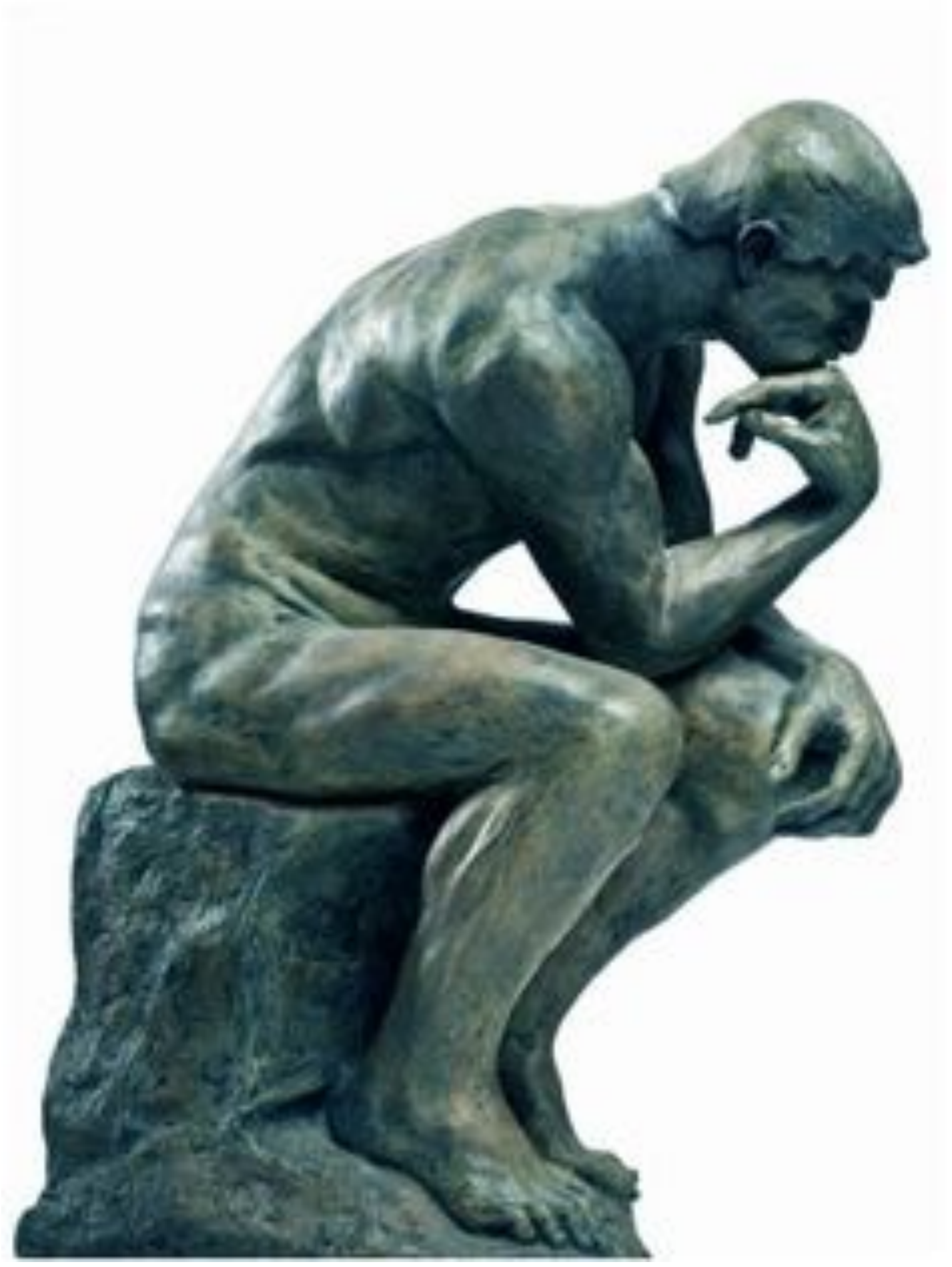
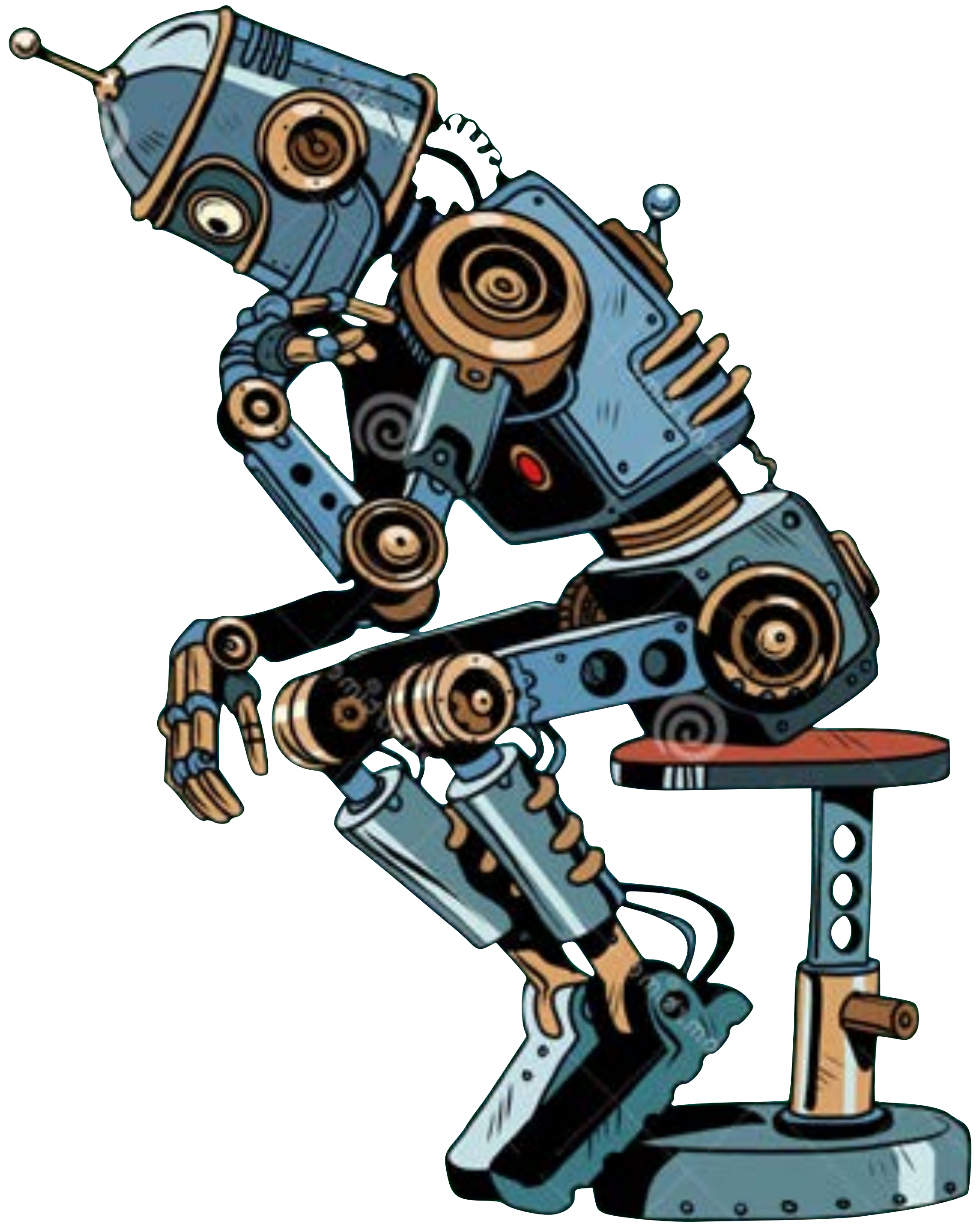
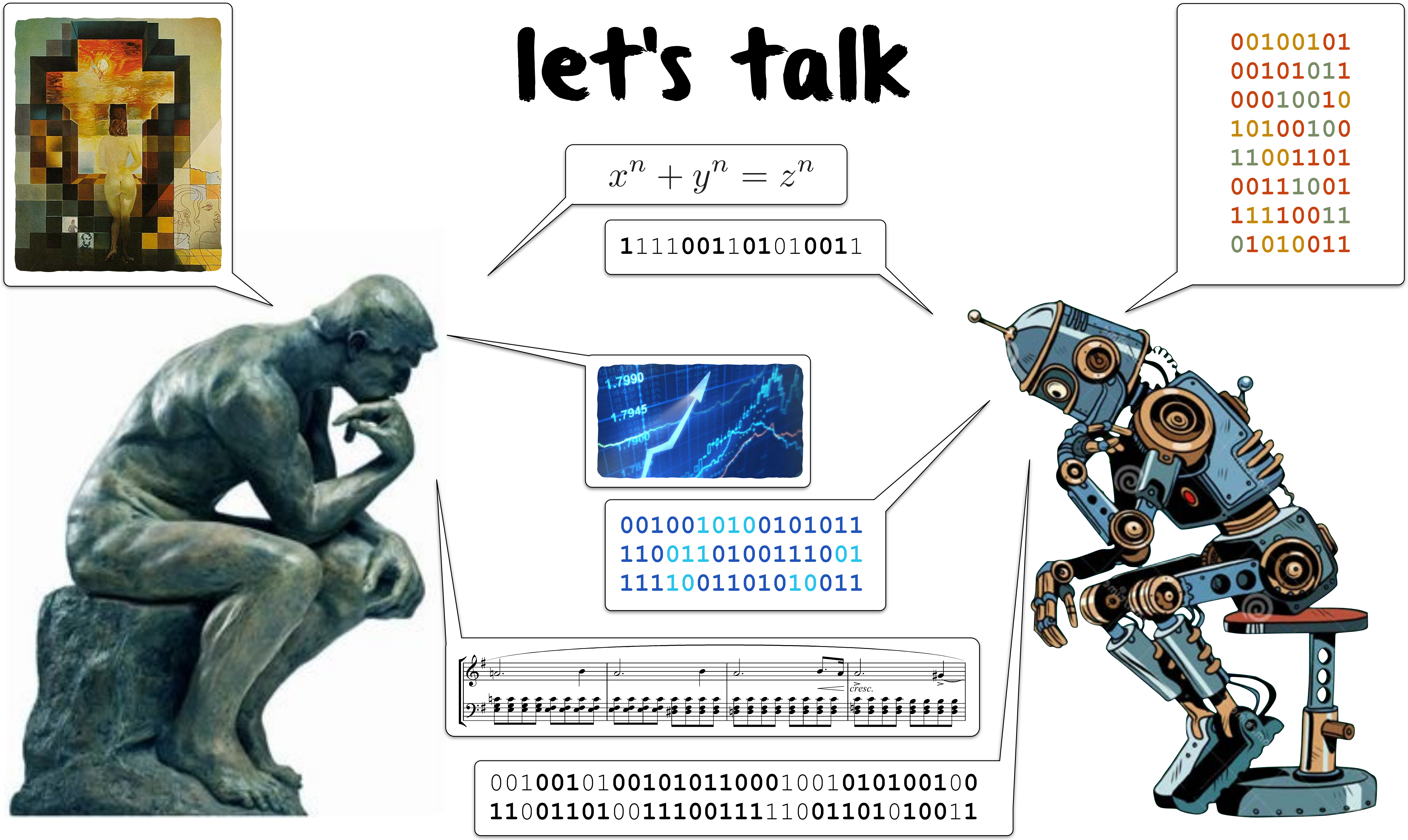
algorithms and computational thinking





