NPRG075

Making programming easier and learnable

Tomáš Petříček, 204 (2nd floor)
petricek@d3s.mff.cuni.cz
https://tomasp.net | @tomaspetricek

Lectures: Tuesday 12:20, S6
https://d3s.mff.cuni.cz/teaching/nprg075

Course feedback

What do you think

- I would love to hear from you!
- tinyurl.com/nprg075-feedback

Some things to consider

- Topics covered in the course?
- Conventional lecture format?
- Alternatives to assignment?

Introduction

Programming for non-programmers

What & why

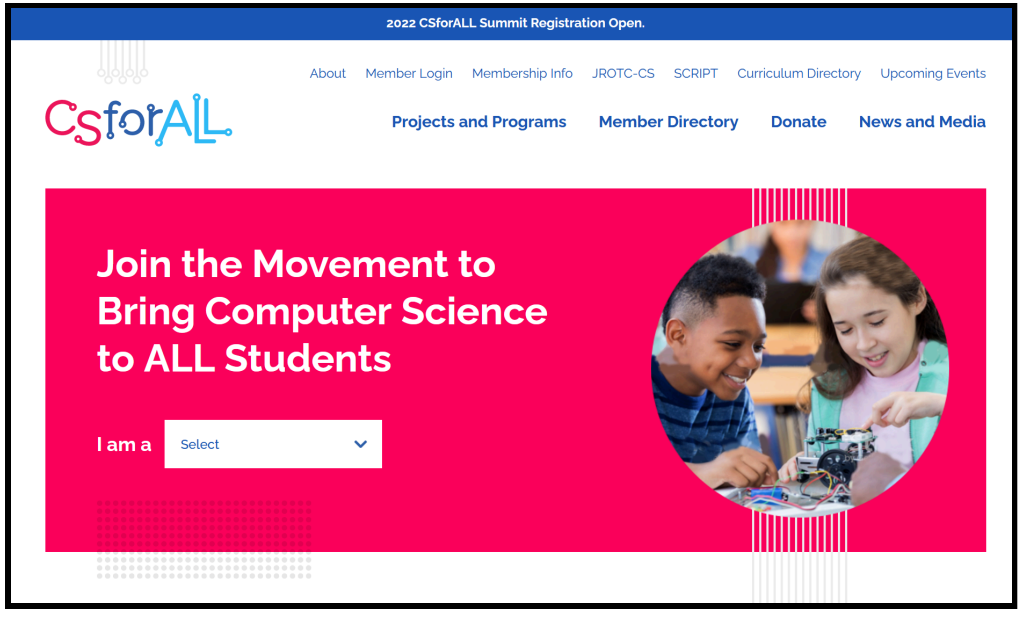
Programming for non-programmers

 Augmenting human intellect research theme

 Reducing costs of programming for businesses

 Computer science & general education

 Thinking about how to think when programming!



Computational thinking

Is that teaching everyone to code?

What to teach and how to best do it?

Designing languages for education?

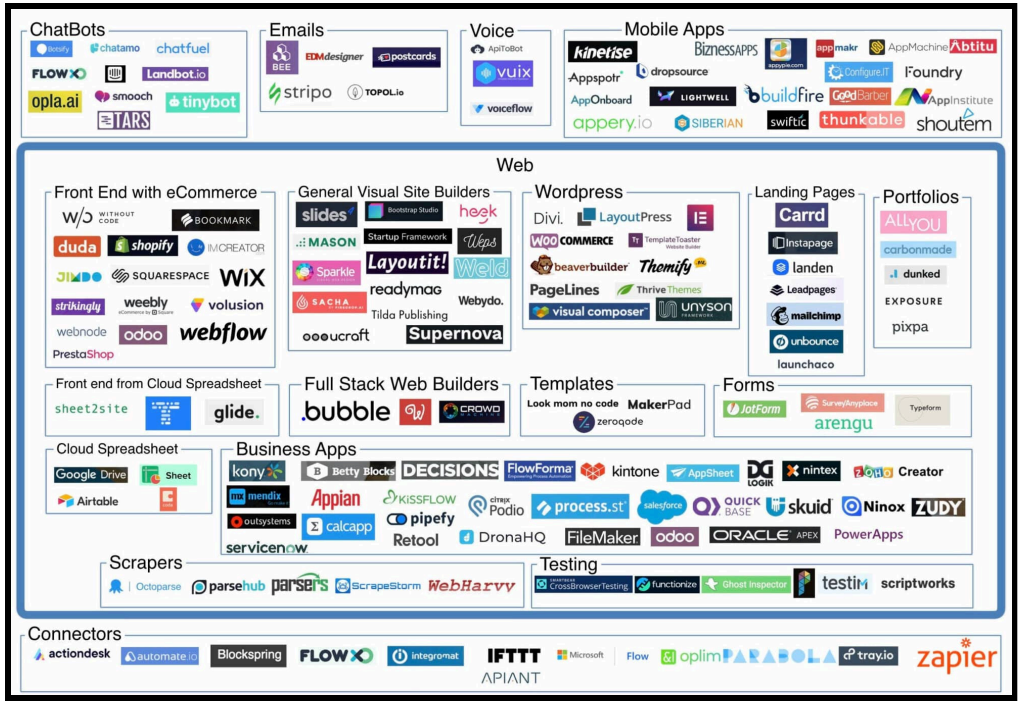
LOGO (1967)

