Perspectives on Programming

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Programming is . . .

A Form of Communication

Talking to children

Did you notice how we talk to children?

We don't say:

> Assuming the standard three-dimensional physical space, please identify the coordinates of the spherical object in question.

Instead we say: Where . . . is . . . ball?
and then we might say: Here is ball!

Why?

Why do we talk to children this way?

- Children can only understand a simple vocabulary
- Children only understand simple ideas
- Children can only understand slowly- and clearly-enunciated sounds
- Children understand the emotion in the sentence more than the actual words

Instructing a child

We talk to children to express love, to make them feel safe, etc., and sometimes to make them do things for us.

We talk to machines to make them do things for us.

Instructing a 3-year old to get you a drink

- Walk to the fridge
- Open the fridge
- Get the milk. Be careful, it's heavy.
- Put the milk on the counter.
- Close the fridge
- Get a glass from the cabinet to your right.
- Pour some milk. Not too much. It might spill.
- Bring me the glass. Use two hands.
- Put the milk back in the fridge. Don't forget to close the door.

Instructing a 3-year old to get you a drink

Our instructions are tailored to what we understand about the child's abilities.

- We assume that the child can interpret basic English sentences, that the child can walk, that the child can exercise the right muscles to carry a heavy container, etc. We don't give any instructions about how to perform such tasks.
- We are careful to use instructions that the child can understand and has a chance at performing. We don't ask the child to go to the store to buy some milk or ask the child to read the labels on the containers.

Instructing a 3-year old to get you a drink

- We assume the child can carry a full glass but we know this is challenging. We give detailed instructions about such tasks.

- We assume the child can only remember a few things at once. We break the task into small steps and wait for feedback before giving the next step.

Asking a close adult to get you a drink

I am thirsty honey.

The person understands that when you are thirsty and that the nice thing to do is to offer you a drink. We can rely on the person to have a memory of our preferences and to get a glass of milk; if there is no milk we expect the person to make a decision to get water instead, etc.

Talking to a microwave

- Sometimes it is very easy to say what we want to say. If we want to say "heat this item for one minute" all we have to do is push one button.
- Some things are harder to say. Have you ever tried to thaw a chicken using a microwave? It involves a long complicated process with many buttons and it usually does not work!
- Some things are easy to say but only once you convert them to the right language. When a recipe says to cook the food for 3 minutes, it generally assumes a standard 700-watt oven. If your oven is a 1400-watt oven, for how long should you cook the food?

Talking to a cell phone

- Dialing a phone number is trivial: Grandma can do it.

- Maintaining a "Contacts List" is almost trivial: Grandma's contact list will likely have duplicates, stale, and conflicting information. Actually my contact list has duplicates, stale, and conflicting information.

- Turning your favorite song into a ringtone is more complicated. Grand-daughter will do it for Grandma.

Programming Microwaves and Cell Phones

Talking to a machine is generally called programming the machine. With microwaves and cell phones we can usually express two kinds of programs:

- Microwaves and cell phones are very special-purpose computers and we "talk" to them all the time.
- The simplest programs just tell the machine to do something it was designed to do automatically — with the push of one button. Heat food for one minute.
- More complicated programs involve a sequence of commands. Set the power to 30%, then cook for 10 minutes, then increase the power to 50%, and cook for 10 more minutes.

Programming

With more advanced machines (computers!), we can express more sophisticated programs:

- Repeat the following commands until a certain condition holds.
  Keep downloading pictures until the user clicks “Done”.

- Try to do the following commands. If something goes wrong, abort the commands and execute these other commands instead.
  Try to copy this folder and the files it contains to the data stick; if the data sticks becomes full in the middle of copying one file, erase this one file, and tell the user that the operation failed.

Lessons on how to talk to children (or machines!)

As in any communication, we must tailor our instructions to the machine.