course overview

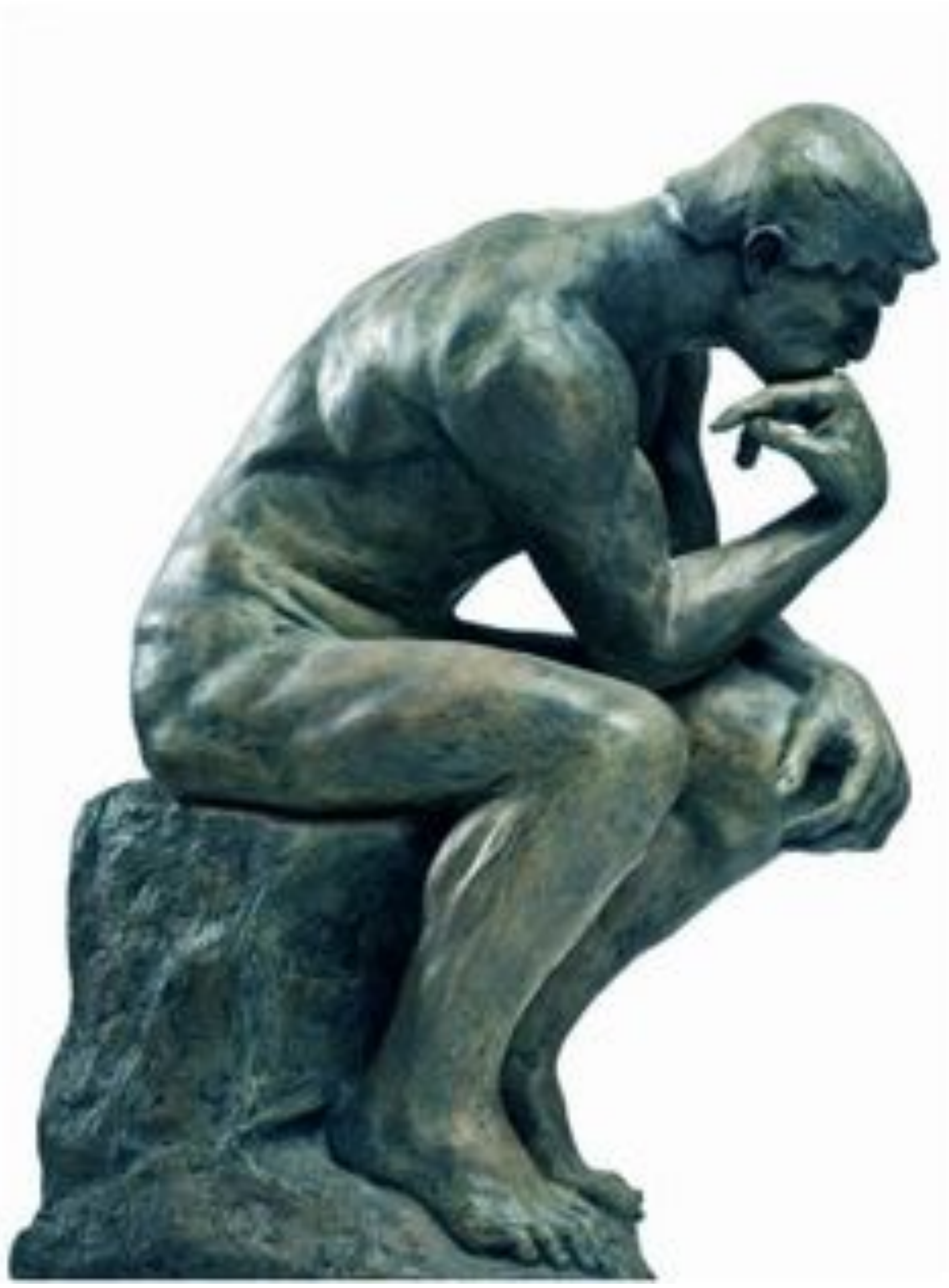

let's talk
$x^n + y^n = z^n$
1111001101010011
1.7990
1.7945
0010010100101011
1100110100111001
1111001101010011
cresc.
00100101001010110001001010100100
11001101001110011111001101010011
00100101
00101011
00010010
10100100
11001101
00111001
11110011
01010011

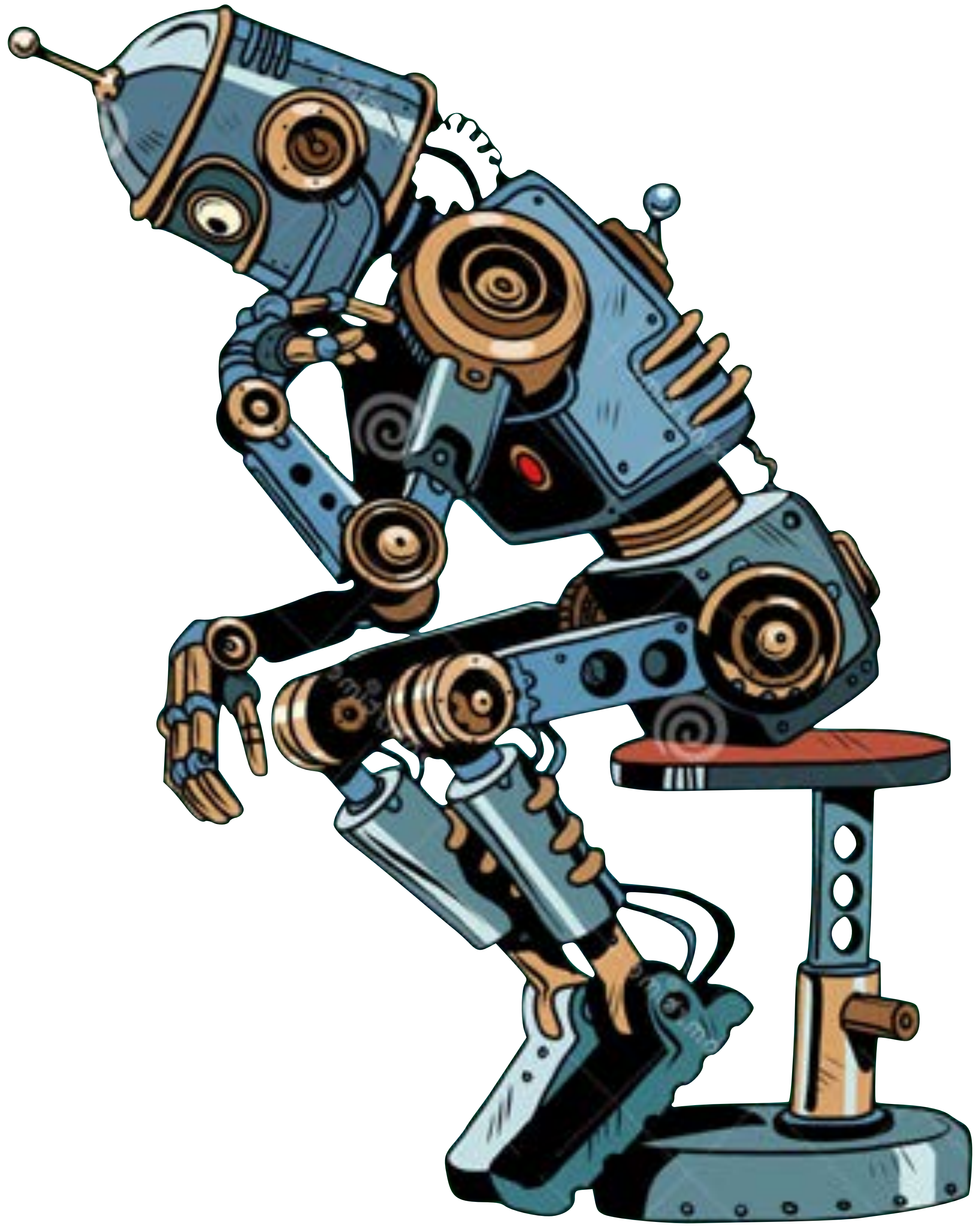
problem

how do you tell the computer what to do, if you don't speak its language and it doesn't speak yours?


spark-1.3.1 — bash — 130×38
3ebc6a/userFiles-eadd4714-93e2-47d5-8a37-9b8d5cc7ccaf/spark-examples-1.3.1-hadoop2.4.0.jar to class loader
15/07/24 13:12:15 INFO Executor: Finished task 7.0 in stage 0.0 (TID 7). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Starting task 8.0 in stage 0.0 (TID 8, localhost, PROCESS_LOCAL, 1338 bytes)
15/07/24 13:12:15 INFO Executor: Finished task 3.0 in stage 0.0 (TID 3). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Starting task 9.0 in stage 0.0 (TID 9, localhost, PROCESS_LOCAL, 1338 bytes)
15/07/24 13:12:15 INFO Executor: Finished task 5.0 in stage 0.0 (TID 5). 736 bytes result sent to driver
15/07/24 13:12:15 INFO Executor: Running task 9.0 in stage 0.0 (TID 9)
15/07/24 13:12:15 INFO Executor: Running task 8.0 in stage 0.0 (TID 8)
15/07/24 13:12:15 INFO Executor: Finished task 0.0 in stage 0.0 (TID 0). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Finished task 3.0 in stage 0.0 (TID 3) in 803 ms on localhost (1/10)
15/07/24 13:12:15 INFO TaskSetManager: Finished task 7.0 in stage 0.0 (TID 7) in 805 ms on localhost (2/10)
15/07/24 13:12:15 INFO TaskSetManager: Finished task 5.0 in stage 0.0 (TID 5) in 809 ms on localhost (3/10)
15/07/24 13:12:15 INFO TaskSetManager: Finished task 0.0 in stage 0.0 (TID 0) in 826 ms on localhost (4/10)
15/07/24 13:12:15 INFO Executor: Finished task 4.0 in stage 0.0 (TID 4). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Finished task 4.0 in stage 0.0 (TID 4) in 818 ms on localhost (5/10)
15/07/24 13:12:15 INFO Executor: Finished task 1.0 in stage 0.0 (TID 1). 736 bytes result sent to driver
15/07/24 13:12:15 INFO Executor: Finished task 6.0 in stage 0.0 (TID 6). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Finished task 1.0 in stage 0.0 (TID 1) in 825 ms on localhost (6/10)
15/07/24 13:12:15 INFO TaskSetManager: Finished task 6.0 in stage 0.0 (TID 6) in 822 ms on localhost (7/10)
15/07/24 13:12:15 INFO Executor: Finished task 2.0 in stage 0.0 (TID 2). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Finished task 2.0 in stage 0.0 (TID 2) in 869 ms on localhost (8/10)
15/07/24 13:12:15 INFO Executor: Finished task 9.0 in stage 0.0 (TID 9). 736 bytes result sent to driver
15/07/24 13:12:15 INFO TaskSetManager: Finished task 9.0 in stage 0.0 (TID 9) in 71 ms on localhost (9/10)
15/07/24 13:12:15 INFO Executor: Finished task 8.0 in stage 0.0 (TID 8). 736 bytes result sent to driv
15/07/24 13:12:15 INFO TaskSetManager: Finished task 8.0 in stage 0.0 (TID 8) in 78 ms on localhost
15/07/24 13:12:15 INFO DAGScheduler: Stage 0 (reduce at SparkPi.scala:35) finished in 0.900 s
15/07/24 13:12:15 INFO TaskSchedulerImpl: Removed TaskSet 0.0, whose tasks have all completed, from p
15/07/24 13:12:15 INFO DAGSchedul reduce at SparkPi.scala:35, took 1.068825 s
Pi is roughly 3.140524
15/07/24 13:12:15 INFO o.s.j.s.ServletContextHandler{/metrics/json,null}
15/07/24 13:12:15 INFO .s.j.s.ServletContextHandler{/stages/stage/kill,null}
15/07/24 13:12:15 .j.s.ServletContextHandler{/,null}
15/07/24 13:12:15 .j.s.ServletContextHandler{/static,null}
15/07/24 13:12:15 .s.ServletContextHandler{/executors/threadDump/js
15/07/24 13:12:15 .s.ServletContextHandler{/executors/threadDump,nu
15/07/24 13:12:15 .s.ServletContextHandler{/executors/json,null}
15/07/24 13:12:15 .s.ServletContextHandler{/executors,null}
15/07/24 13:12:15 .s.ServletContextHandler{/environment/json,null}
9:41 AM
100%
Done
World Clock
Cupertino
Today, +0HRS
New York
Today, +3HRS
Detroit
Today, +3HRS
London
Today, +8HRS
World Clock
Alarm
Bedtime
Stopwatch