Characteristics of the era

Not just a programming language for kids

Computer environment: people, things, ideas

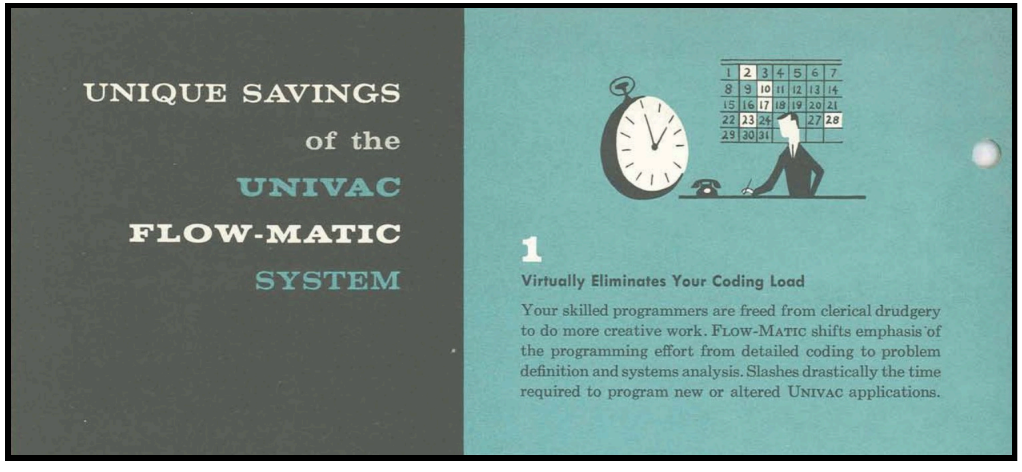
Computer culture: a way of thinking about thinking



No-code and low-code

Platforms for creating applications with minimal code

A new take on end-user programming



FLOW-MATIC

High-level business oriented predecessor of COBOL (1957)

Makes coding so easy your company will not need programmers!

