About Informatics Distributed Computing and our Job a View

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I have reached the day where I can't remember the day I stopped being immortal.

In *Livro de Crónicas*, António Lobo Antunes

So now I think that

Any life is a merge of
the Illiad (Achilles) and the Odyssey (Ulysses)

Content of the talk

- Where do we come from?
- The impact of informatics on sciences/society
- About distributed computing
- What is our job (teaching, research, dissemination of research results, ...)?

Not a polemic talk, only encourage each of us to have a view

Part 1

WHERE DO WE COME FROM?

See also:

What came first: Maths or Computing?
by Moshe Wardi, CACM, 66(11), 2023

Part 1

A short historical perspective
and ...
a point of view on what is
INFORMATICS

(~~computer science~~)

A concept must be denoted with ONE word!
Denotations with more words are always ambiguous...

Vocabulary and notations are fundamental ....

From the very beginning (?)

mankind is
Looking for UNIVERSALITY!

Remark:
The words *universe*, *universality*, and *university*, ...
have the same root!

A short story from Sumer to Turing

One upon a time...

Plimpton tablet 322

(1800 BC)

15 lines
Pythagorean triplets
($a^2 + b^2 = c^2$)
Sexagesimal base

Algorithms seem to be born with writing..
(only recipes at this time, no formalization, no proofs)

(applications: field-area, transmission of heritage, and interest-rate computation)

A little bit later...

A great step ahead!

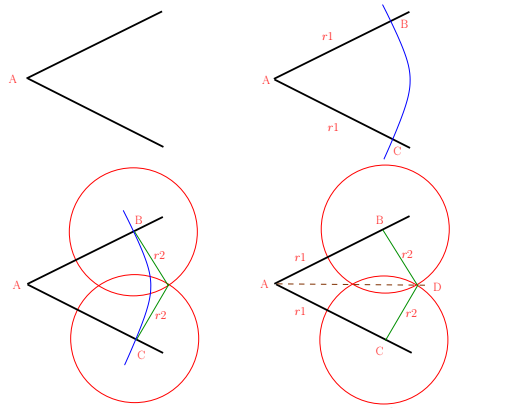
Axioms: Euclid ($\simeq$ 300 BC)

Constructions (algo.) based on
Ruler + compass
which define the

We have then:

algorithms + proofs
not recipes only

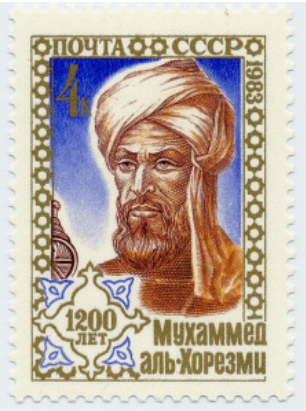
Ex.: Bissecting an angle with compass + ruler



Proof: show that the triangles ABD and ACD are equal

What about trisecting an angle?
ruler + compass op. are not universal for geometry!

Still a little bit later...



M. Ibn Musa Al Khwârizmî
780, Khiva - 850, Bagdad

House of the Wisdom (Bagdad)
Hârun ar-Rashîd (786-809)

Contributed to algebra ... but
gave its name to algorithms!
(He proposed "algorithms"
to solve quadratic equations)

Same period: the book "The thousand and one nights"

One of many works of Al Khwârizmî

- Our today formulas were "long sentences"
- Negative numbers are meaningless
  they will be "admitted" after Descartes and Gauss)
- He considered the quadratic polynomial $ax^2 + bx + c$
- He introduced transposition and reduction
  - ⋆ Important remark:
    the signs "+", "−" and "=" were introduced much later (15th century)
  - ⋆ transposition (al-jabr):
    $4x - 3 = 5$ becomes $4x = 5 + 3$
  - ⋆ reduction (muqabala):
    $4x = 9 + 3x$ becomes $x = 9$

The six Al Khwârizmî's patterns

Number means Indian numbers
Root because we do not see it, it is in the soil

today formula	Al Khwârizmî's statement
$ax = b$	root equals numbers
$x^2 = a$	square equals numbers
$x^2 = ax$	square equals roots
$x^2 + ax = b$	square and roots equal roots
$x^2 = ax + b$	square equals roots and numbers
$x^2 + a = bx$	square and numbers equal roots