approach of this course

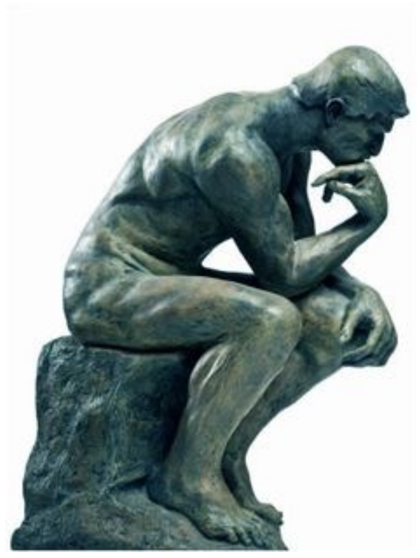




approach of this course

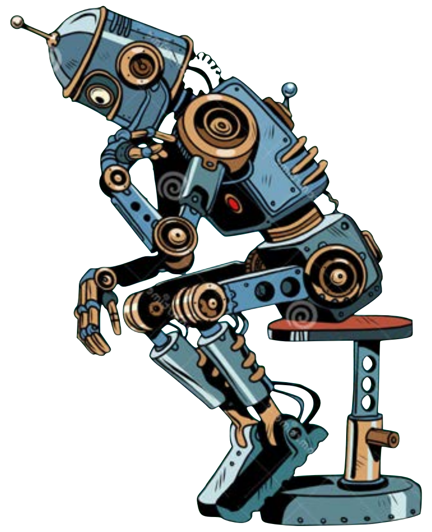
think precisely in computational terms

express problems formally and solutions algorithmically



use high-level programming languages

use tools to develop, and debug programs



computer science

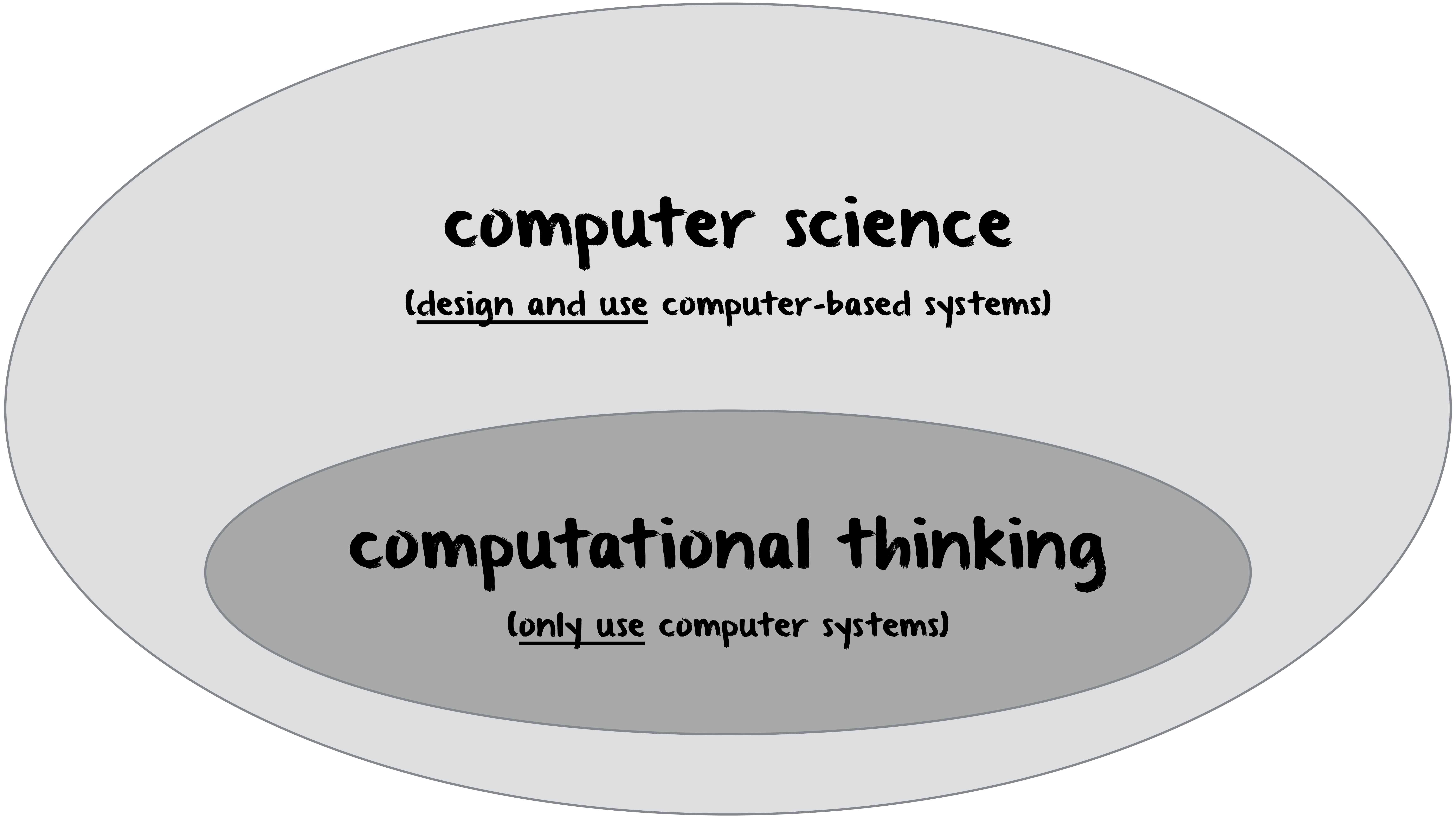
theoretical and practical study
of how to design and use
computer-based systems

computer science aims at devising automated algorithmic processes
and computer-based systems that can run in a scalable manner

computational thinking

thought processes involved in formulating problems and expressing their solutions so that a computer can execute them

such solutions are expressed in terms of algorithms, which are in turn written in some programming language compiled and executed on some computer-based system



$$\textit{computational thinking} \subset \textit{computer science}$$

$$\textit{computer science} \not\subset \textit{computational thinking}$$

teaching staff

Benoît Garbinato

professor

Alpha Diallo

assistant

student assistants

Gaëtan

Johannes

Maeva

Nathan

Richard

Yasser

course objective

learn a set of thinking skills and practical methods to formulate and solve problems using algorithms and computing devices

course objective

what's a computer?

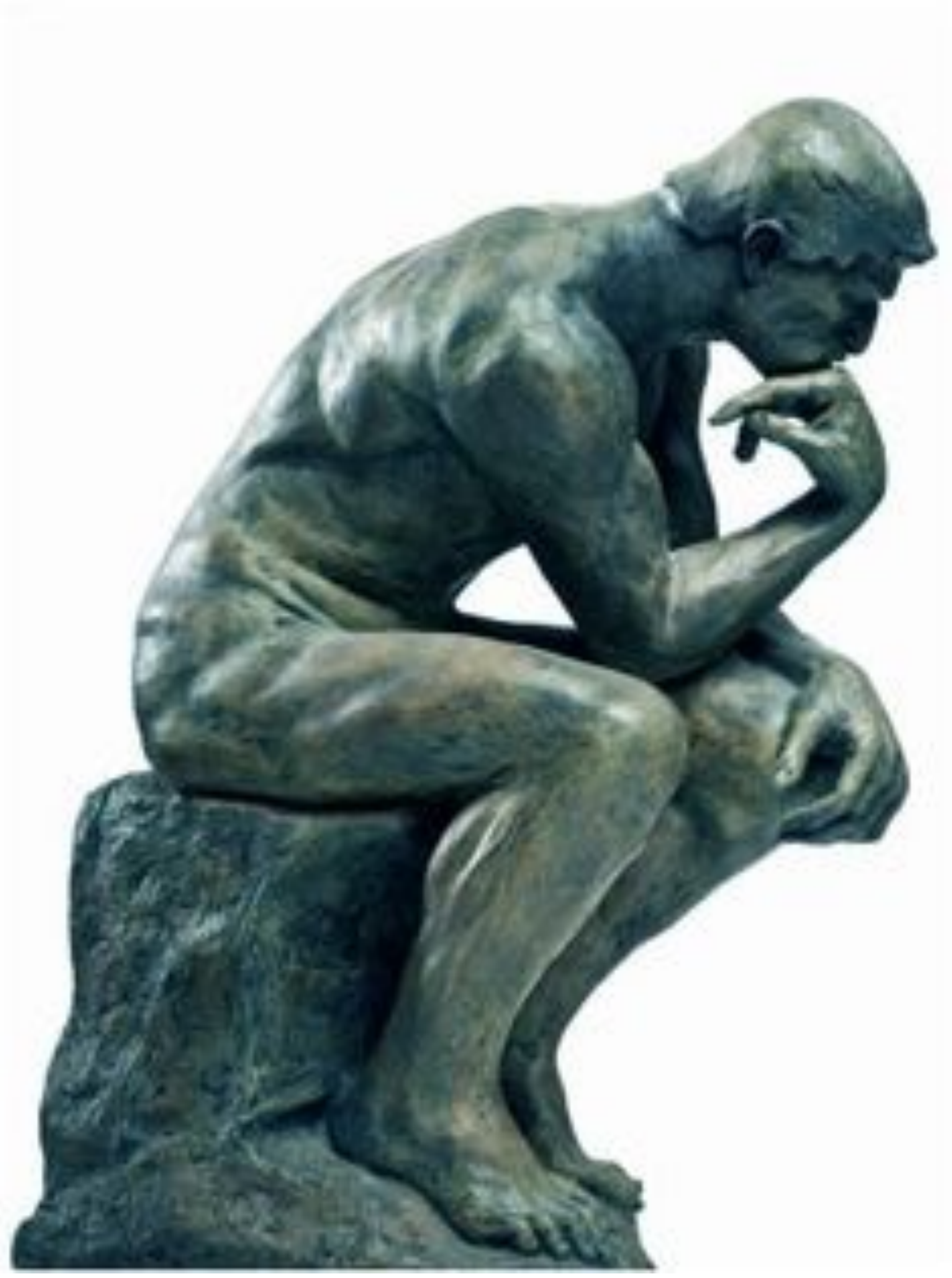
what's an algorithm?

what's a compiler?

what's programming?

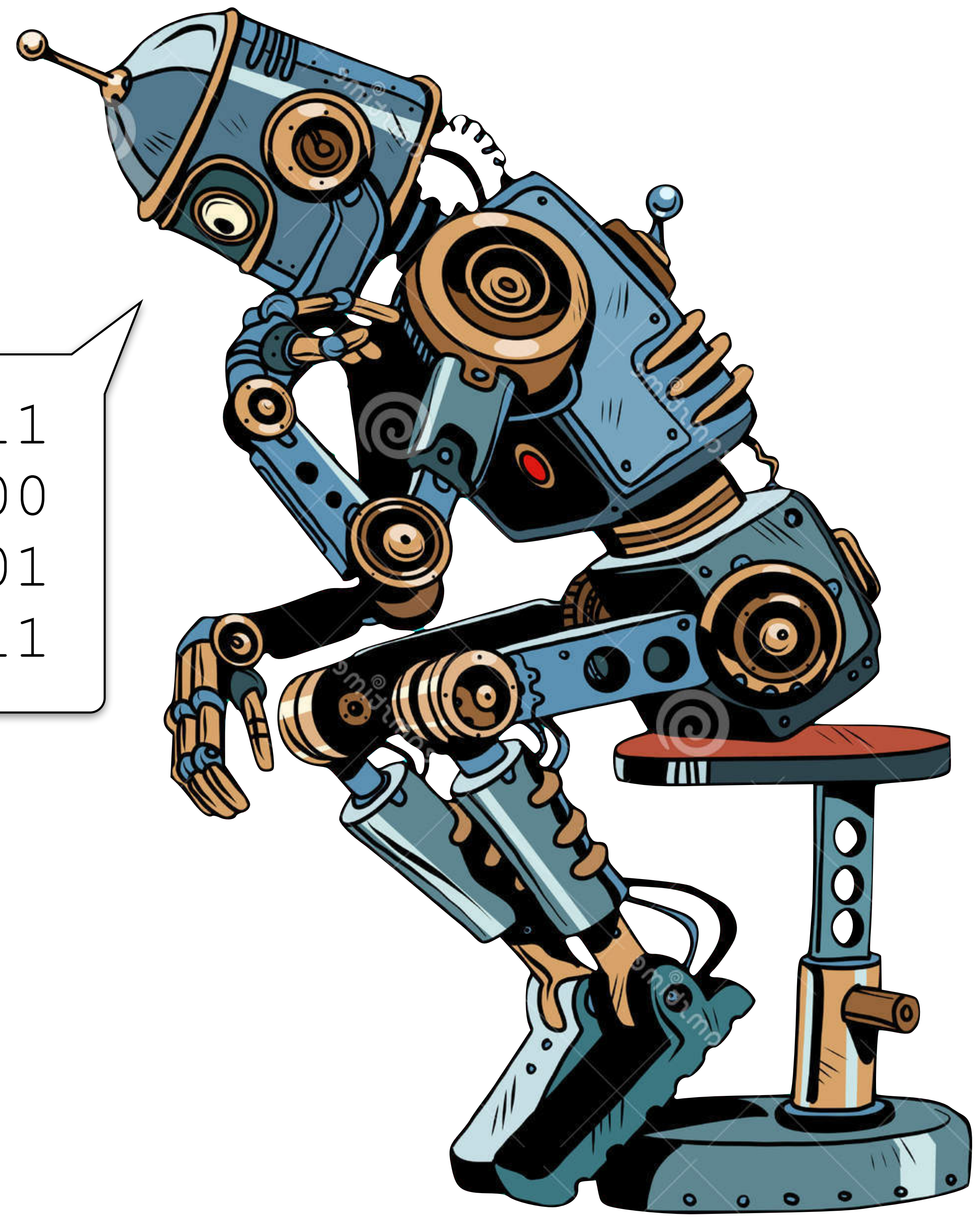
etc...