Methodology

Programming for non-programmers

 Metaphors for explaining programming

 Cognitive models to understand human thinking

 Finding more manageable kinds of interactions

 Understanding & assisting with common errors

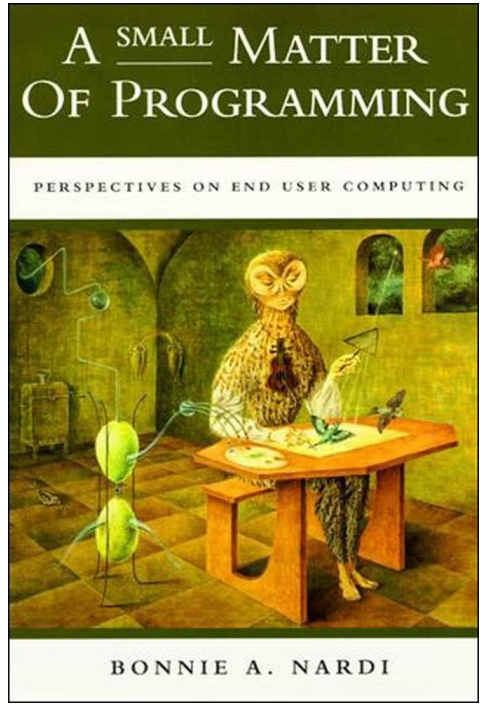
End-user programming

Making programming super easy

A small matter of programming

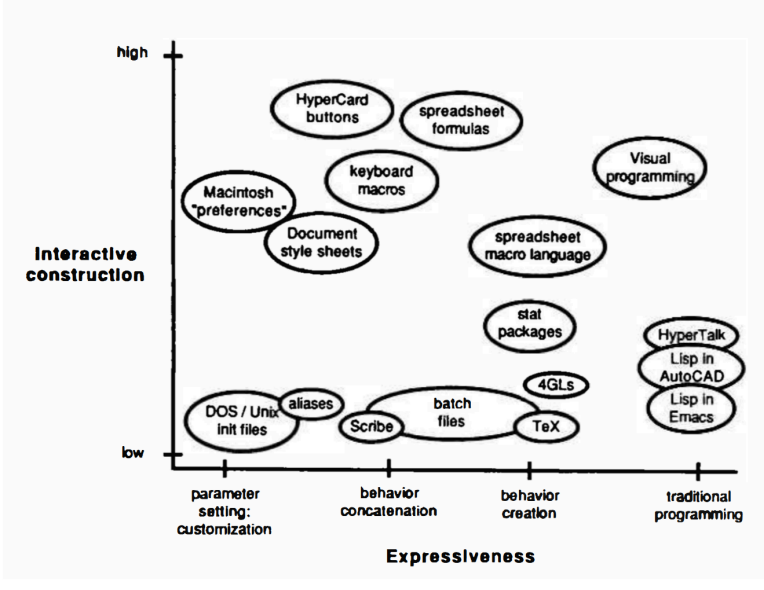
End-user programming (1993)

- Spreadsheets, CAD systems, statistical packages
- Task specific systems



An elusive dream?

- Can anyone become a programmer?
- Beyond task-specific?
- Programmable end-user systems?