- We must understand what the machine is capable of doing! Can't ask your cell phone to heat your pizza
- We must understand the language that the machine can interpret. Can't ask the microwave to heat your leftovers by singing to it. Must push the right buttons on the panel.
- We must monitor the progress of the machine and give appropriate instructions. Turn the microwave off when the popping sounds are more than a second apart.

Programming is . . .

About Algorithms

Sorting

Let's do something simple: sorting a deck of cards

Algorithm I:

- Find the ace of spades and put it upside down
- Find the 2 of spades and put it upside down on the ace of spades
- Find the 3 of spades …
- …

Sorting

Algorithm I

- Find the ace of spades and put it upside down: might have to go through 52 cards
- Find the 2 of spades and put it upside down on the ace of spades: might have to go through 51 cards
- Find the 3 of spades …
- …

Might have to go through 52 + 51 + 50 + … cards = 1378

Sorting

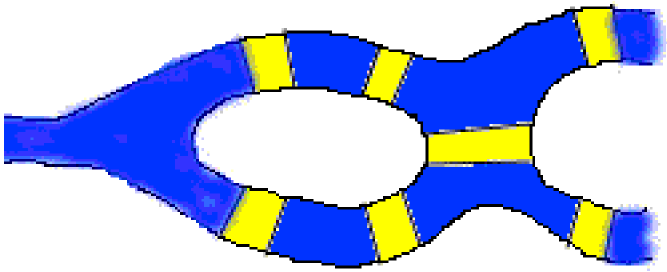
Algorithm II

- Separate the four suits: Goes through 52 cards
- Sort each of the suits using Algorithm I: might have to go through 13+12+11+... cards four times

Goes through 416 cards

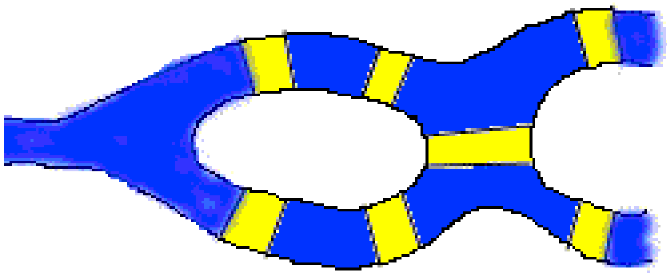
Best algorithm: goes through at most 205 cards

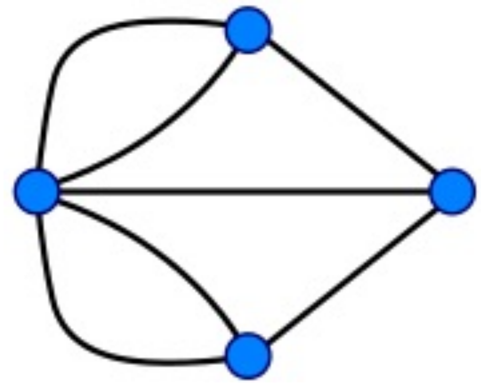
The Seven Bridges of Königsberg



Can one walk around the city in a way that would involve crossing each bridge exactly once ?

The Seven Bridges of Königsberg





Can one walk around the city in a way that would involve crossing each bridge exactly once ?

Programming is . . .

About Language

What is programming again?

A program is a set of directions telling a computer exactly what to do.

A programming language is a precise notation for specifying sequences of directions to a computer. Unlike English there are no ambiguities and no nuances.

An algorithm is the “general idea” with which we try and solve the problem.

Programming a “bare” computer

- When you buy a new laptop, it says “Intel inside”
- What if we only had that “Intel” thing and nothing else?
- To print `Hello` on the screen in x86 assembly language:

```
Message db "Hello"
.code

mov dx,OFFSET Message
mov ax,SEG Message
mov dx,ax
mov ah,9
int 21h
mov ax,4c00h
int 21h
END
```

System software

- For convenience, modern computers come with layers and layers and layers of software who job is to translate from some human-like language to the low-level assembly language.

- Even better it is very easy to teach a computer to speak almost any language of our choice, provided somebody knows how to translate this language to the low-level assembly language — or to some other language that has a translation to assembly language.