content & approach



$i \leftarrow i + 1$

0010010100101011
0001001010100100
1100110100111001
1111001101010011



content & approach

algorithms

$i \leftarrow i + 1$

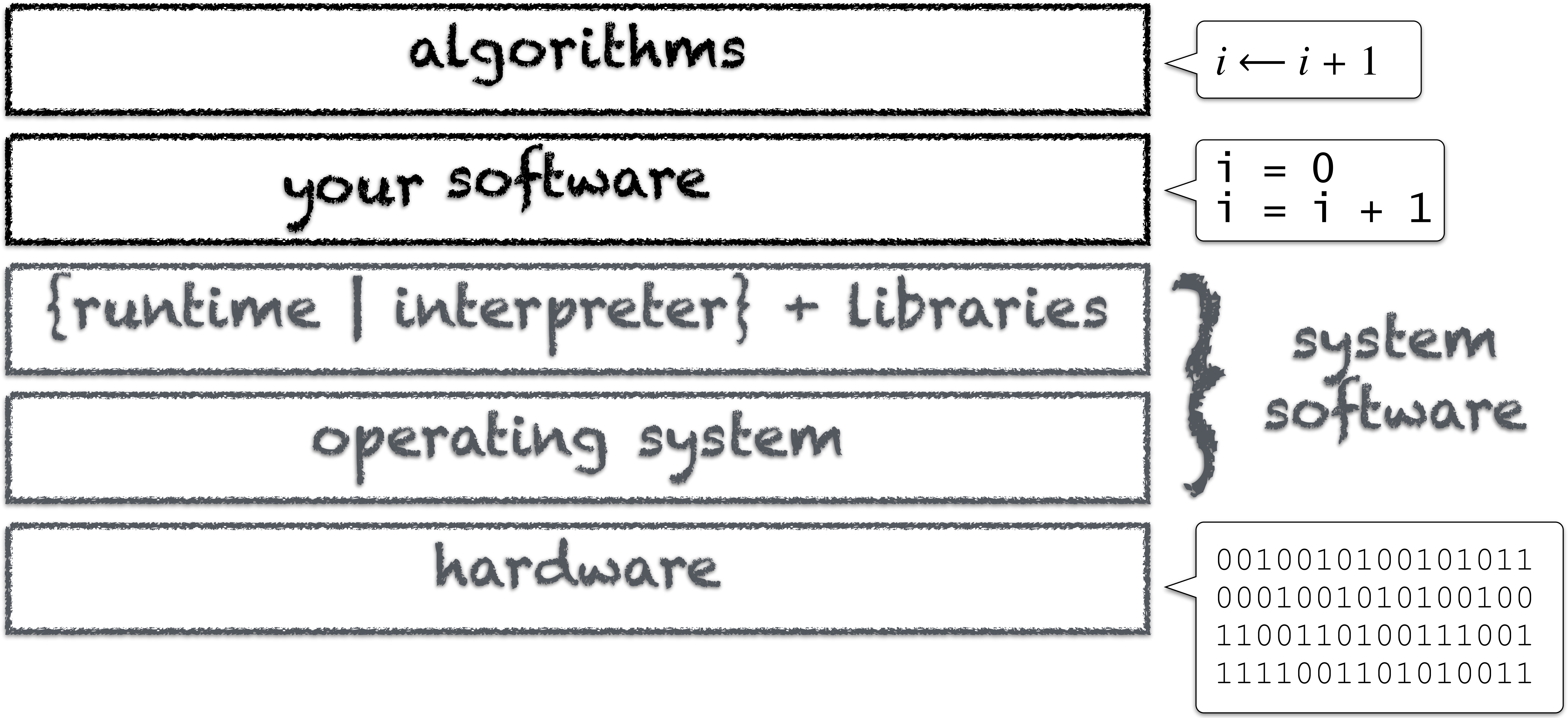
software

```
i = 0
i = i + 1
```

hardware

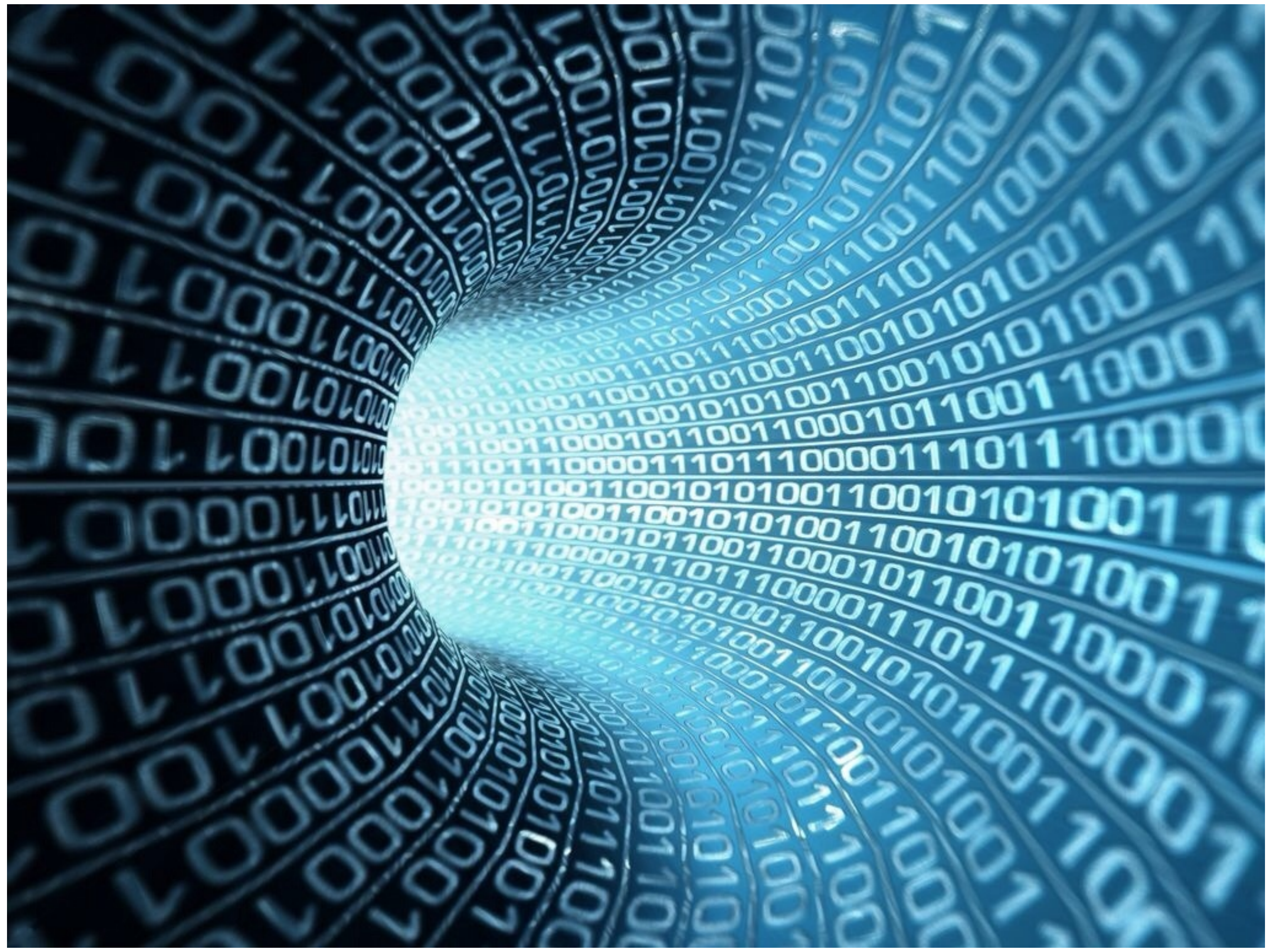
```
0010010100101011
0001001010100100
1100110100111001
1111001101010011
```

content & approach



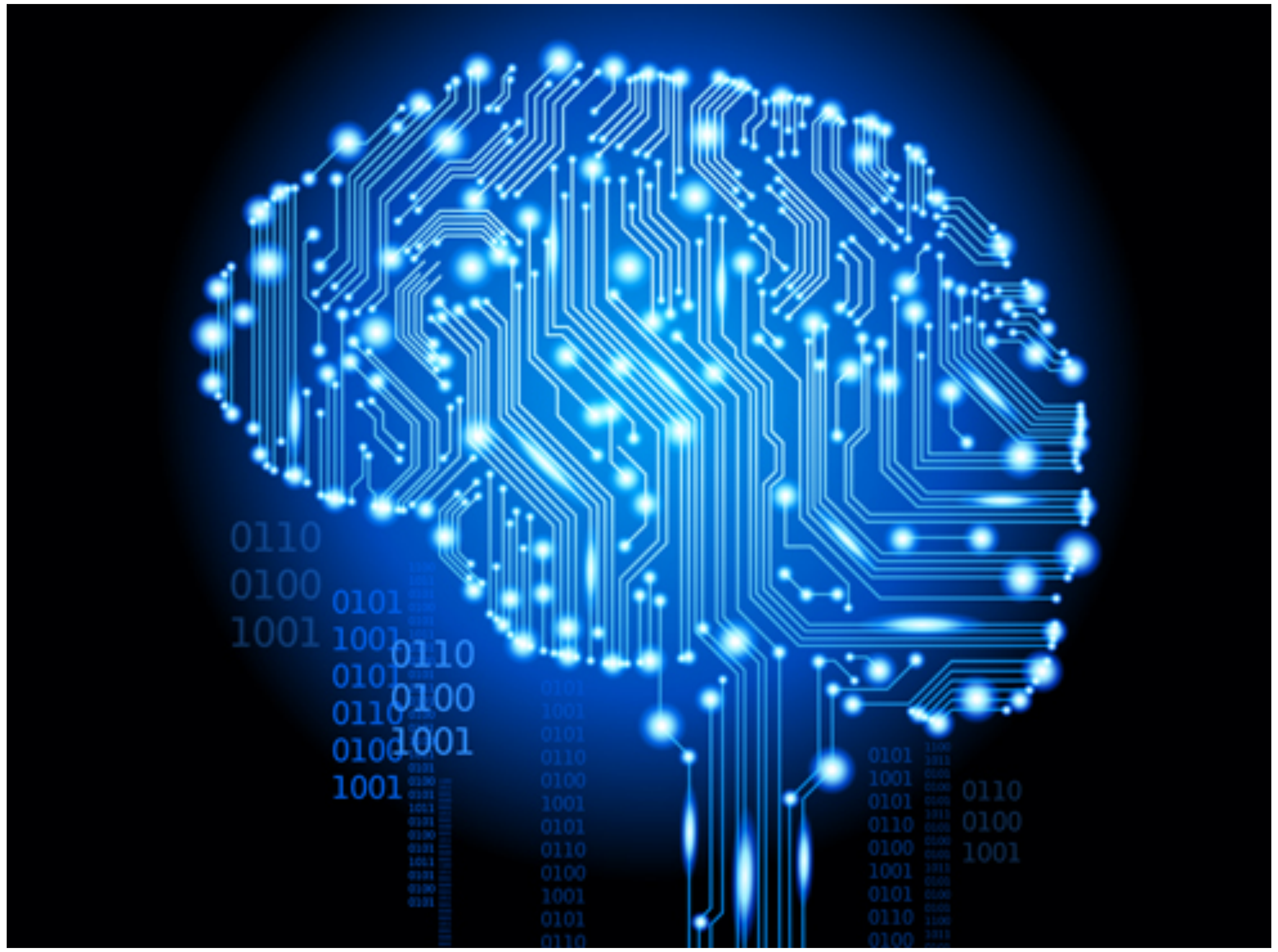
what are the **benefits** of this course?