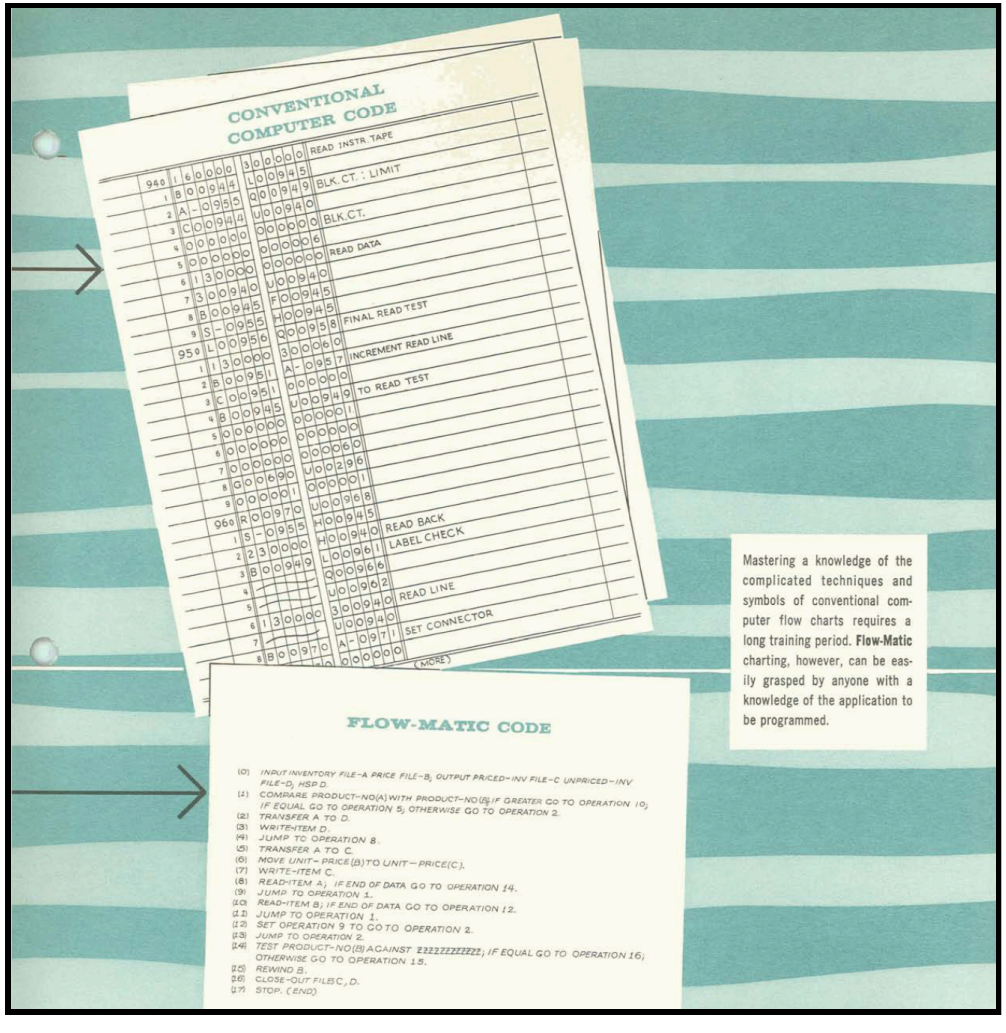


End-user programming

① Very high-level
Domain-specific languages

② Spreadsheets
CAD & statistical systems

③ User interaction
New kinds of specifying

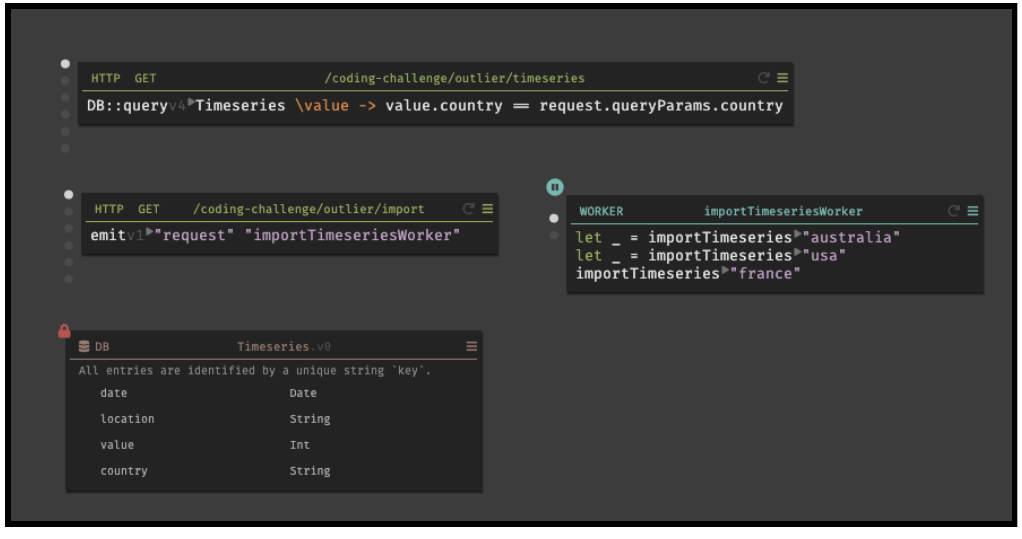


High-level languages

FLOW-MATIC (1960s)
English; easily taught to clerical workers

DSLs (2000s)
Small languages for specific problems

Low-code (2020s)
GUI-based entire app development



Case study: Darklang

Domain-specific abstractions for server-less backends

- HTTP handler
- Worker
- Database
- CRON job

Notations

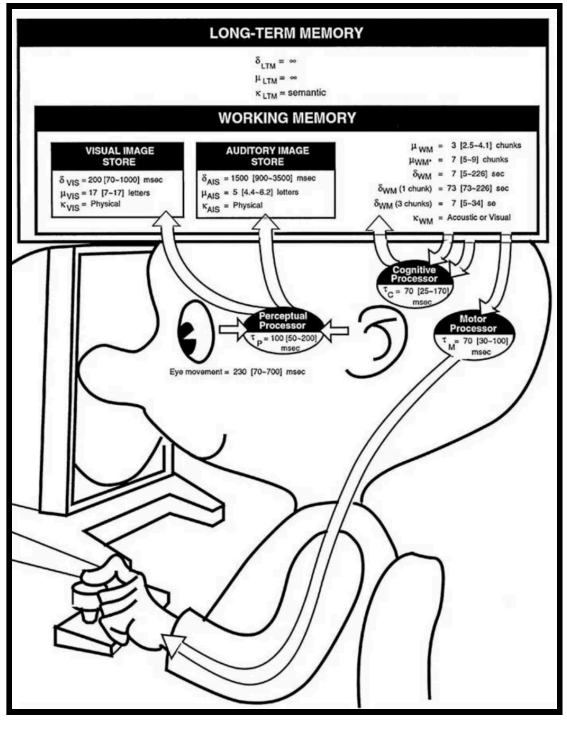
Limits of high-level notations

- Requires a "tidy" problem domain
- There is no universal language
- Adaptable notations tend to be complex