Choosing a language

If I want to say something to this computer, the first decision is to choose the language in which I want to say it.

There are millions of computer languages; some are general-purpose, and some very specific to a class of applications.

Even better, we can make up our own language!

Invent a language

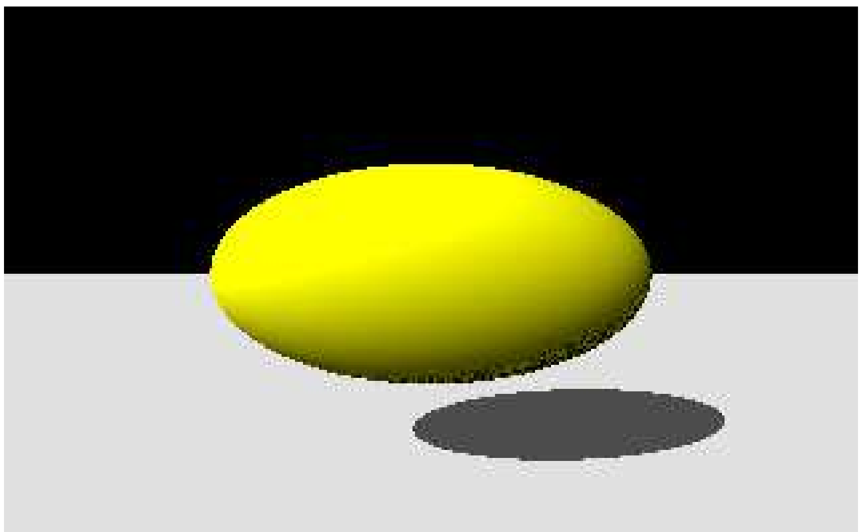
- A honors project for H211 students.
- Take a description written in this made-up language:

```
yellow matte apply sphere 2.0 1.0 1.0 scale
                          0.0 0.0 3.0 translate
white matte apply plane 0.0 -2.0 0.0 translate
union /scene

1.0 -1.0 1.0 point
1.0 1.0 1.0 point light /l
0.3 0.3 0.3 point
[l]

scene 1 90.0 320 200 "ellipsoid.ppm" render
```

And the output is…



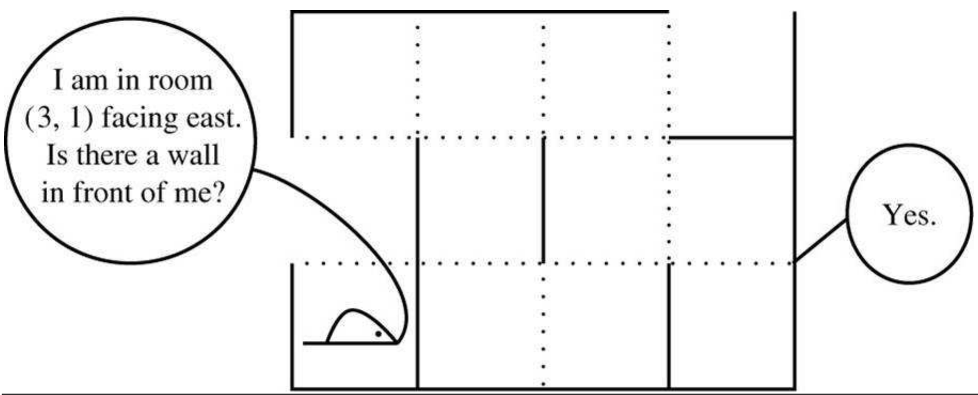
How?

Write an interpreter from our made-up language to some language that the computer already understands.

Really once you master interpreters you can say anything you want to the computer and in the way you want it!

Mouse in a maze

Let's try to develop a complete but small example to tell the computer how to find its way in a maze.



Commands

Let’s invent a language with the following commands:

- Step forward
- Turn left
- Turn right
- In maze?
- Facing wall?

