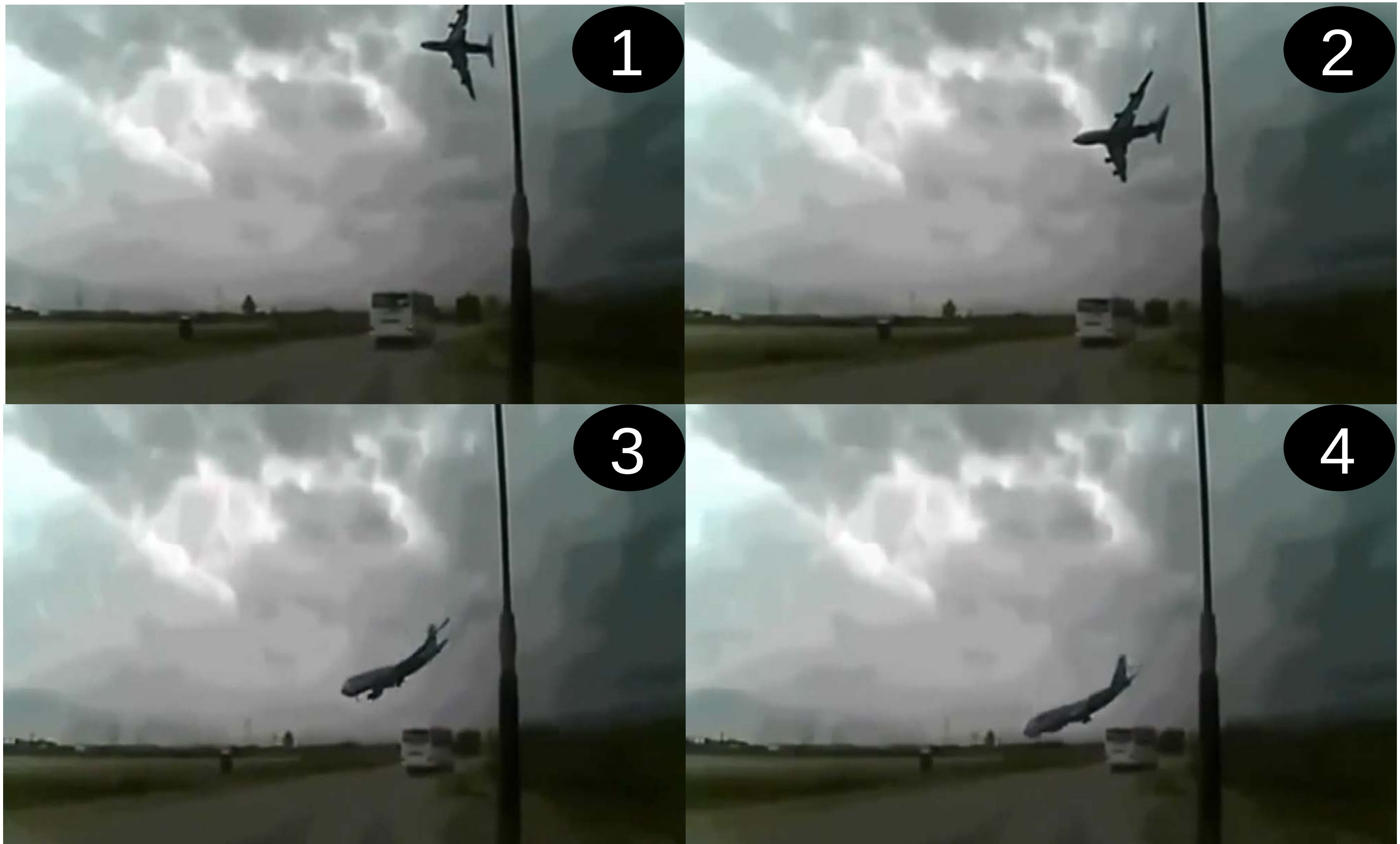
Intelligence – Common Sense Reasoning

Humans are much superior to computers in using common sense knowledge and reasoning.