- Cannot (should not?) accept human vagueness

What makes programming hard?

Cognitive obstacles

- Loss of direct manipulation (and the frame problem)
- Use of (specialized) notation
- Abstraction for complexity



Attention investment model

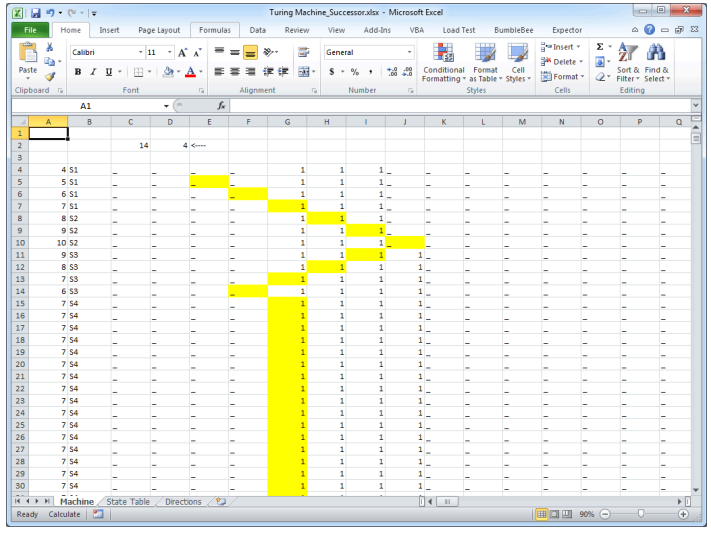
- Cognitive obstacles have cost
- Programming as an investment
- When is the gain worth it?

Eliminating cognitive obstacles

- Spreadsheet-based interfaces
  Avoid abstraction and give immediate feedback
- £ Programming by example
  No need for notation and abstraction
- Direct manipulation
  Manipulate concrete entities & post-hoc abstraction

Spreadsheets as programming

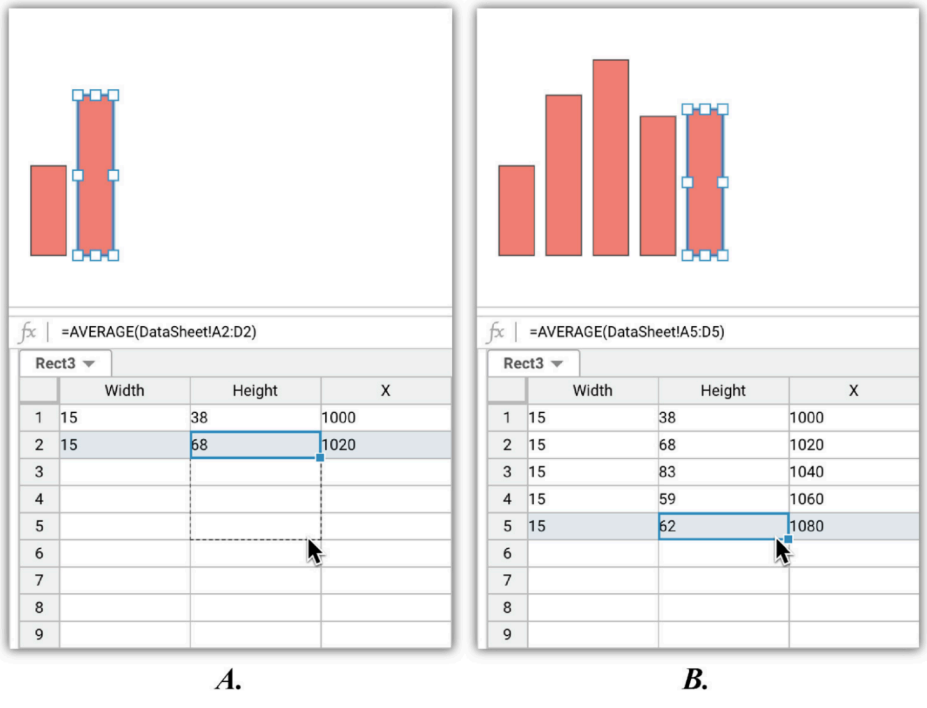
Are they really programming?



