ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
CAMPUS DI FORLÌ

DIT PhD
Introduction to Computational Thinking and Programming

Lesson 1. Computational Thinking

Alberto Barrón-Cedeño
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29/10/2025

L'idonietà

This activity includes two modules: Programming and Statistics

You will submit your solution to a couple of problems/exercises from each module

Details at due time

Table of Contents

You and your instructor

Quick Introduction

Who are you?

The instructor

1. BEng in Computing at UNAM, Mexico
   MSc in Computing at UNAM, Mexico
   - Internship at UdeM, Canada

The instructor

1. BEng in Computing at UNAM, Mexico
   MSc in Computing at UNAM, Mexico
   - Internship at UdeM, Canada
2. MSc in AI at UPV, Spain
   PhD in AI at UPV, Spain
   - Internship at UofS, UK

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   - Internship at BUW, Germany
4. Scientist at QCRI, Qatar
5. Professor at UniBO, Italy

PhDs that I am supervising

3rd year

Paolo Gajo

Gastronomy research through LLMs

PhDs that I am supervising

3rd year

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Gastronomy research through LLMs

- Internship at Dalhousie University (Halifax, Canada)
- 6+ peer-reviewed full papers published (incl. Neurips and IPM)
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Hate speech identification

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Arianna Muti (Università Milano-Bocconi, Italy)
Hidden in Plain Sight: Detecting Misogyny beneath Ambiguities and Implicit Bias in Language

- Internship at Expert.ai (Modena, Italy)
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Marco Casavantes (co-supervision)
Multidimensional Analysis of Text for Automated Detection of Computational Propaganda in Twitter

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Analysis of phishing and spam email (cybersecurity)

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Unfinished

Francesco Fernicola (CL at the European Parliament)
Return to the Source: Assessing Machine Translation Suitability

- In co-supervision with EURAC Research (Bolzano, Italy)
- 5+ peer-reviewed full papers published (two during his masters)

Computing at DIT

Recent and ongoing research projects[1]

- Giara on DL and LLMs for gastronomy explanation
  `https://progettogiara.it`

[1] Non exhaustive

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- UNITE on exploiting LLMs for language learning
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Computing at DIT

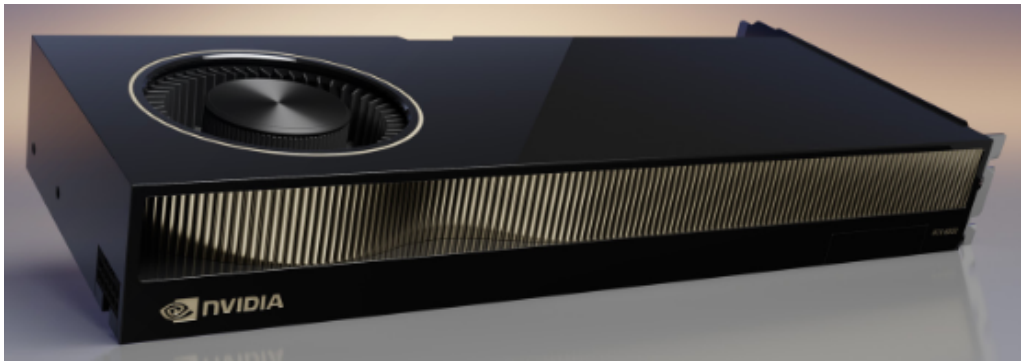
Computing Power[2]

- 4 NVIDIA RTX 6000 Ada

  https://www.nvidia.com/en-us/design-visualization/rtx-6000

- 2 NVIDIA Quadro P4000

  https://www.techpowerup.com/gpu-specs/quadro-p4000.c2930



[2] Dedicated to deep learning (training and out-of-the-box)

Lesson coordinates

Slides and code available at:

- `https://albarron.github.io/teaching/phd-comp-thinking/`

Tools

Python 3 programming language
We will use Google's Colab: `https://colab.research.google.com`

For (more) serious affairs, you could consider

1. Command line or
2. Integrated development environment; e.g., Pycharm[3], Eclipse[4] or local Jupyter[5]

[3] `https://www.jetbrains.com/pycharm/`
[4] `https://www.eclipse.org/`
[5] `https://jupyter.org/`

Contents

Lesson contents

Introduction to computational thinking

1. Problem definition and solving
2. Decomposition
3. Pattern recognition
4. Abstraction
5. Algorithmic thinking

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Introduction to computational thinking

1. Problem definition and solving
2. Decomposition
3. Pattern recognition
4. Abstraction
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Programming

6. Introduction to programming
7. Jupyter notebooks
8. Basic operations
9. Dealing with text

Computational Thinking

The tools we use have a profound and devious influence on our thinking habits, and therefore on our thinking abilities.