Intelligence – Common Sense Reasoning

The instantaneous interpretation of this sequence by a human as an aircraft crash requires the combination of implicit knowledge and of rules of reasoning which is hard to make explicit and formalize.



Artificial vs. Natural Intelligence – Thinking Fast and Slow

Human mind combines two types of thinking (Thinking Fast and Slow by Daniel Kahneman):

- *Slow conscious thinking* that is procedural and applies rules of logic
- *Fast automated thinking* that is used to solve computationally hard problems e.g. speaking, walking, playing the piano etc.

Computers are well-suited for modeling slow, deliberate, analytical and consciously effortful human reasoning but not for fast, automatic, intuitive and largely unconscious thinking.

- Mathematics and Logic as the creation of conscious procedural thinking capture and reflect its internal laws implemented in computers
- Natural computing seems to be more adequate for studying fast thinking.
- Unfortunately, as fast thinking is non-conscious it is impossible to understand and analyze the underlying mechanisms and laws, as we did for slow thinking.

Artificial vs. Natural Intelligence – The Limits of Understanding

- *Understanding* means that we can connect a model (relation between objects) to our mental representations in some meaningful manner
- We cannot determine the behavior of a complex system not because we cannot know “how it works” but because its complexity exceeds our cognitive capabilities

The limits of understanding

- The *cognitive complexity* of a model can be measured as the time needed by a subject.
- There is a *limit in the size* of the relations that human mind can deal with: relations of rank five (one predicate + four arguments)
- To break complexity human mind uses *abstraction* (layering), *modularity* and if possible *segmentation* (temporal, procedural decomposition).

Extending the limits of understanding

- Computers can be used to significantly improve/extend our capabilities of understanding complex phenomena and creating knowledge

Artificial vs. Natural Intelligence – Predicting w/o Understanding

For many domains of knowledge e.g. earth sciences, epidemiology, economics phenomena are irreducibly complex and depend on a large number of parameters.

- The development of all encompassing theoretical models seems practically impossible.
- Theories are necessarily partial - consider drastic abstractions. Thus modeling techniques combine

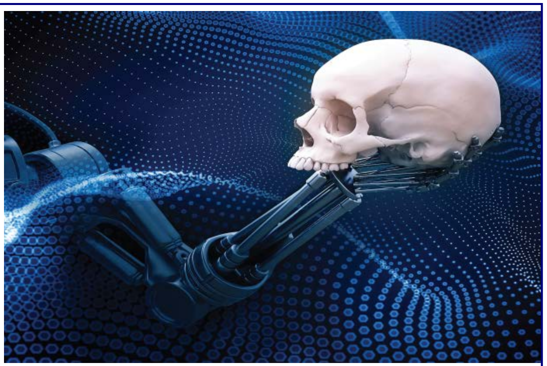
Big data analytics

Discovering correlations between parameters in huge amounts of data to find new correlations to "spot business trends, prevent diseases, combat crime and so on“.

- “Prediction without understanding” or with 0-theory (lack of any conclusive evidence or even of sufficient evidence).
- Criticism: correlation does not imply causality (The Deluge of Spurious Correlations in Big Data by C. Calude and G. Longo)
- Toward “Data science”, a field of investigation of the Cyber-Universe ?

Artificial vs. Natural Intelligence – Singularity

- The technological singularity (also, simply, the singularity) is the hypothesis that the invention of artificial superintelligence will abruptly trigger runaway technological growth, resulting in unfathomable changes to human civilization (Wikipedia)



- Ray Kurzweil has predicted that the singularity will occur around 2045—a prediction based on Moore's Law as the time when machine speed and memory capacity will rival human capacity.

Exponential increase of hardware does not imply any "increase of intelligence" (!!!!)

- I.J. Good has predicted that such super-intelligent machines will then build even more intelligent machines in an accelerating 'intelligence explosion.' Super-intelligent machines will pose an existential threat to humanity, for example, keep humans as pets or kill us all.