- Domain-specific, but powerful
- Turing-complete (in a way)
- Lambdas, macros, extensions

Spreadsheets & programming

- IDEs can learn about liveness
- Spreadsheets can learn about software engineering
- TechDims: Abstraction construction, feedback loops



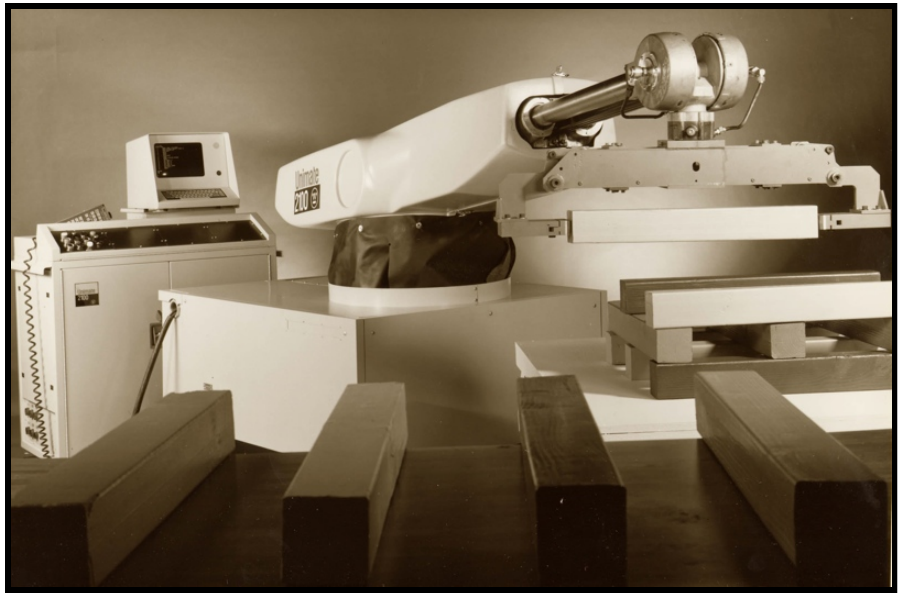
General-purpose spreadsheets?

(Marasoiu, 2019)

Spreadsheet-based data visualization

Spreadsheet interface for constructing custom charts

What else could we express this way?