Edsger W. Dijkstra[6]

[6] https://amturing.acm.org/award_winners/dijkstra_1053701.cfm

Computational Thinking

"[Computational Thinking] represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use"

Jeannette M. Wing, CMU (2006)

Humans and Computers

Computational methods and models give us the *courage* to solve problems and design systems

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Computational thinking confronts the riddle of machine intelligence:

- What can humans do better than computers?
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Some examples of each?

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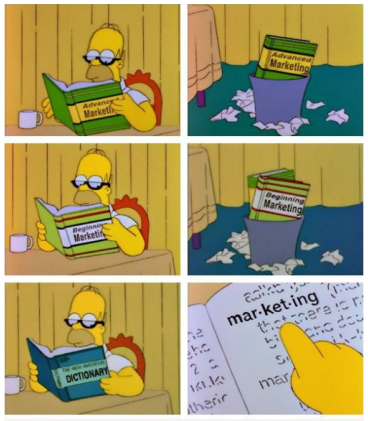
  Some examples of each?

- What is computable?

A few definitions



https://en.wiktionary.org/wiki/problem
https://en.wikipedia.org/wiki/System
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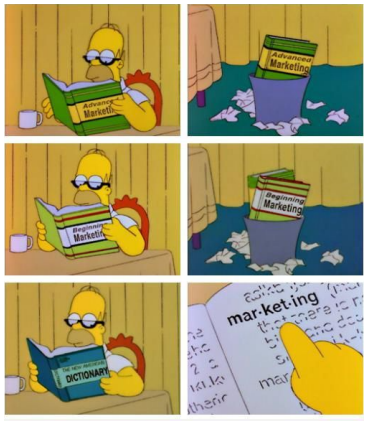

Problem

1. A difficulty that has to be resolved or dealt with
2. A question to be answered, schoolwork exercise

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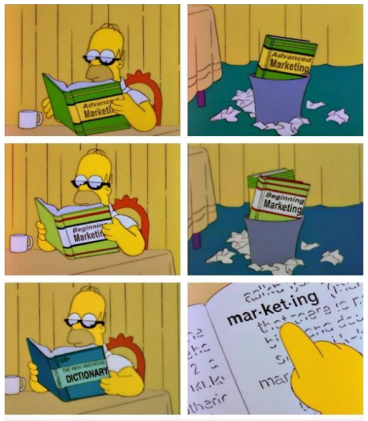

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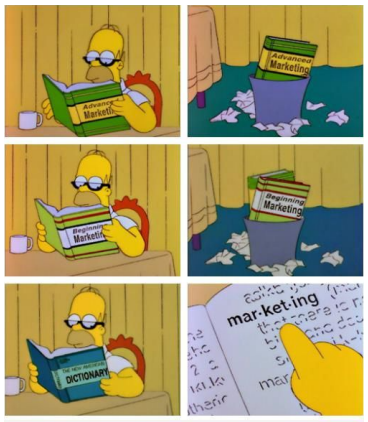

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System

1. A group of interacting or interrelated elements that act according to a set of rules to form a unified whole

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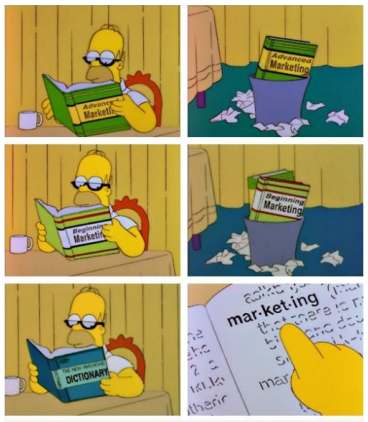