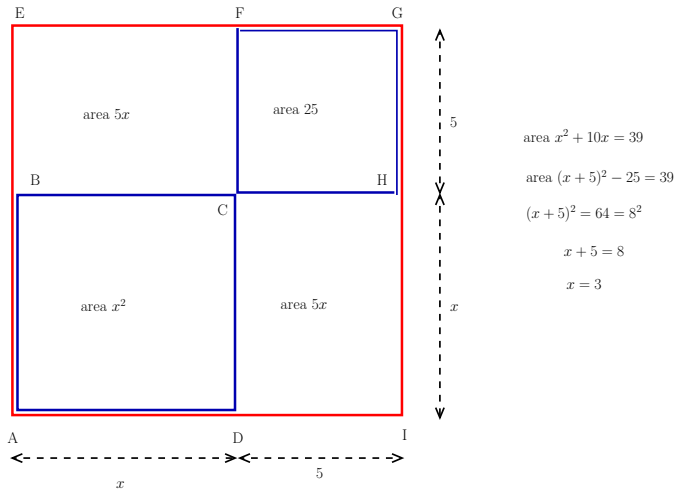
Al Khawarizmi's algorithm for $x^2 + 21 = 10x$

Divide the roots in two; this gives 5; multiply 5 by itself, you get 25; remove the 21 that are added to the square; there remains 4; extract the root, which gives 2; and take it out of the half of the roots, that is to say of 5; it remains 3; it is the root of the square you are looking for and the square is 9.

If you wish, add this to half the root, which gives 7, which is the root of the square you are looking for and the square is 49. If you encounter a problem that comes down to this case, then examine its correctness with the help of addition; If you cannot, you will certainly obtain (the solution) by means of subtraction.

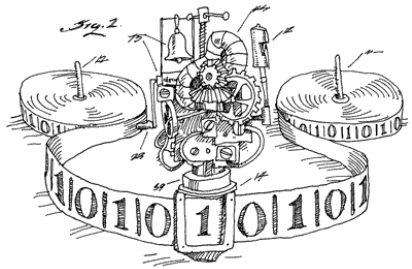
Of the three cases in which one must divide the roots in two, this is the only one where addition and subtraction are used. Know also that if in this case you divide the root in two, multiply it by itself and the product is smaller than the dirhams that are added to the square, then the problem is impossible. But if it is equal to the dirhams, the root of the square is equal to half of the root, without anything being added or taken away.

Example: construction and proof for $x^2 + 10x = 39$



A few centuries later, closer to us

1912-1954



1936

- Turing A. M., On computable numbers with an application to the Entscheidungsproblem. *Proc. of the London Mathematical Society*, 42:230-265 (1936)

Pantheon including Newton, Darwin, Descartes, Lavoisier, Humbolt, etc.

Universality and Limits of sequential computing

- Founding result (sequential computing):
  - ⋆ FSA ⊂ Pushdown Automata ⊂ Turing Machines
  - ⋆ Machines to process SYMBOLS
- Church-Turing Thesis: universal machine
- Universality of data representation: sequences de bits (books, images, files, etc.)
- Limits of seq. computing: Impossibility results

Two great colleagues!

1903-1995

1897-1954

Who are they?

ALGORITHMICS

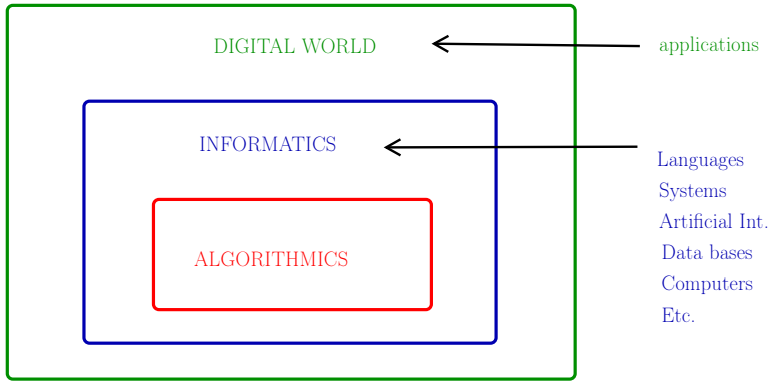
The science of building higher and higher level computing abtractions and appropriate data representations

from a set of predefined basic primitive operations

Looking for universality!