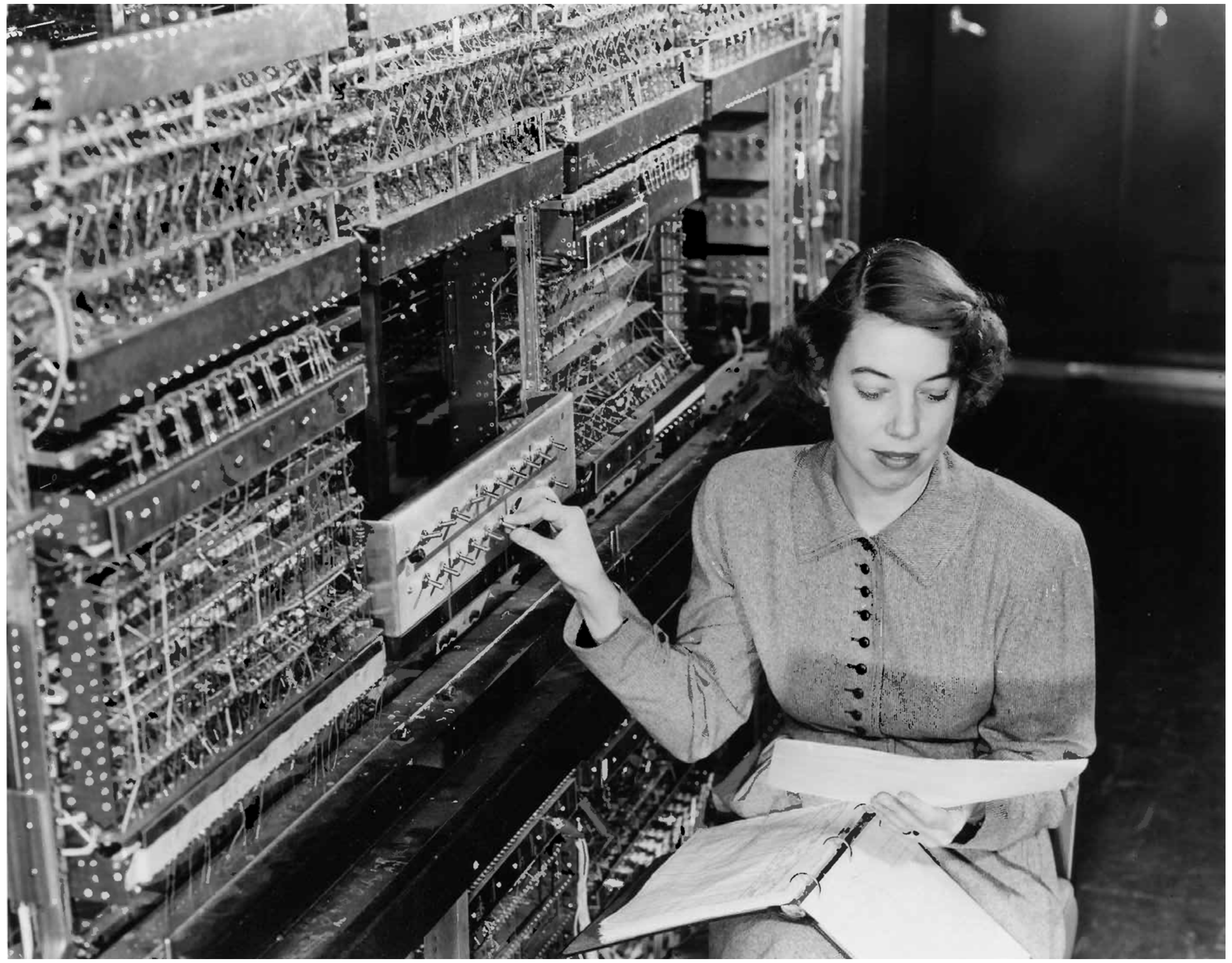
direct benefits



the ability to reason in algorithmic terms

and under computational constraints

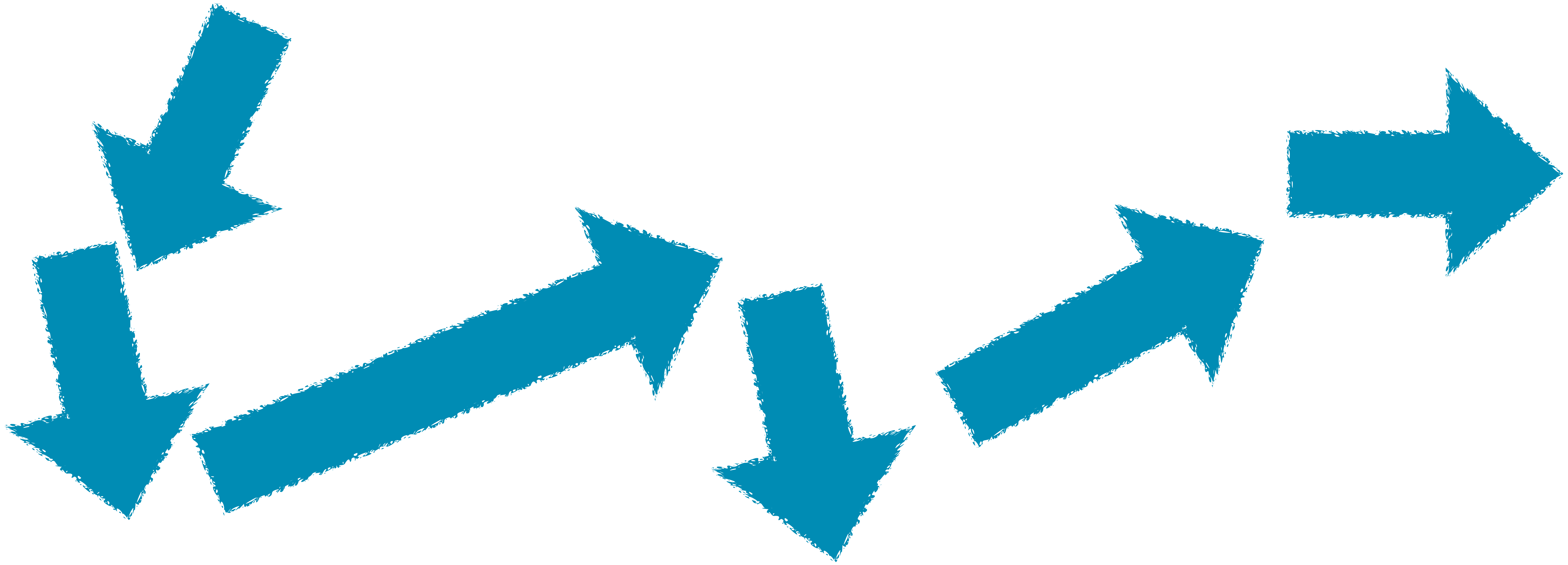




the ability to precisely specify various problems

and solve them by writing computers programs

indirect benefits




learn to think differently
learn to think creatively
experiment the design attitude
learn to navigate through different levels of abstraction
be ready for the digital transformation

decision attitude

assumes that the alternative courses of action are ready at hand, including the best one

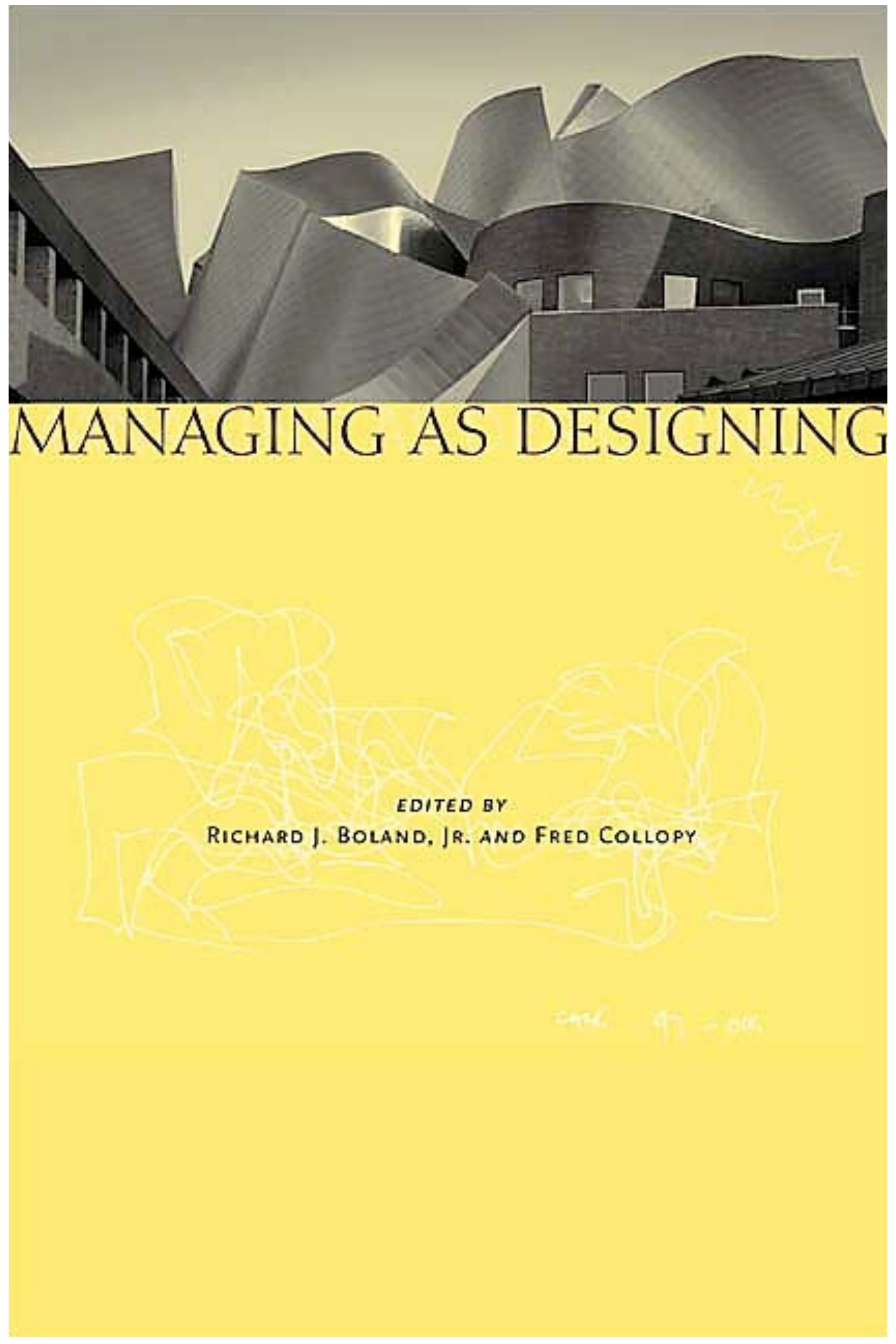
passive view of the decision maker as a problem solver

design attitude

a design attitude views each project as an opportunity for invention that includes a questioning of basic assumptions

designers relish the lack of predetermined outcomes

managing as designing

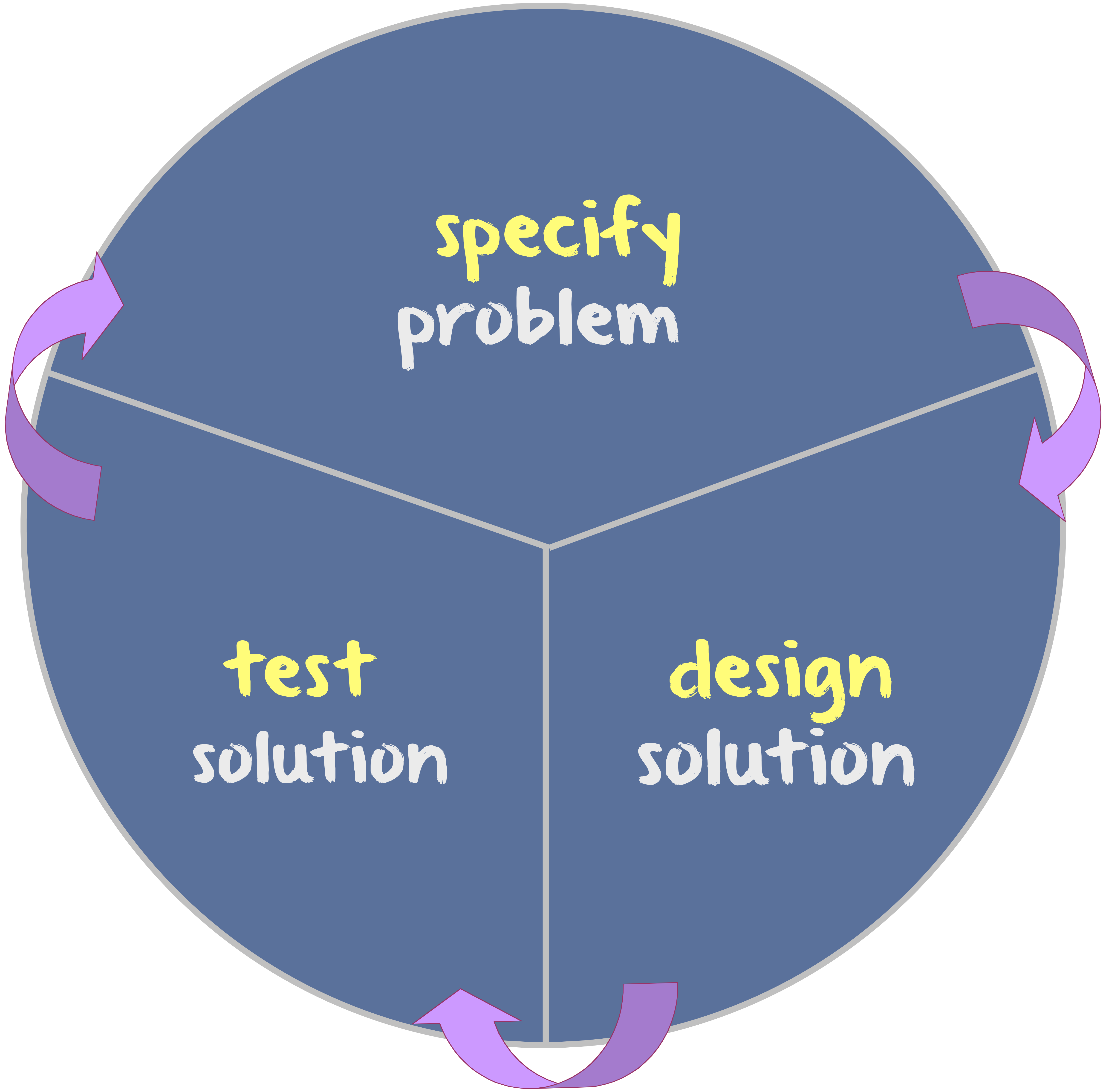


Managing as Designing
R. Boland, F. Collopy
Stanford Press

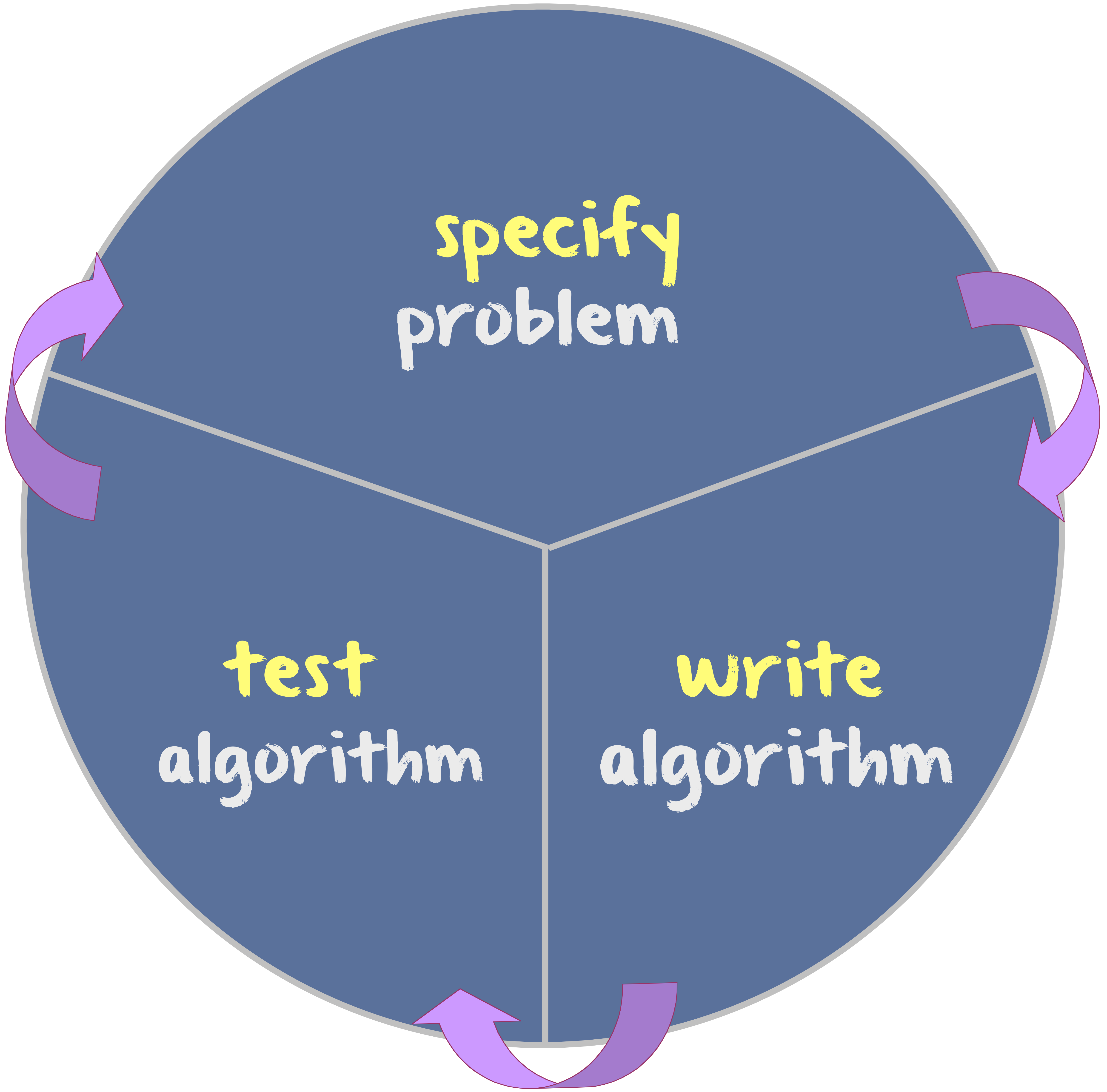
managers should act not only as decision makers, but also as designers

though decision and design are linked in management action, managers and scholars have emphasized the decision face over the design face.