It is sad that all these purely speculative ideas are taken seriously.

<u>Real Danger</u>: the rise of AI-driven automation will greatly exacerbate the already acute disparity in wealth between those who design, build, market, and own these systems on one hand, and the remainder of the population on the other hand

Artificial vs. Natural Intelligence – Singularity

- People hastily believe in sensational fictitious threats while they are slow to react to real dangers identified through rational thinking and lucid analysis
- Worrying about machines that are too smart distracts us from the real and present threat from machines that are too dumb!

Asimov's Laws of Robotics

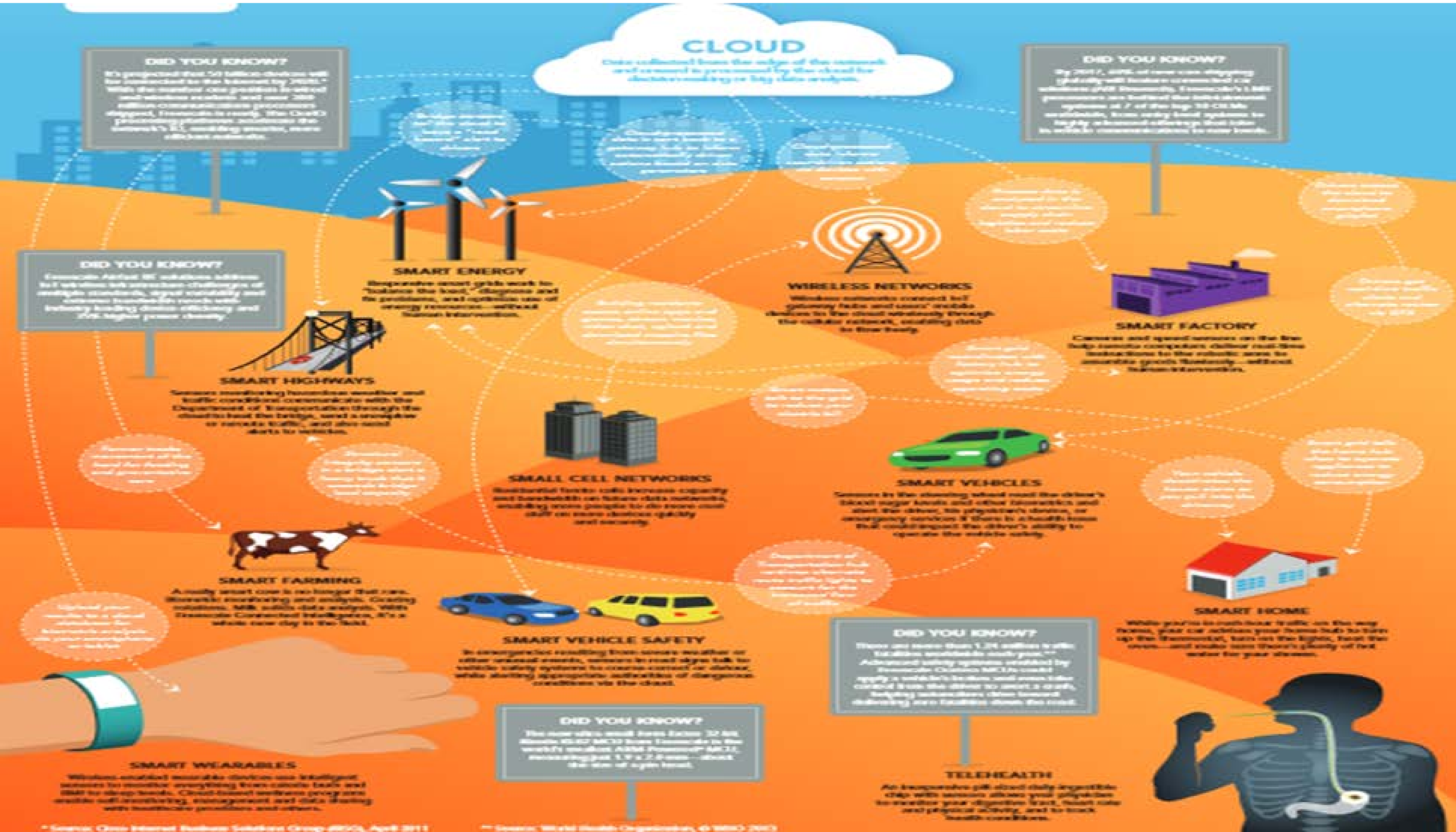
1. *A robot may not injure a human being or, through inaction, allow a human being to come to harm.*
2. *A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.*
3. *A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.*