A very nice book Algorithmics: the spirit of computing by Harel D. and Feldman Y., 3rd edition Springer, 572 pagers (2012) [First edition: 1992]

A unifying view



Part 2

THE IMPACT of INFORMATICS

on SCIENCES

(and undirectly on the society)

Observations (1)

- Main resources:
  - ⋆ up to mid of XX-th century: matter/energy
  - ⋆ from mid of XX-th century: information (data)
  - ⋆ as matter/energy: information can be collected, consumed, transformed, stored, carried, etc.
  - ⋆ differently from matter/energy: as it is abstract it does not burn and can be ∞-copied at "zero cost"

Observations (1 continued)

For interested people
see Joseph Sifakis' 2022 Springer book

Understanding and Changing the World:
From Information to Knowledge and Intelligence

Observations (2)

- Produces a "new" way of thinking (algorithmics-based)
- From putting the world into equations
  to putting the world into algorithms
- Science of (operation) abstractions

The incredible power of informatics

- the great book of nature is written in mathematical language (Galileo Galileo)

  True for physics, not for life sciences
- Today Conjecture:

> informatics + mathematics
>
> is the language of ALL sciences!

Informatics vs Mathematics

- The power of the touch "run"
- On the objects we manipulate ("1+2" vs "3")
- On the nature of "finite" (memory/time, e.g π)
  - ⋆ Algorithms must produce a result
  - ⋆ Maths stop before the touch "run"
- not only formulas and theorems but the power of computation and simulation
- The difference betwen science and technology? (the parents vs children dichotomy!)

Part 3

DISTRIBUTED COMPUTING

or BEYOND TURING WORLD

What is distributed computing

- A set of imposed computing entities that must cooperate to attain a common goal
- on top of a communication medium
  - ⋆ Read/write registers
  - ⋆ message-passing network
  - ⋆ or both (hybrid with clusters)
- In the presence of adversaries asynchrony, failures, process mobility, etc.

The World Is DistrbutEd = WIDE

Distributed computing

- DC arises when one has to solve a problem in terms of entities (processes, agents, sensors, peers, actors, nodes, processors, ...) such that each entity has only a partial knowledge of the many parameters involved in the problem that has to be solved

DC is about Mastering COOPERATION in an UNCERTAINTY WORLD

- A famous quote (its formalization is FLP85) A distributed system is one in which the failure of a computer you didn't even know existed can render your own computer unusable (L. Lamport)

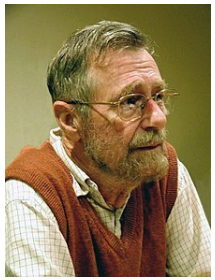
Parallel computing ≠ Distributed computing

- Parallel computing: (controlled by programmers): Discover and exploit data independence to obtain efficient executions
- Distributed computing: (imposed to programmers):
  - ⋆ Allow predefined independent computing entities to coordinate to solve a given problem
  - ⋆ To this end define and build appropriate distributed commmunication/cooperation abstractions (distributed objects)

Father of Synchronization

Edsger W. Dijkstra (1930-2002)

Solution of a problem in concurrent programming control *Communications of the ACM*, 8(9):569 (1965)



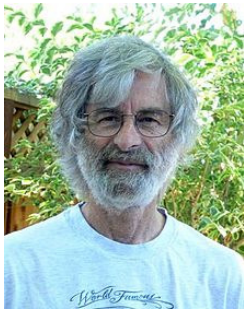
- Concept of a process
- Concurrency
- Synchronization
- Invariants, Prog. Proofs
- Sofware engineering
- Self-stabilization, ...

Father of distributed computing

Leslie Lamport(1941)

l'homme qui a appris aux ordinateurs à travailler ensemble

Time, clocks and the ordering of events in a distributed system *Communications of the ACM*, 21(7):558-565 (1978)



- Partial order on events
- Scalar clocks
- State machine replication
- Byzantine failures
- Bakery mutex algorithm (no underlying atomicity)
- Beyond atomicity
- Etc.

No trick! Concepts and methods!

Most famous DC problems

- The most famous DC problem in the presence of failures: CONSENSUS
- Another fundamental DC problem: Reliable Broadcast in the presence of process and channel failures
- types of failures:
  - ⋆ Crash failures (premature stop)
  - ⋆ Byzantine failure (arbitrary behavior)
  - ⋆ What about the blockchain ??

A fundamental impossibilities result: FLP

Fischer-Lynch-Paterson's Impossibility result (1985)

There is no deterministic algorithm that solves consensus in an asynchronous distributed system that is subject to even a single process crash

Fischer M.J., Lynch N.A. and Paterson M.S., Impossibility of distributed consensus with one faulty process. *Journal of the ACM*, 32(2):374-382 (1985)

The nature of impossibility in distributed computing

"In sequential systems, computability is understood through the Church-Turing Thesis: anything that can be computed, can be computed by a Turing Machine.