typical design cycle



software development cycle



think abstractions

an abstraction is a set of common properties and laws extracted from several particular examples

examples:

$$\sum \vec{F} = m\vec{a}$$

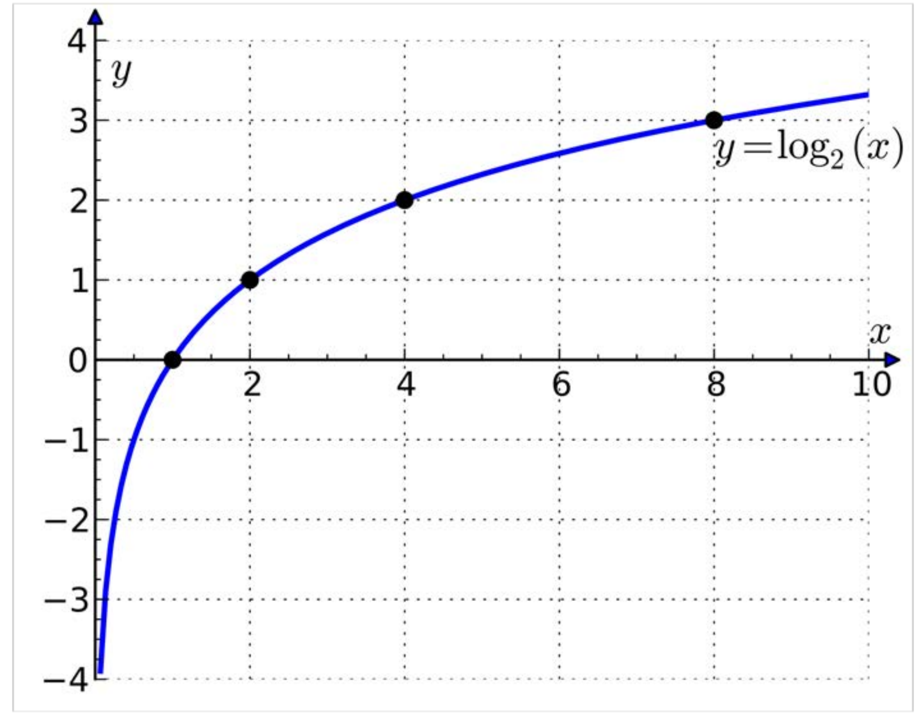
Mutationem motus proportionalem esse vi motrici impressae, et fieri secundum lineam rectam qua vis illa imprimitur

The alteration of motion is ever proportional to the motive force impressed, and is made in the direction of the right line in which that force is impressed

mammals

$$f(x, y) = \sqrt{x^2 + y^2}$$

sphere



thinking in abstractions is one of the key traits in human being

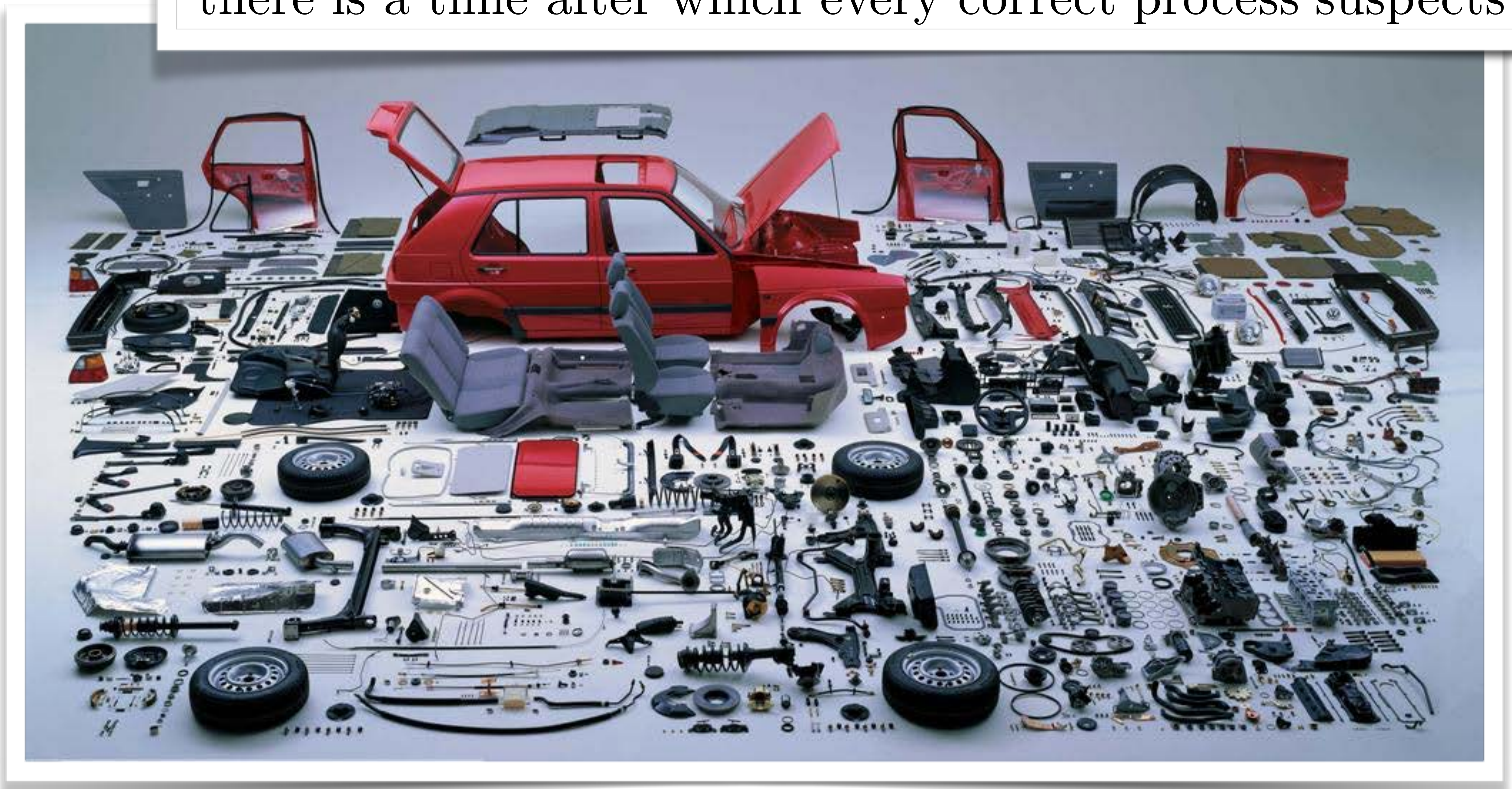
stacking abstractions

THEOREM 1. *$\mathcal{Q} \succeq \mathcal{P}$, $\mathcal{W} \succeq \mathcal{S}$, $\Diamond\mathcal{Q} \succeq \Diamond\mathcal{P}$, and $\Diamond\mathcal{W} \succeq \Diamond\mathcal{S}$.*

PROOF. Let $\mathcal{D}$ be any failure detector in $\mathcal{Q}$, $\mathcal{W}$, $\Diamond\mathcal{Q}$, or $\Diamond\mathcal{W}$. We show that $T_{\mathcal{D}\to\mathcal{D}'}$ transforms $\mathcal{D}$ into a failure detector $\mathcal{D}'$ in $\mathcal{P}$, $\mathcal{S}$, $\Diamond\mathcal{P}$, or $\Diamond\mathcal{S}$, respectively. Since $\mathcal{D}$ satisfies weak completeness, by Lemma 1, $\mathcal{D}'$ satisfies strong completeness.

LEMMA 1. *$T_{\mathcal{D}\to\mathcal{D}'}$ satisfies P1.*

PROOF. Let p be any process that crashes. Suppose that there is a time t after which some correct process q permanently suspects p in $H_{\mathcal{D}}$. We must show that there is a time after which every correct process suspects p in $output^R$.



algorithms

your software

system software

operating system

hardware

get ready for the digital transformation

software is not longer being simply used as support for existing human activities but rather becoming the driver of profound changes in the way we do things and even the source of totally new activities


because for better
or for worse...
... software is now
ruling the world

software is now ruling the world

did you know...

... the largest taxi company owns no vehicles?

... the largest accommodation provider owns no building?

... the most valuable retailer has no inventory?

... the largest travel agency has no public offices?

the amazon effect

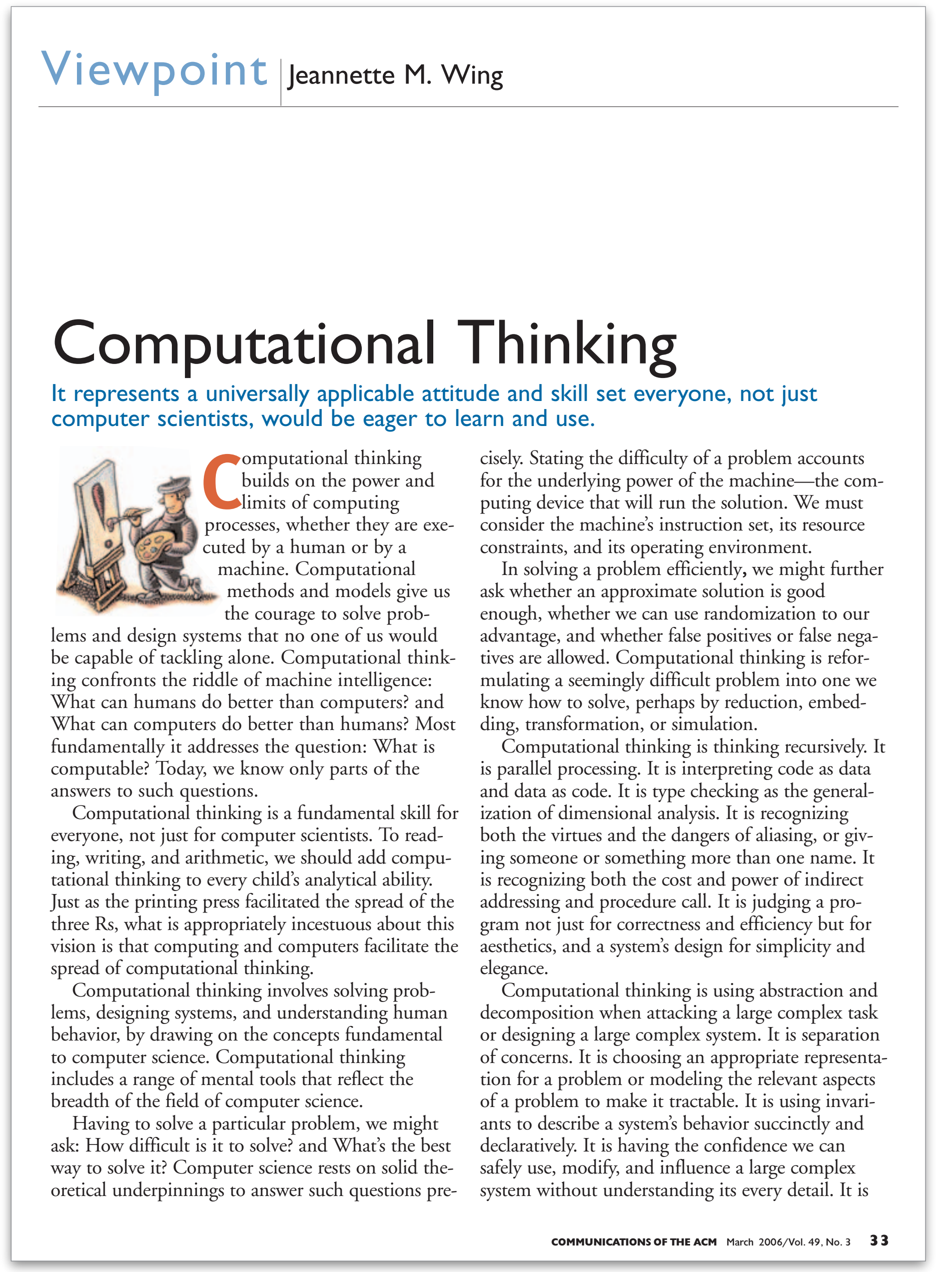
the amazon effect

shopping malls: the american dream

the amazon effect

shopping malls: now zombieland...

books & papers


Viewpoint | Jeannette M. Wing

Computational Thinking

It represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use.