Big Bad Robots vs. Complex Mindless Systems

- Systems although mindless and devoid of intention, can violate any of these laws with humongous consequences!
- Increasing system integration changes social relations and concentrates decisional power in the hands of a small minority.

Trends in Systems Engineering –The Internet of Things

We see the IoT as billions of smart, connected “things” – a sort of “universal global neural network” in the cloud– that will encompass every aspect of our lives and its foundation is the intelligence that embedded processing provides



Trends in Systems Engineering – Requirements

Trustworthiness requirements express assurance that the designed system can be trusted that it will perform as expected despite

HW failures

Design Errors

Environment Disturbances

Malevolent Actions

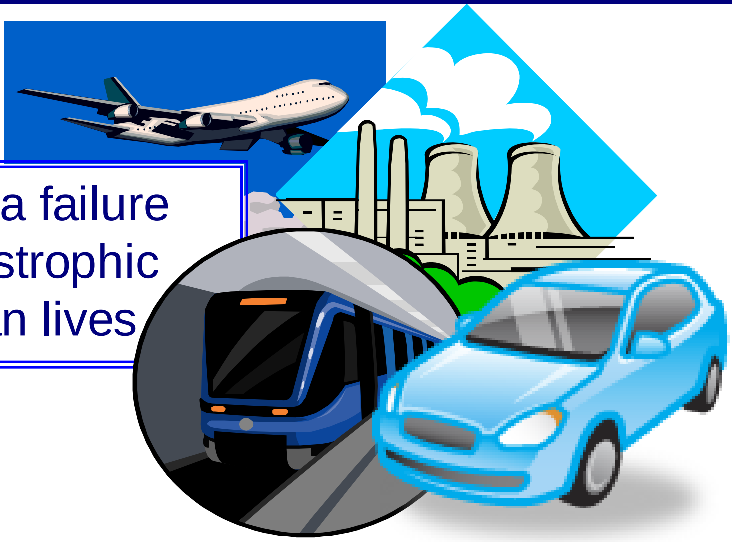
Optimization requirements are quantitative constraints on resources such as time, memory and energy characterizing

1) performance e.g. throughput, jitter and latency;
2) resources e.g. storage efficiency, processor utilizability

The two types of requirements are antagonistic: System design should determine tradeoffs between cost and quality

Trends in Systems Engineering – Levels of Criticality

10^{-9}



Safety critical: a failure may be a catastrophic threat to human lives

Security critical: harmful unauthorized access

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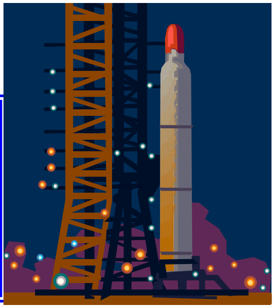
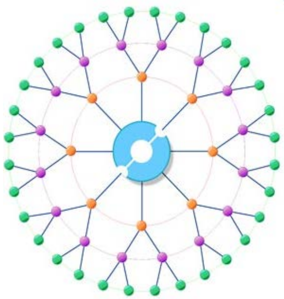
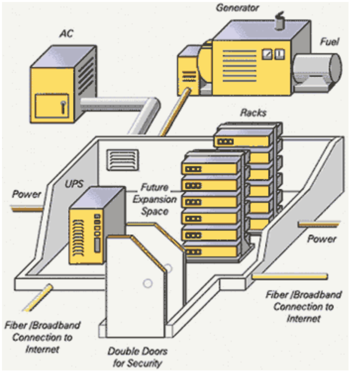
Mission critical: system availability is essential for the proper running of an organization or of a larger system