In distributed systems, where computations require coordination among multiple participants, computability questions have a different flavor. Here, too, there are many problems which are not computable, but these limits to computability reflect the difficulty of making decisions in the face of ambiguity, and have little to do with the inherent computational power of individual participants."

- Herlihy M., Rajsbaum S., and Raynal M., Power and limits of distributed computing shared memory models. *Theoretical Computer Science*, 509:3-24 (2013)

The nature of impossibility in ditributed computing

Intrinsic difficultly : The uncertainty (non-determinism) CREATED by the ENVIRONMENT (asynch., failures, etc.) is an HIDDEN INPUT of the distributed execution itself

The run itself is one of its inputs!

One of the main issues of DC:
non-determinism created by the environment

We say "an adversary controls the environment"
(example: driving a car in a road, pothole, animals, etc.)

In a few words

Distributed Computing

is the Science of Cooperation

- The world of asynchrony, failures, etc.
- The world of the underlying communication graphs
- Merge of both worlds with the notions of message adversaries and process adversaries seen at the very same abstraction level

PART 4

A FEW PERSONAL THOUGHTS

on the following topics

- On scientific competition
- On the notion of "what is a good good paper"
- On a kind of evolution
- On the duality/complementarity: teaching vs research

On scientific competition

- Industrial competition: win or die
  patents, products, technology dependence, ...
- Competition between University labs/researchers
  - ⋆ helping friendly competition
  - ⋆ nothing is hidden
  - ⋆ Cooperation-based work
  - ⋆ lots of common publications (no country/company-based)
  - ⋆ some naivety?
  - ⋆ Too many researchers are interested "only" in the paper they are working on...
  - ⋆ Anecdote on Bitcoin (total order for cryptocurrency)

On the notion of "good article"

- A paper ranked "best paper" in a conference?
- A paper whose significance and impact have been evident for at least ten years?
- etc. ???
- My (today) criterion

An anecdote when I started teaching

On a type of evolution: where are we going?

- Today, Informatics is eaten by its applications, It is anti-Chronos (see research credits)
- 1936: Alan Mathison Turing (1912-1954)
  - ⋆ Foundations od sequential computing
  - ⋆ We know what is computable, and what is not
  - ⋆ Theory preceded applications
- Today: change of paradigm: the pattern has been reversed
  - ⋆ many app. precede theory but few fertilize it
  - ⋆ unfortuntely a lot applications are to Informatics what sandwiches are to Three Stars restaurants!

Our job

- Understand difficult things (in our domain)
- Make things as simple as possible (but no more!)
- Reminder: research is the raison d'être of universities
- Year after year ... this creates revolutions in industry

On the duality: teaching/research

- What is teaching?
  - ⋆ Teaching is not an accumulation of facts (L. Lamport)
  - ⋆ Teaching is thinking aloud in front of students (H. Lebesgue)
- Which balance?
- Teaching at undergraduate level: truth and certainty
- Teaching at graduate level:truth and questioning
  - ⋆ Teaching/research: two sides of the same coin
  - ⋆ Teach students so that they will still have a job when the technology with which they started their studies will go to the garbage can !

To conclude: a question

Is there an end to the story?

To conclude: an answer (to take away)

The best way to predict the future ...
...
...
is to invent it!

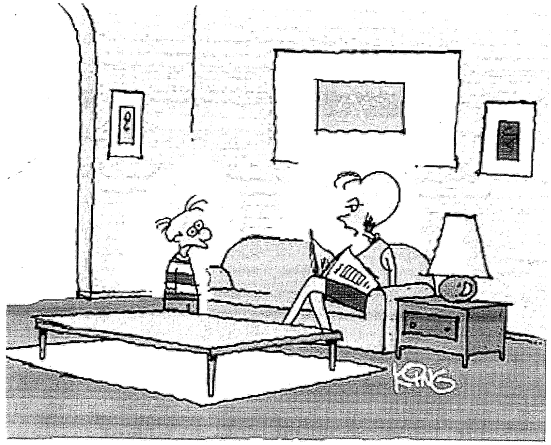
An anecdote

From the book "Probably approximatively correct" by Leslie Valiant (2013)

When he was a young researcher, the first time he met E. W. Dijkstra

- Dijkstra asked him "on which topic are you working?"
- Valiant answered "On AI"
- and Dijkstra answered "Why you dont work on I?"

Never forget ....



"No, you weren't downloaded.
Your were born."

Un coup de griffe

Pour remplacer "ils vécurent heureux et eurent beaucoup d'enfants"

Colorín colorado,

este cuento NO se ha acabado...