Problem

- Construct a program that gets the mouse from entry to exit!

- Use the commands on the previous slide.

- Don't go through walls!

Ideas?

Ideas?

Hug the wall!

- Have the mouse walk hugging the wall to its right.

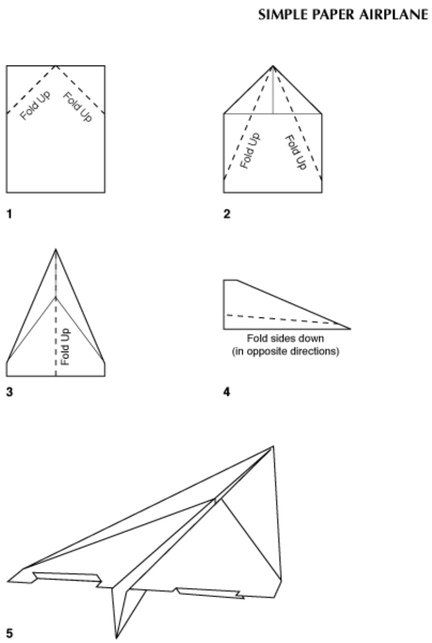
Algorithm

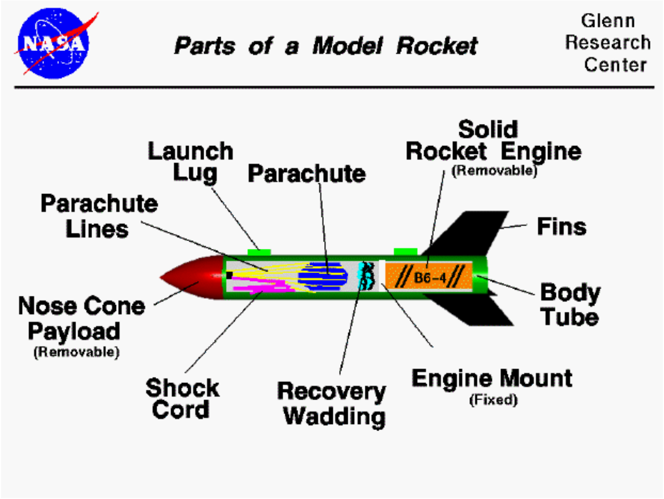
```
step forward;
while (inside the maze?) {
  turn right;
  while (facing a wall?) {
    turn left;
  }
  step forward;
}
```

Programming is . . .

About Scale

Scaling Up


SIMPLE PAPER AIRPLANE
Fold Up
Fold Up
1
Fold Up
Fold Up
2
Fold Up
3
Fold sides down
(in opposite directions)
4
5


NASA
Parts of a Model Rocket
Glenn
Research
Center
Launch
Lug
Parachute
Solid
Rocket Engine
(Removable)
Parachute
Lines
Fins
B6-4
Nose Cone
Payload
(Removable)
Body
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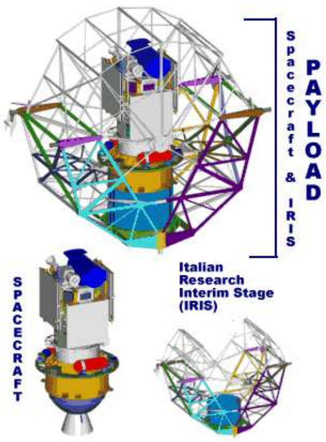
Shock
Cord
Recovery
Wadding
Engine Mount
(Fixed)