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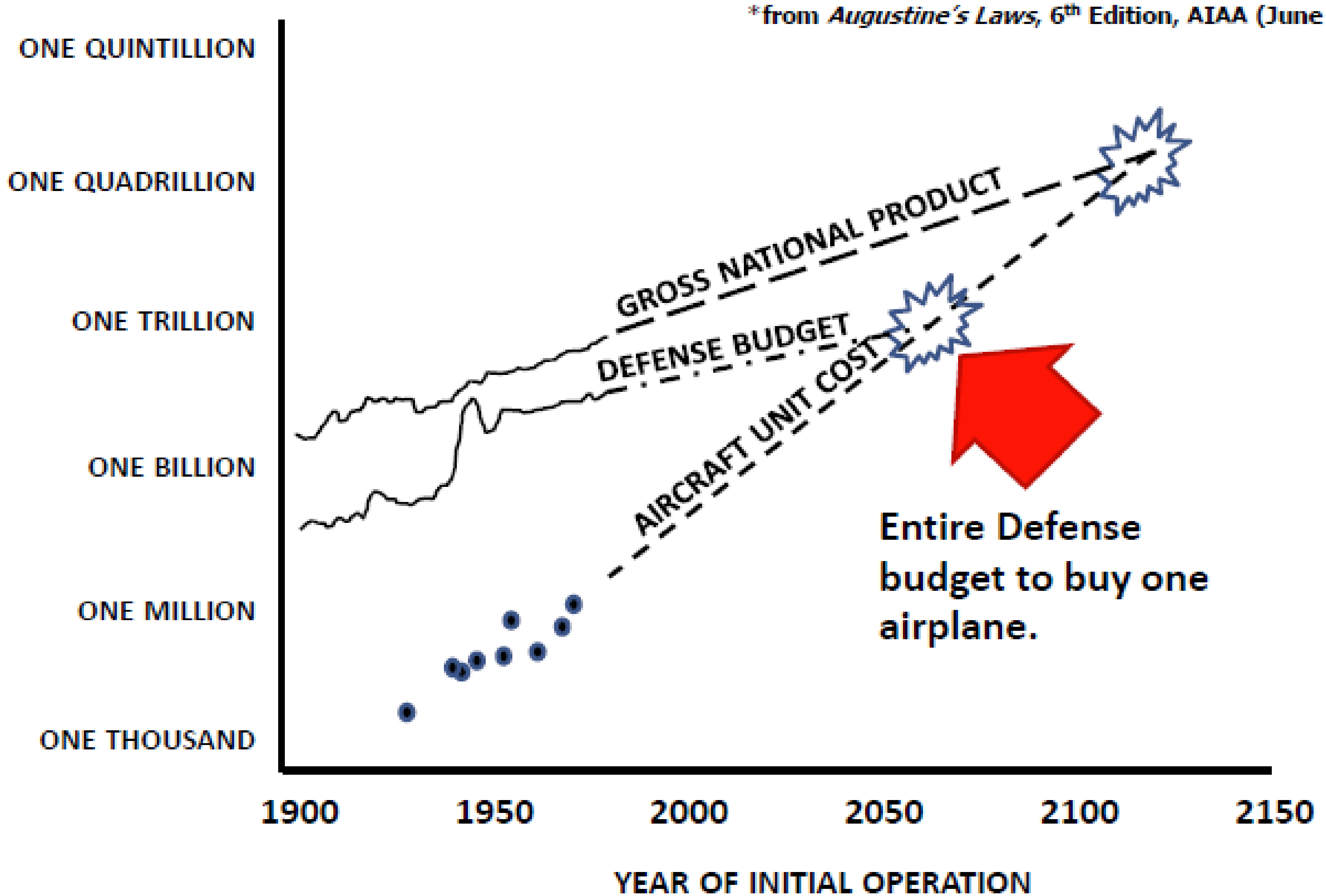
Best effort: optimized use of resources for an acceptable level of trustworthiness

amazon.com

Google

The problem

*from *Augustine's Laws*, 6th Edition, AIAA (June 1997)