Computational thinking builds on the power and limits of computing processes, whether they are executed by a human or by a machine. Computational methods and models give us the courage to solve problems and design systems that no one of us would be capable of tackling alone. Computational thinking confronts the riddle of machine intelligence: What can humans do better than computers? and What can computers do better than humans? Most fundamentally it addresses the question: What is computable? Today, we know only parts of the answers to such questions.

Computational thinking is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability. Just as the printing press facilitated the spread of the three Rs, what is appropriately incestuous about this vision is that computing and computers facilitate the spread of computational thinking.

Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. Computational thinking includes a range of mental tools that reflect the breadth of the field of computer science.

Having to solve a particular problem, we might ask: How difficult is it to solve? and What's the best way to solve it? Computer science rests on solid theoretical underpinnings to answer such questions precisely. Stating the difficulty of a problem accounts for the underlying power of the machine—the computing device that will run the solution. We must consider the machine's instruction set, its resource constraints, and its operating environment.

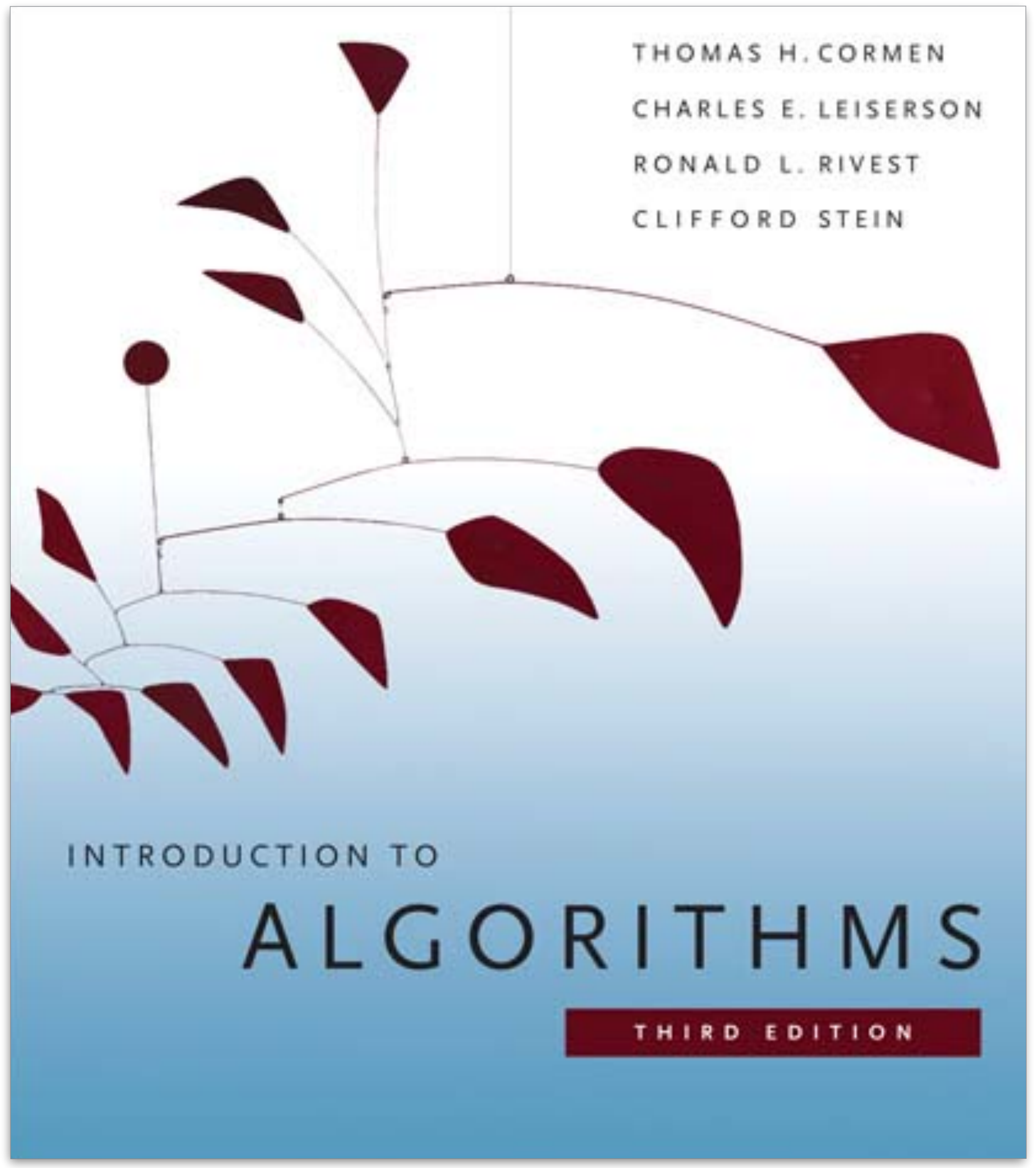
In solving a problem efficiently, we might further ask whether an approximate solution is good enough, whether we can use randomization to our advantage, and whether false positives or false negatives are allowed. Computational thinking is reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation.

Computational thinking is thinking recursively. It is parallel processing. It is interpreting code as data and data as code. It is type checking as the generalization of dimensional analysis. It is recognizing both the virtues and the dangers of aliasing, or giving someone or something more than one name. It is recognizing both the cost and power of indirect addressing and procedure call. It is judging a program not just for correctness and efficiency but for aesthetics, and a system's design for simplicity and elegance.

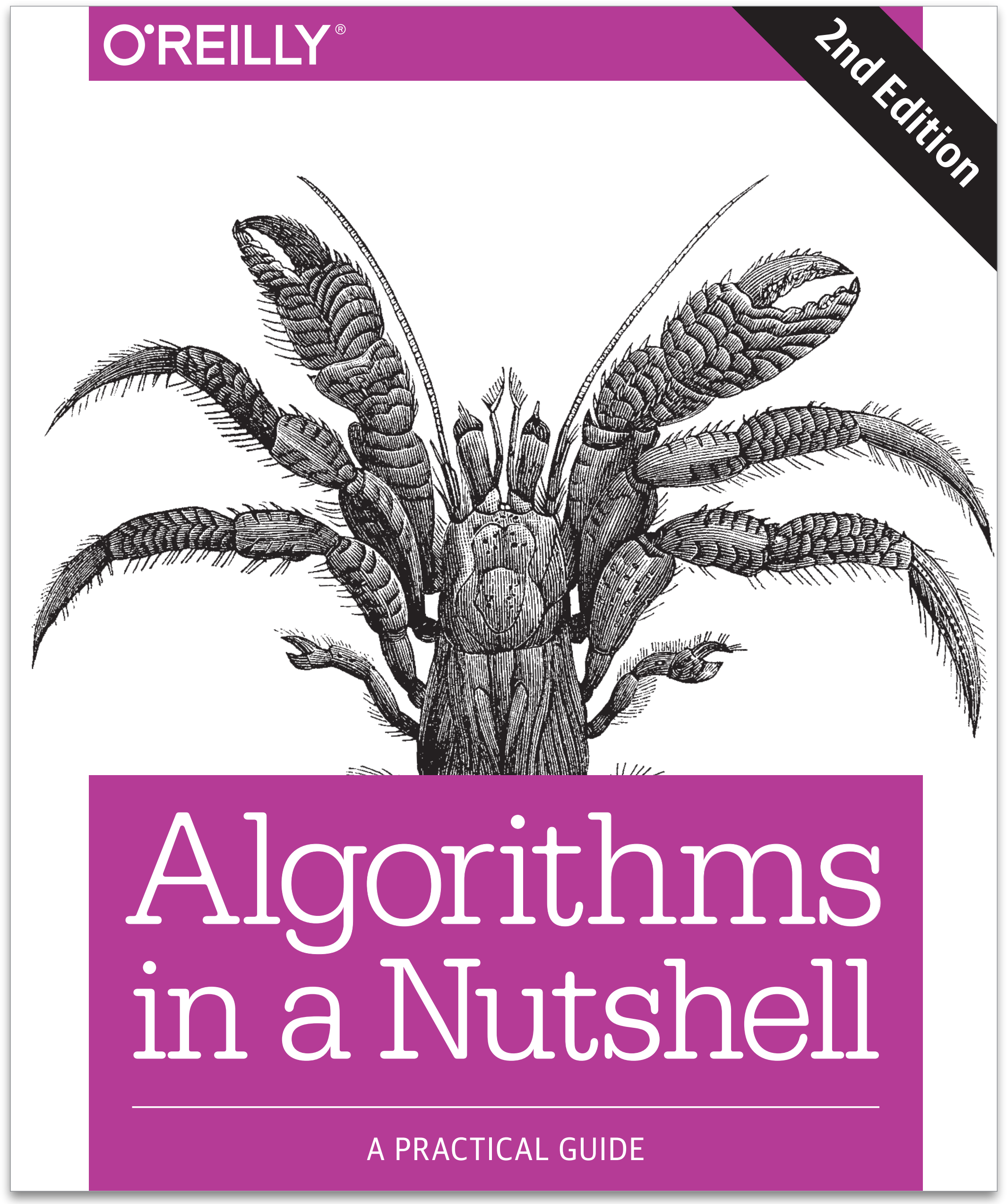
Computational thinking is using abstraction and decomposition when attacking a large complex task or designing a large complex system. It is separation of concerns. It is choosing an appropriate representation for a problem or modeling the relevant aspects of a problem to make it tractable. It is using invariants to describe a system's behavior succinctly and declaratively. It is having the confidence we can safely use, modify, and influence a large complex system without understanding its every detail. It is

COMMUNICATIONS OF THE ACM March 2006/Vol. 49, No. 3 33

Computational thinking. J.M. Wing. Communication of the ACM, 49(3):33–35, March 2006.

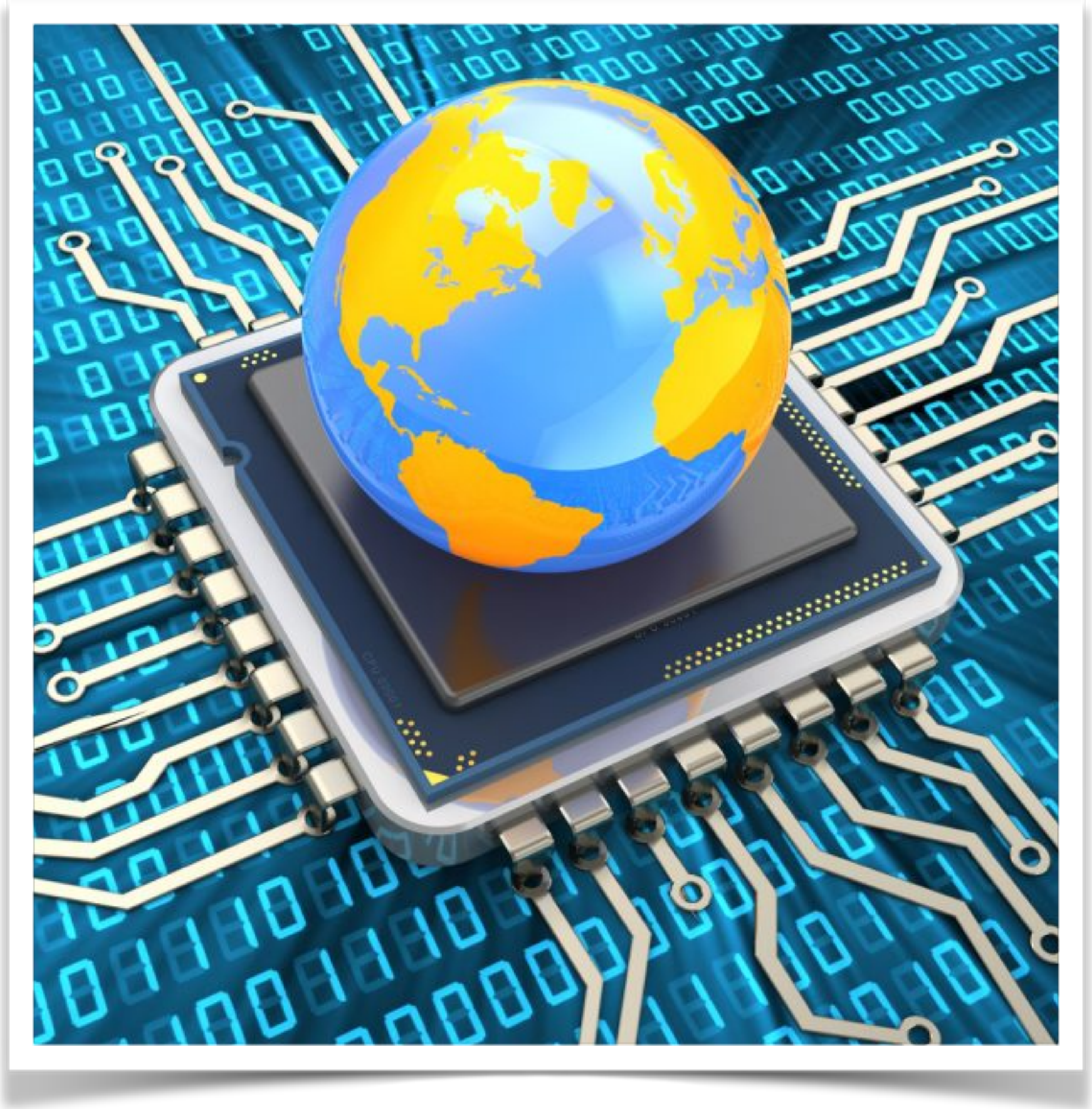


Introduction to Algorithms, 3rd Edition. T.H.Cormen, C.E. Leiserson, R.L. Rivest, C. Stein. July 2009. MIT Press.