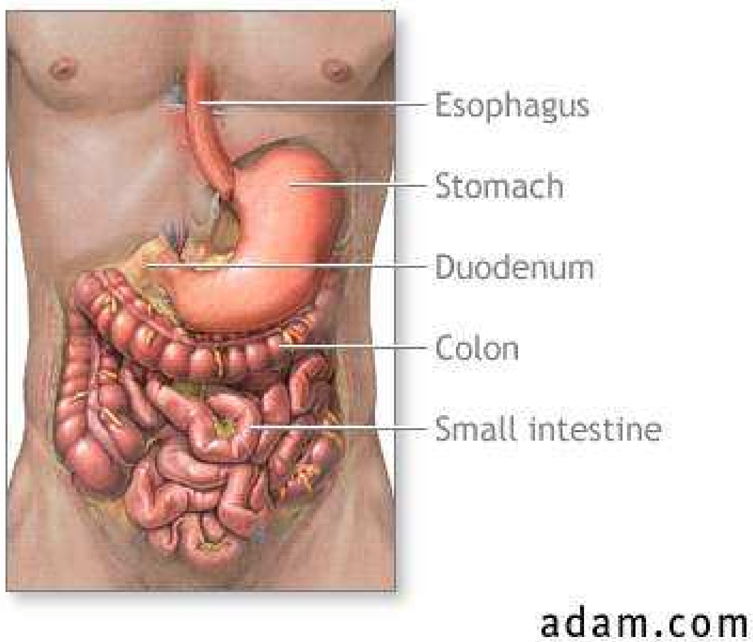

Spacecraft & IRIS
PAYLOAD
SPACECRAFT
Italian
Research
Interim Stage
(IRIS)

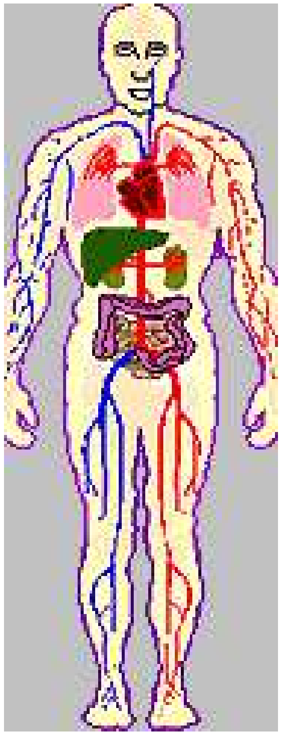
Scaling Up

- Now let's scale this up to programs that are millions of lines of code.
- Nobody can keep track of that much information in their head
- We need ABSTRACTION to be able to focus on one part of problem
- We want to be able to break the program into manageable pieces that we can develop individually and then COMPOSE together.

Finding the right abstraction

Which is the right abstraction for a human?





Enforcing abstraction

- Programming language must enforce levels of abstraction
- Checked and enforced by the compiler
- Types, types, and types
- With really advanced type systems, we have the following "the- orem": if it typechecks it is correct!!!

Programming is . . .

About Interacting with
the Physical World

Quantum Computing

Computing is the process of transforming information about a situation to information about another situation