Trends in Systems Engineering – The Cost of Trustworthiness

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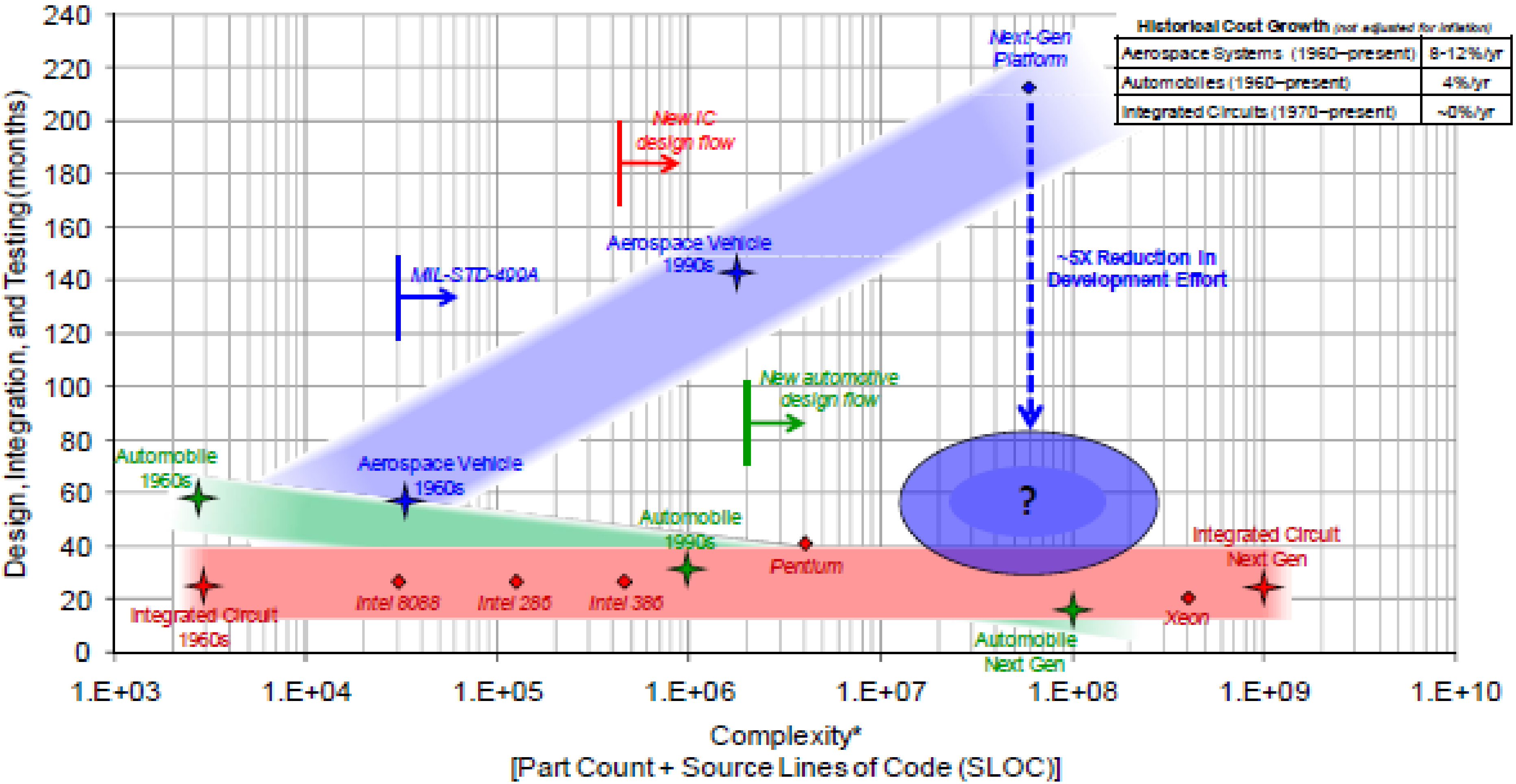
Historical schedule trends with complexity