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Computability

1. The ability to solve a problem in an effective manner

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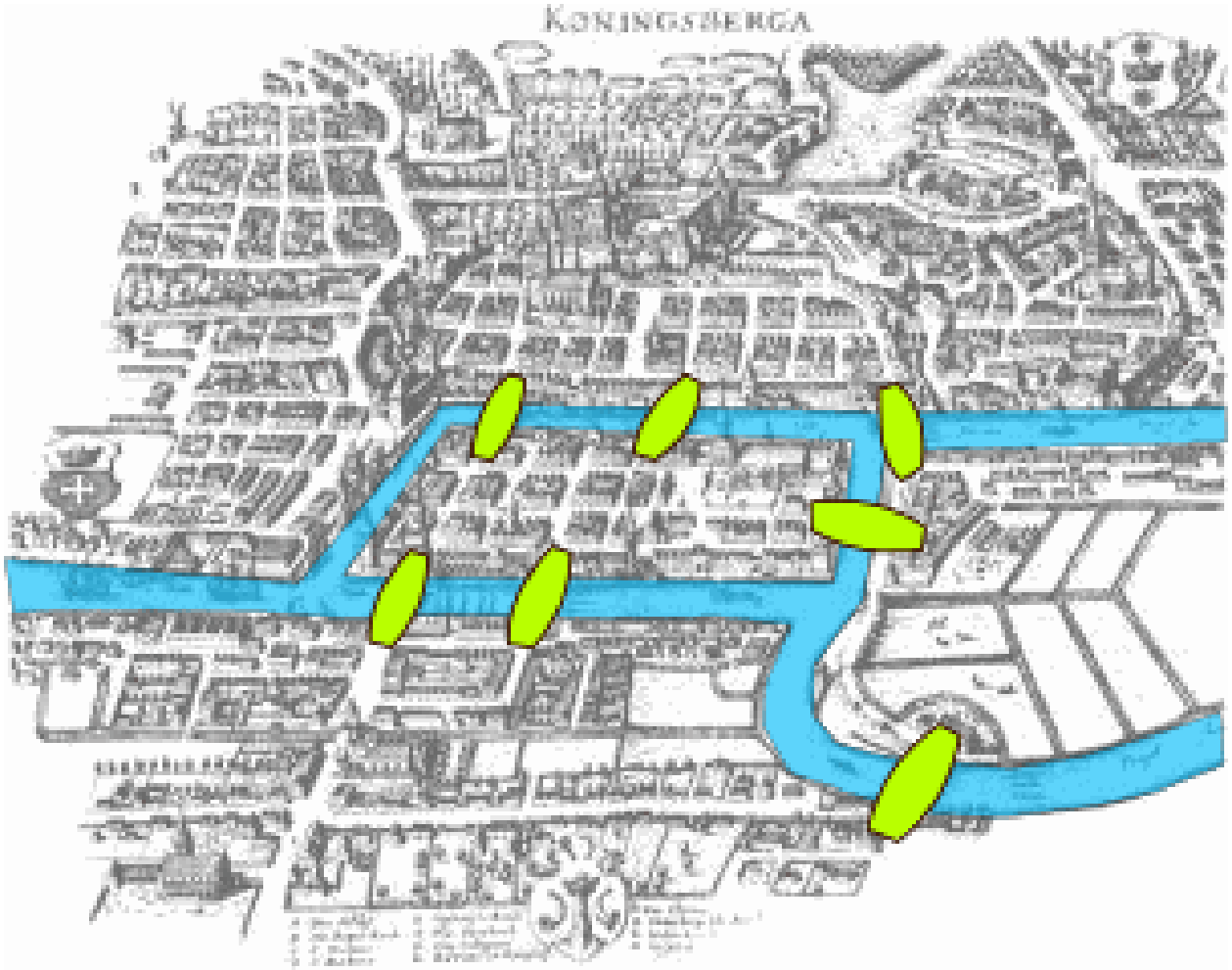
Activity 1: The Seven Bridges of Königsberg

Task: Devise a path through the city of Königsberg that would cross each of the bridges once and only once



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Looking for a solution

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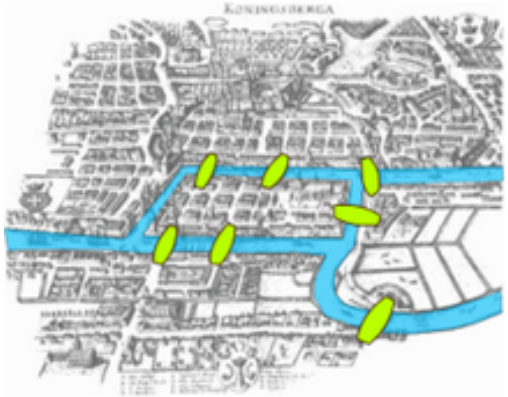