Algorithms in a Nutshell, 2nd Edition. G.T. Heineman, G. Pollice, S. Selkow. March 2016. O'Reilly.

overview - week 1



computer architecture

overview - week 2

system software

overview - week 3

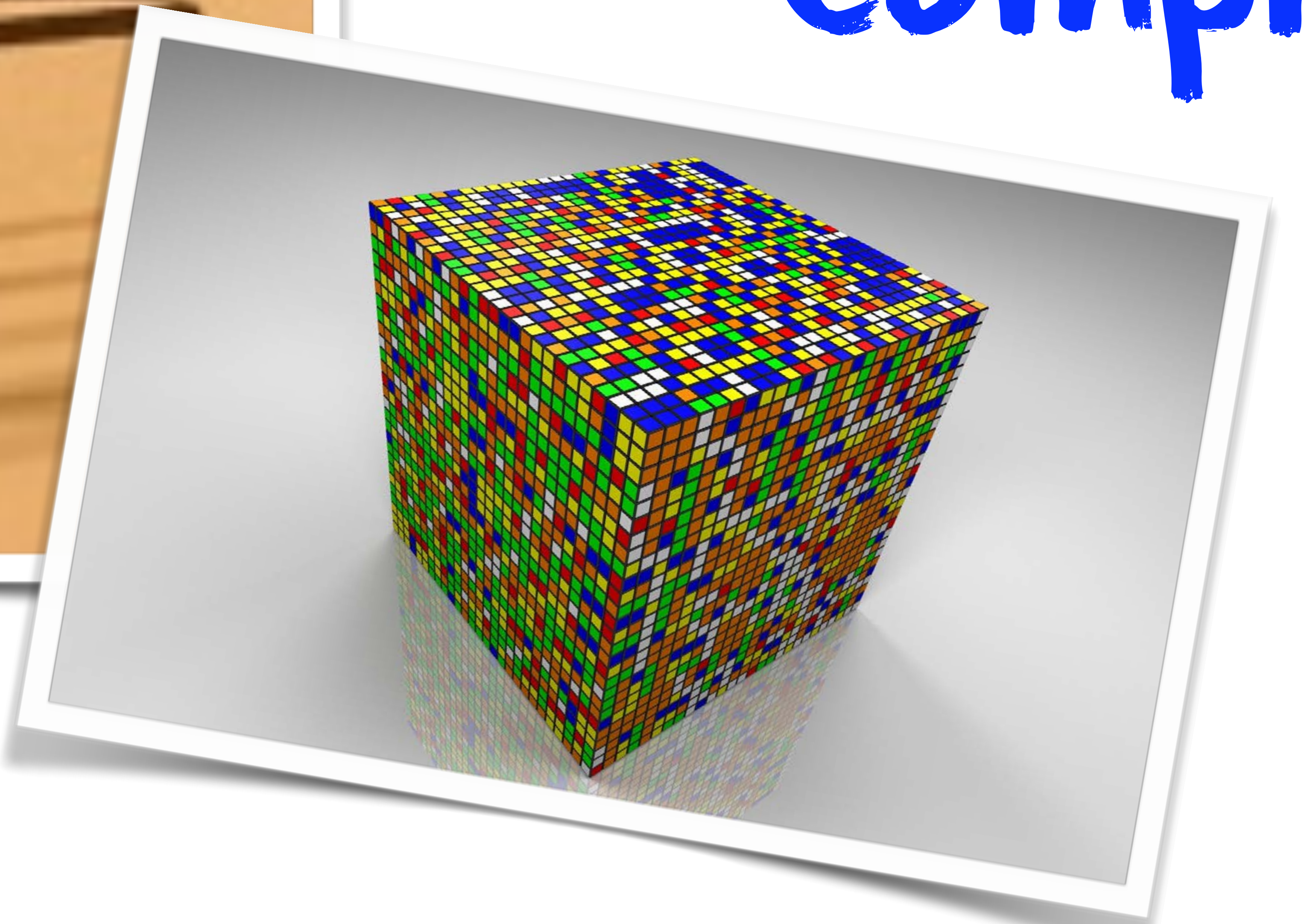
programming basics

overview - week 4

induction &
recursion

overview - week 5

algorithms & computational complexity

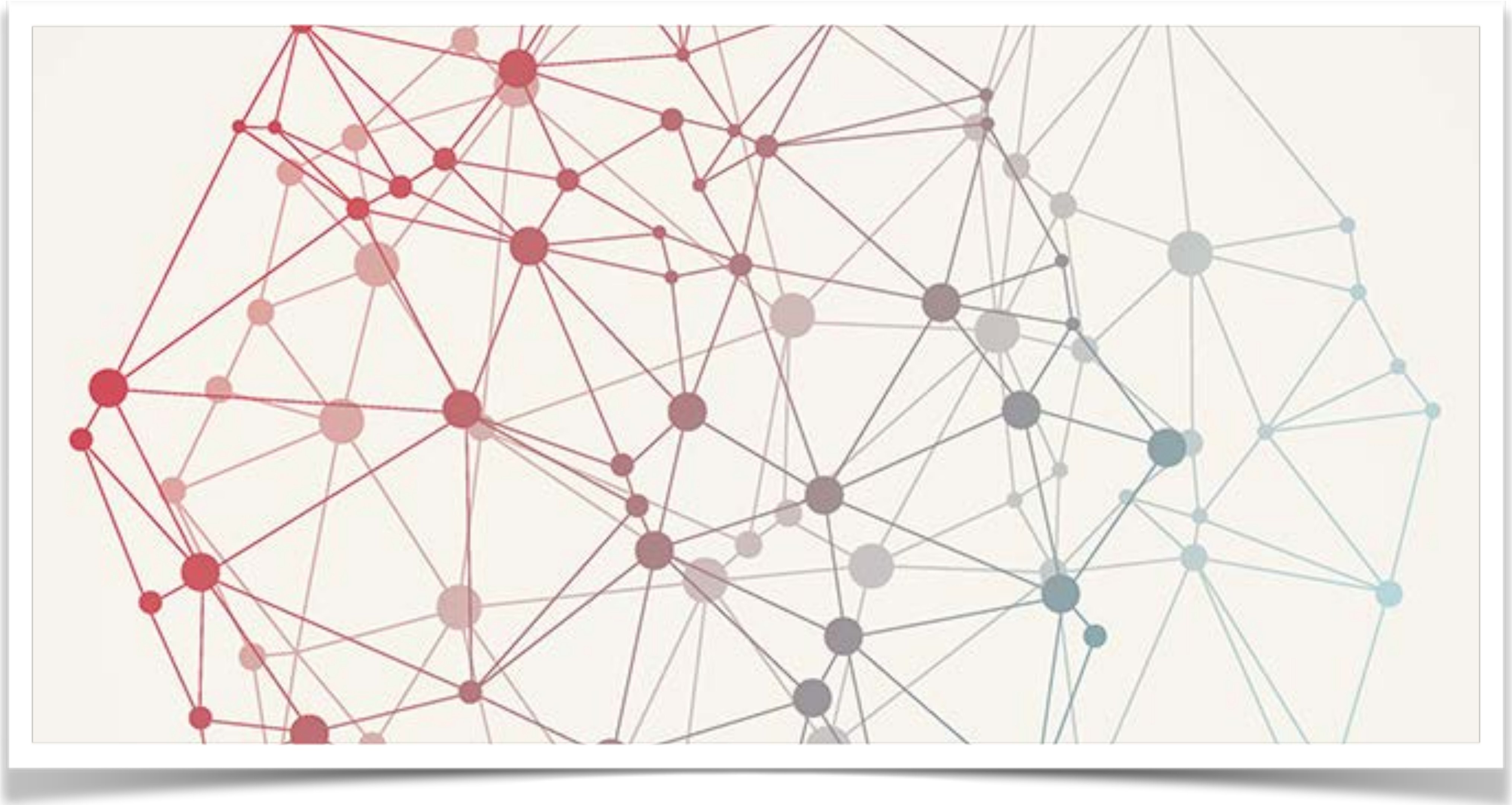


overview - week 6

searching

algorithms

overview - week 7



graph
algorithms

overview - week 8

mid-term test

overview - week 9

mid-term test
correction

overview - week 10

spatial tree

algorithms

overview - week 11

probabilistic algorithms

overview - week 12

classes,

objects &

methods

overview - week 13

inheritance &

polymorphism

overview - week 14

abstract
classes &
types

Calendar

TUESDAY	8.00–10.00		Group A : 14.15–16.00 + Group B 16.15–18.00
Sep 15	course overview	computer architecture	exercises on computer architecture
Sep 22	system software		exercises on system software
Sep 29	programming basics		exercises on programming basics
Oct 06	induction and recursion		exercises on induction and recursion
Oct 13	algorithms and their complexity		exercises on algorithms and their complexity
Oct 20	searching algorithms		exercises on searching algorithms
Oct 27	graphs algorithms		consolidation exercises
Nov 03	intermediate test		exercises on graph algorithms
Nov 10	intermediate test – Correction		consolidation exercises
Nov 17	spatial tree algorithms		exercises on spatial tree algorithms
Nov 24	probabilistic algorithms		exercises on probabilistic algorithms
Dec 01	classes, objects and interfaces		exercises on classes, objects and interfaces
Dec 08	inheritance and polymorphism		exercises on inheritance and polymorphism
Dec 15	abstract classes & types		exercises on abstract classes & types

Legend:

Course
Exercise
Evaluation

this exercise session is moved to Friday 6th November

programming languages

python

java

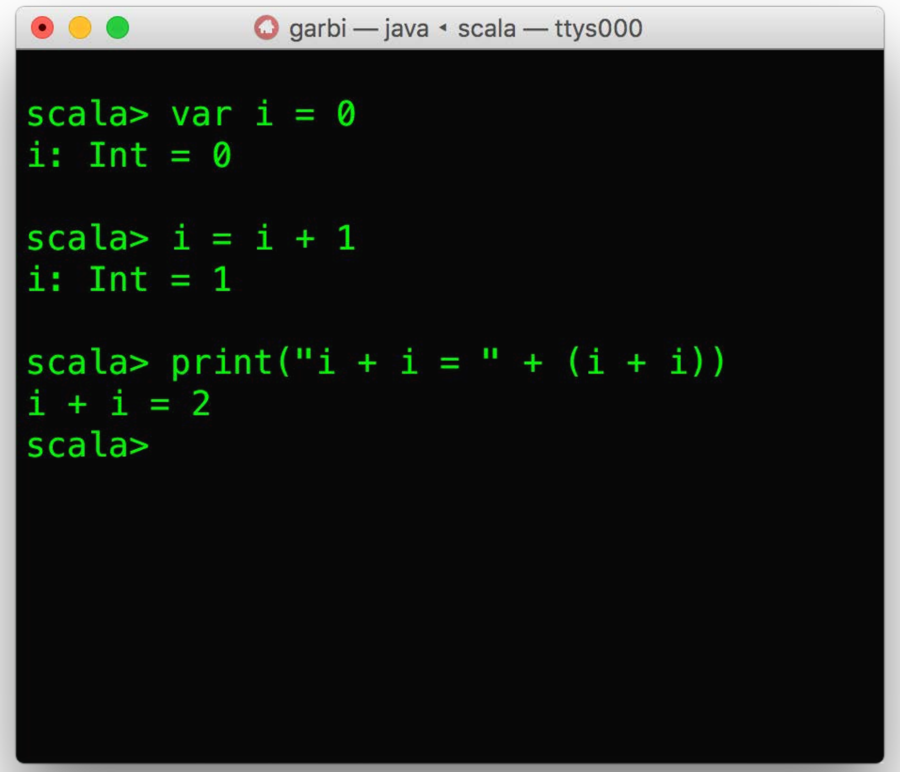
development tools

PyCharm

(python)

IntelliJ

(python / java)



the good old terminal

practical issues

each week

1/3 of the students follow the course

in the class room

2/3 of the students follow the course

online via streaming

lectures: Amphimax 351

exercises: Amphipôle 140 + 146

exercise support only
provided online, via zoom

practical issues

Septembre

Lu	Ma	Me	Je	Ve	Sa	Di
	01	02	03	04	05	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Octobre

Lu	Ma	Me	Je	Ve	Sa	Di
			01	02	03	04
05	06	07	08	09	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Novembre

Lu	Ma	Me	Je	Ve	Sa	Di
						01
02	03	04	05	06	07	08
09	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

Décembre

Lu	Ma	Me	Je	Ve	Sa	Di
	01	02	03	04	05	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

practical issues

web sites

doplab.unil.ch/act

doplab.unil.ch/act-moodle

evaluation

the evaluation is based on

- an intermediate test during the semester
- a final exam* during the exam session

$$\text{grade} = 0.4 \times \text{test} + 0.6 \times \text{exam}$$

* the final exam is written in the regular session and either oral or written in the retake session