Trends in Systems Engineering – Coping with Uncertainty

Critical systems engineering

- has been successfully applied based on standards guaranteeing predictable behavior e.g. avionics, trains, nuclear plants
- is based on worst-case analysis and static resource reservation e.g. hard real-time approaches, massive redundancy
- leads to over-dimensioned systems due to *increasing uncertainty* from

    1. Execution platforms : aging, varying execution times, timing anomalies

    2. External environment: non determinism, attacks, malevolent actions

    3. Analysis and interpretation of raw data e.g. image recognition

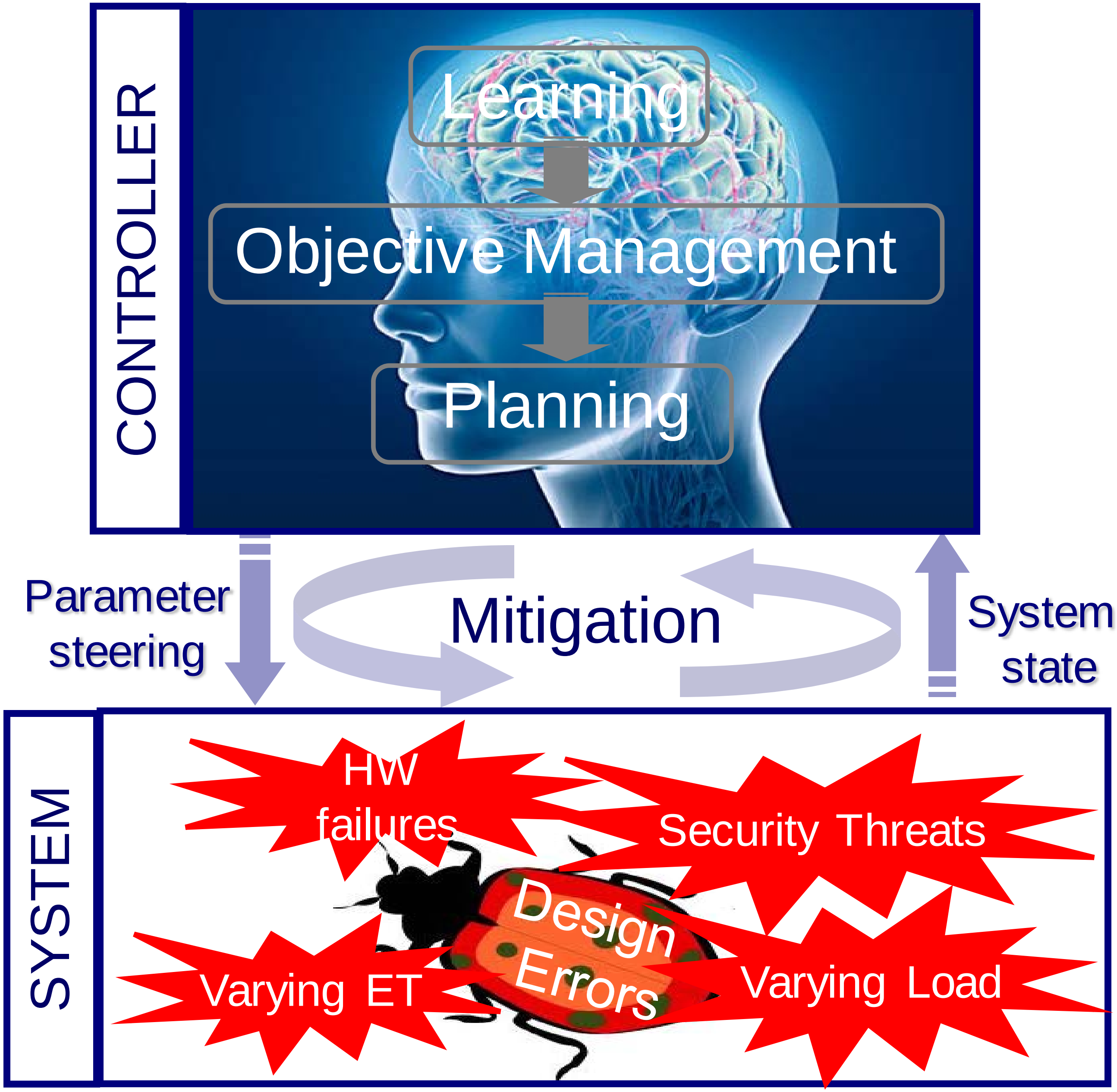
<u>Adaptivity:</u>

System's behavior adapts so as to cope with failures and hazards of any kind and meet given requirements including safety, security, and performance, in the presence of uncertainty in its external or execution environment

Trends in Systems Engineering – Adaptivity

- ❑ Systems must provide services meeting given requirements in interaction with intrinsically uncertain (non-deterministic) environments

- ❑ Adaptivity consists in using control-based techniques to ensure correctness despite uncertainty



Trends in Systems Engineering – Adaptivity

Learning

Movie would have been better …

Management of objectives

Go to the: 1) Stadium 2) Cinema 3) Restaurant

Planning

Trends in Systems Engineering – Paradigm Shift

Achieving predictable and provably correct behavior *at design time* is practically impossible for complex interactive systems

- impossible to foresee all possible faults and hazards and their mitigation
- trustworthiness of the built artefact cannot be justified as prescribed by standards
- available infrastructures have been designed in an ad hoc manner – nobody can guarantee its security and safety.
- the extensive use of IA techniques that do not admit rigorous justification makes things even more complicated

There are no strict standards – only guidelines - for critical medical systems and probably there will be no such standards for self-driving cars.

<u>Tradeoff between trustworthiness and individual liberties</u>:

- Either stop the increasing integration of systems and services in the IoT
- Or limit individual liberties e.g. Elon Musk's "*cars you can drive will eventually be outlawed - Because humans can't have nice things*" March 17, 2015.

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- What is Information
- What is Computing
- Domains of Knowledge
- Linking Physicality and Computation
- Artificial vs. Natural Intelligence
- Discussion

Discussion

- Computing is a distinct domain of knowledge, a broad field that studies information processes, natural and artificial as well as methods for building computing artefacts.

- Computing should be enriched and extended to encompass physicality –
  - resources such as memory, time, and energy to become first class concepts.
  - Integrate natural computing processes that seem like computation but do not fit the traditional algorithmic definitions.

- Computing has a deep impact on the development of science and technology similar to the discovery of mechanical tools and machines.
  - Computers multiply our mental faculties by extending our ability for fast and precise computation.
  - Nonetheless, as an aircraft is not a bird, a computer is not a mind!
    To make computers more intelligent we should better understand how our mind works and cope with linguistic complexity of natural languages.

Discussion

- Computing has revealed the importance of design as a "problem-solving process" leading from requirements expressing needs to correct artefacts.
  - Design formalization raises a multitude of deep theoretical problems related to the formalization of needs and their functional and extra-functional implementation.
  - Endowing design with a rigorous foundations *is both an intellectually challenging and culturally enlightening endeavor – it nicely complements the quest for scientific discovery in natural sciences*

- Computing has revealed the importance of knowledge and its cross-fertilization to achieve enhanced predictability and designability.

- Computing complements and enriches our understanding of the world with a constructive and computational view different from the declarative and analytic adopted by Physics.

Merci