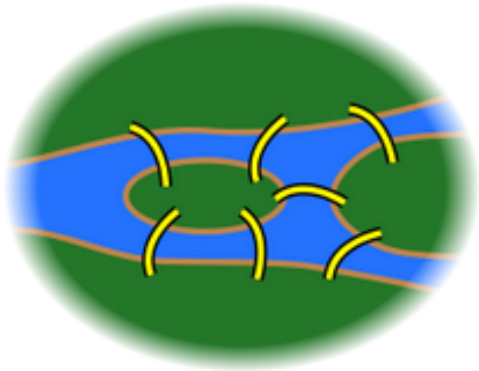

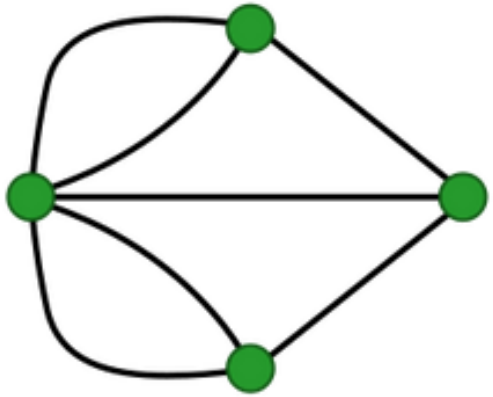

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Looking for a solution

Can you devise a solution using this abstraction?

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Solution: There is no solution

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The foundations of graph theory
Leonhard Euler (1736)

What is involved in computational thinking

- Defining problems

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- Solving problems

What is involved in computational thinking

- Defining problems
- Solving problems
- Designing systems

What is involved in computational thinking

- Defining problems
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- Designing systems
- Understanding human behavior

All by drawing on the concepts fundamental to computer science

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- How difficult is it to solve?

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- How difficult is it to solve?
- What's the best [doable|acceptable|affordable] way to solve it?

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- Defining problems
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All by drawing on the concepts fundamental to computer science

- How difficult is it to solve?
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- Is an approximate solution enough?

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		predicted label	
		positive	negative
true label	positive	true positive	false positive
	negative	false negative	true negative

How to deal with a difficult problem?

[By] reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation

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Have you solved a problem using any of these techniques?

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Copying a drawing?

`https://www.wikihow.com/Copy-a-Drawing-or-Picture-by-Hand`

The thinking in computational thinking

Thinking in terms of . . .

- Prevention

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Thinking in terms of ...

- Prevention
  Do you backup your mobile phone?

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  Do you backup your mobile phone?
  There are two kinds of people

  1. those who backup
  2. those who have never lost all their data [mobile phone]

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Getting ready to recover from worst-case scenarios through

redundancy → If I keep money in my backpack, I can go home even if I loose my wallet

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redundancy	$\rightarrow$	If I keep money in my backpack, I can go home even if I loose my wallet
damage containment	$\rightarrow$	If I have an exam, I will ride to the university earlier than usual

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redundancy	→	If I keep money in my backpack, I can go home even if I loose my wallet
damage containment	→	If I have an exam, I will ride to the university earlier than usual
error correction	→	Before handling my report, I will pass a spell checker

Computational thinking is search, search, and more search

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How do you

- Buy the best possible item on Amazon?
- Find the best match on Tinder?
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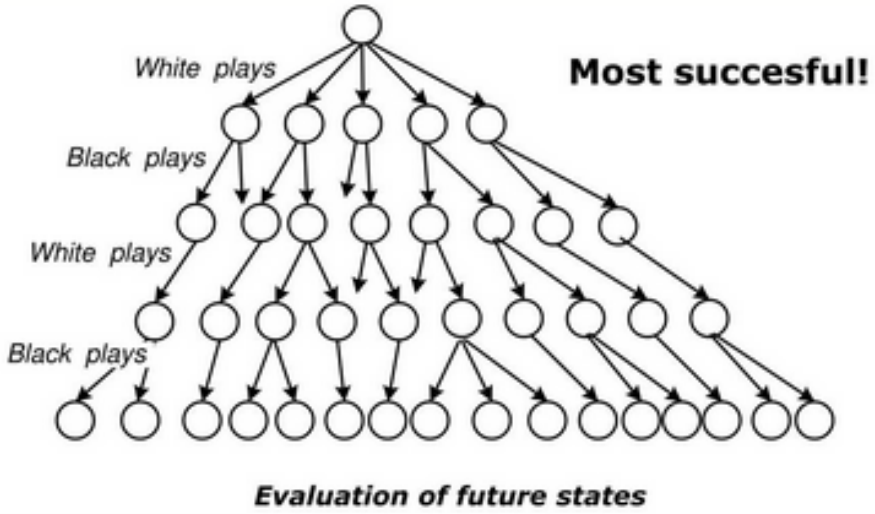