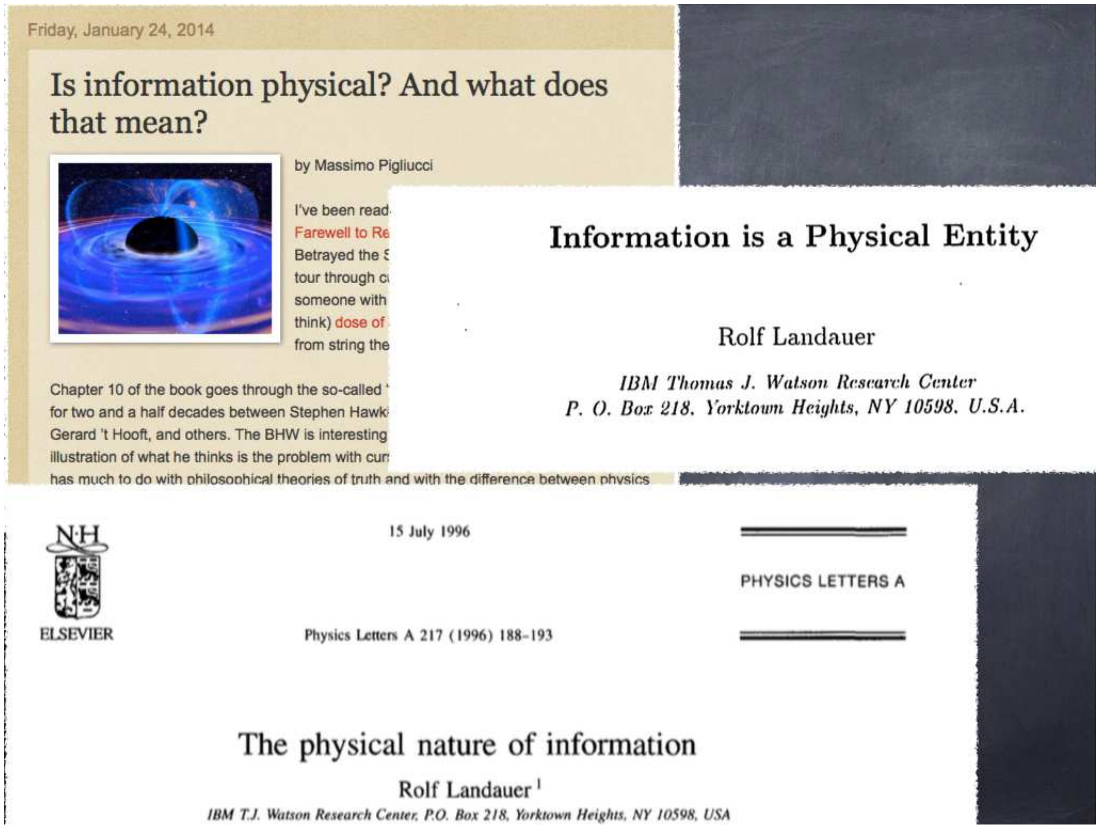
Quantum Computing

- Unit of information: bit

- Is the bit something physical ?

- Many physicists argue YES !

Quantum Computing


Friday, January 24, 2014

Is information physical? And what does that mean?

by Massimo Pigliucci

I've been read
Farewell to Re
Betrayed the S
tour through c
someone with
think) dose of
from string the

Chapter 10 of the book goes through the so-called '
for two and a half decades between Stephen Hawk
Gerard 't Hooft, and others. The BHW is interesting
illustration of what he thinks is the problem with cur
has much to do with philosophical theories of truth and with the difference between physics

Information is a Physical Entity

Rolf Landauer

IBM Thomas J. Watson Research Center
P. O. Box 218, Yorktown Heights, NY 10598, U.S.A.

N·H
ELSEVIER

15 July 1996

PHYSICS LETTERS A

Physics Letters A 217 (1996) 188–193

The physical nature of information

Rolf Landauer[1]

IBM T.J. Watson Research Center, P.O. Box 218, Yorktown Heights, NY 10598, USA

Quantum Computing

- In any case, computers manipulate physical representations of bits, e.g., electric signals which are quite real: they drain your battery and heat up your computer

- Your SSN, your bank account, your address, etc. are nothing but bits. Not only are these bits real but they are worth protecting with perhaps millions of dollars.

Quantum Computing

So computing …

- converts some physical representation of information to another
- we do not want to think of energy, electric signals, bits, etc. We want to abstract from that and focus on the structure of information
- the process of computing should obey the laws of physics but should be expressed at an abstract level corresponding to the structure of information

Quantum Computing

Classical vs. quantum computing

- One relies on the laws of classical physics: the world is black and white, fixed, and completely deterministic

- The other relies on the laws of quantum of mechanics: the world is fuzzy, dynamic, and probabilistic

Programming is …

Science, Engineering,

Language, Communication,

Compassion, and Understanding

Conclusions

- Machines are supposed to work for us.
- To tell them what we need done, we must learn their language.
- Machines are very precise: they do what you tell them verbatim! We must be very careful and accurate when talking to machines.
- Sometimes it feels like we work for them. But when we make the machine do something complicated for us — something that we couldn't have done without the machine — it is all worth it!
- Will we ever scale quantum computers? What will this look like ???