What computational thinking is and is not

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Conceptualising, not programming

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- A way humans solve problems
- Not trying to get humans to think like computers

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Computers are dull and boring
Humans are clever and imaginative
Humans make computers exciting

Computational Thinking: The three As

An iterative process based on three stages:

Abstraction (Problem Formulation). One attempts to conceptualize a problem verbally, e.g., by trying to formulate a question such as "How does gravity work?," or through visual thinking, e.g., by drawing a diagram identifying objects and relationships

(Repenning et al., 2016)

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Abstraction (Problem Formulation). One attempts to conceptualize a problem verbally, e.g., by trying to formulate a question such as "How does gravity work?," or through visual thinking, e.g., by drawing a diagram identifying objects and relationships

Automation (Solution Expression). It is expressed in a non-ambiguous way so that the computer can carry it out; e.g., through computer programming (or through *prompting*?)

Analysis (Execution & Evaluation). The solution gets executed (by the computer) in ways that show the direct consequences of one's own thinking. Visualisations could support the evaluation of solutions

(Repenning et al., 2016)

Algorithm

An algorithm is...

Definition 1 A finite sequence of well-defined (computer-implementable) instructions, typically to solve a class of problems or to perform a computation

`https://en.wikipedia.org/wiki/Algorithm`

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Definition 2 An explicit, precise, unambiguous, mechanically-executable sequence of elementary instructions, usually intended to accomplish a specific purpose.

Erickson (2019, p. 1)

Activity 2: The panino[7]

Problem: Write the algorithm to prepare a *panino*

[7] Since recipes are *just* algorithms

Activity 6: The panino

My algorithm to prepare a *panino*[8]

[8] Via Taranto from `https://ilpaninobologna.com`

Activity 6: The panino

My algorithm to prepare a *panino*[8]

Ingredients:

bread • *prosciutto crudo* • *pecorino di Pienza* • *carciofini sott'olio*

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Activity 6: The panino

My algorithm to prepare a *panino*[8]

Ingredients:

bread • *prosciutto crudo* • *pecorino di Pienza* • *carciofini sott'olio*

1. Cut the bread into two halves horizontally

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Activity 6: The panino

My algorithm to prepare a *panino*[8]

Ingredients:

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1. Cut the bread into two halves horizontally
2. Add three slices of *prosciutto* on top of the bottom half
   * get sure not to go beyond the border of the bread

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   * get sure not to get too much oil

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   * get sure not to get too much oil
5. Put the top half of bread on top

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My algorithm to prepare a *panino*[8]

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6. Enjoy

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Activity 6: The panino

Possible *issues* in your/my recipes[9]

- Under-specification?

[9] Keep in mind that this is a toy problem

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Activity 6: The panino

Possible *issues* in your/my recipes[9]

- Under-specification?
- Lack of identification of the input?
- Imprecise identification of the problem?

[9] Keep in mind that this is a toy problem

Describing Algorithms

The 4 components of an algorithm

What: A precise specification of the problem that the algorithm solves

From (Erickson, 2019, p. 11)

[10] Not covered in this lesson
[11] idem
[12] For instance, yourself 6 months ago

Describing Algorithms

The 4 components of an algorithm

- What: A precise specification of the problem that the algorithm solves
- How: A precise description of the algorithm itself

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- Why: A proof that the algorithm solves the problem it is supposed to solve[10]

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- No particular development order
- Write for an audience; this is not intended for yourself
- Write for people who is not as clever as you are[12]

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Natural vs Programming languages

Natural languages

- An *ordinary* language (e.g., Italian)
- Written or oral
- It has evolved naturally in humans, usually without specific and deliberate planning[13]
- *Problem*: ambiguity
  (e.g., "visiting relatives can be annoying")

[13] Consider Klingon or Sith

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Programming languages

- Formal-born languages
- Specific syntactic rules that avoid ambiguous statements
- *Sentences* convey one single meaning
- They can have a significant degree of abstraction

[13] Consider Klingon or Sith

Programming language

A formal language comprising a set of instructions that produce various kinds of output [given an input][14]

[14] https://en.wikipedia.org/wiki/Programming_language

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Diagram from L. Moroney's Introduction to TensorFlow for Artificial Intelligence, Machine Learning, and Deep Learning

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