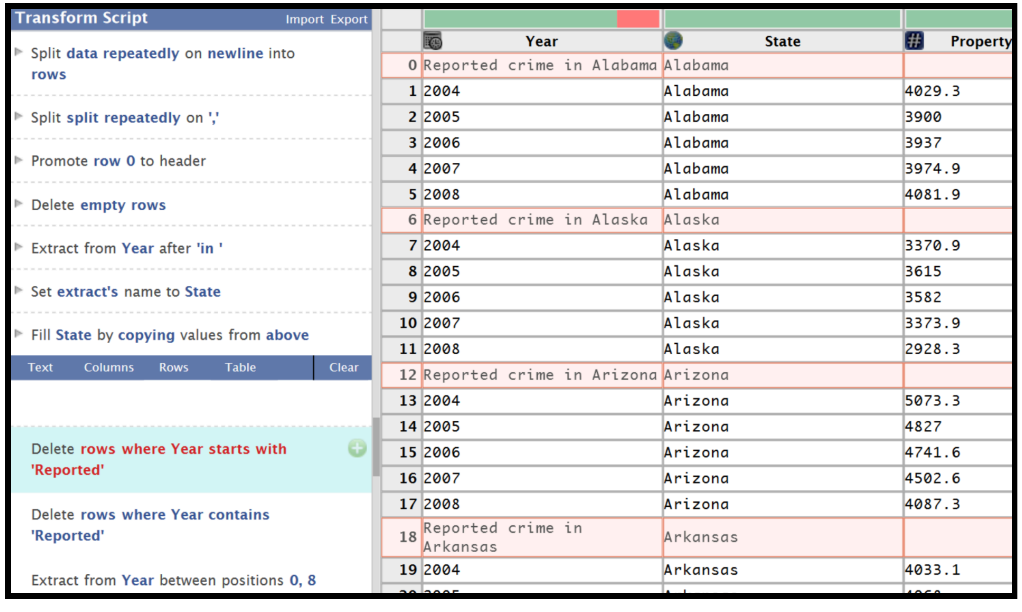


Direct manipulation

Complete task manually, have computer repeat it

Industrial robots, graphics editing, task automation, geometry, formatting

How to allow for small variation in behaviour?



Wrangler

(Kandel et al, 2011)

Data wrangling by direct manipulation

User cleans with data

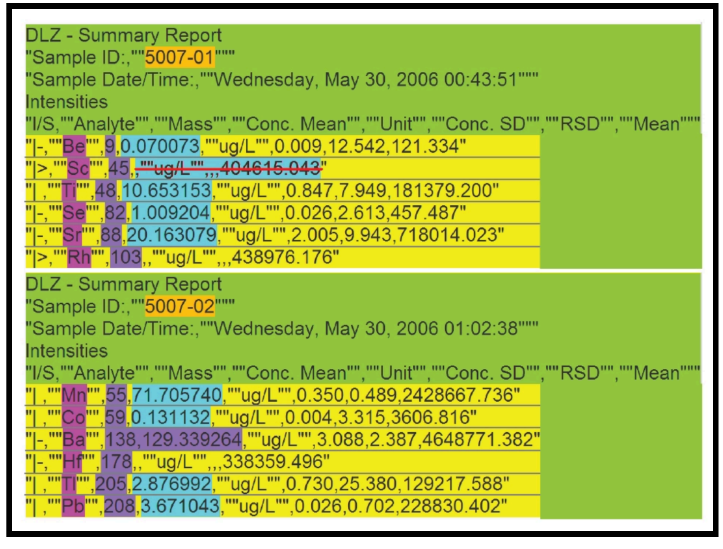
System builds a script

Attempts to generalize concrete interactions

Programming by example

FlashFill and FlashExtract

- Write (or select) examples
- System infers patterns
- Refine examples to clarify



Implementation

- Synthesize programs to match
- Using carefully chosen small language
- And a suitable search algorithm

Education

Teaching programming & thinking

MIT Artificial Intelligence Lab

Minsky & Papert

"Seymour Papert and Marvin Minsky thought about thinking, about children's thinking and about machine's thinking."

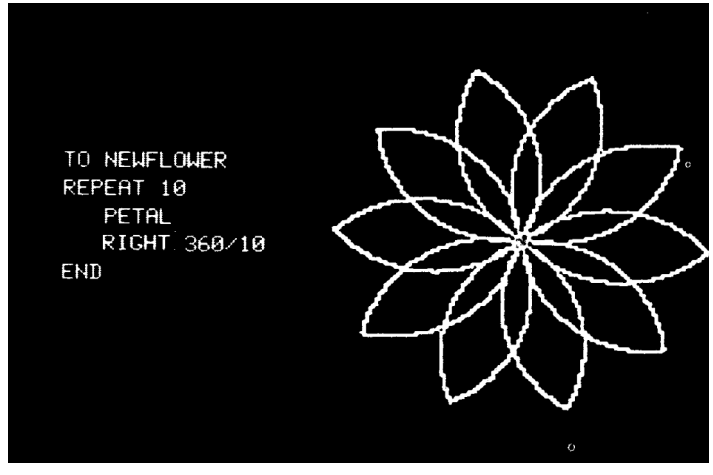
LOGO project & language

- Computers as "native speakers" of mathematics
- Teach creative and logical thinking
- Giving children tools to learn (Montessori)

LOGO as a language

Language features

- Interactive and LISP-inspired
- Lists, recursion, functional
- More of an idea than a language



LOGO for education

- Learning through microworlds
- Give kids the most powerful language created
- Powerful ideas: anthropomorphization, metalanguage

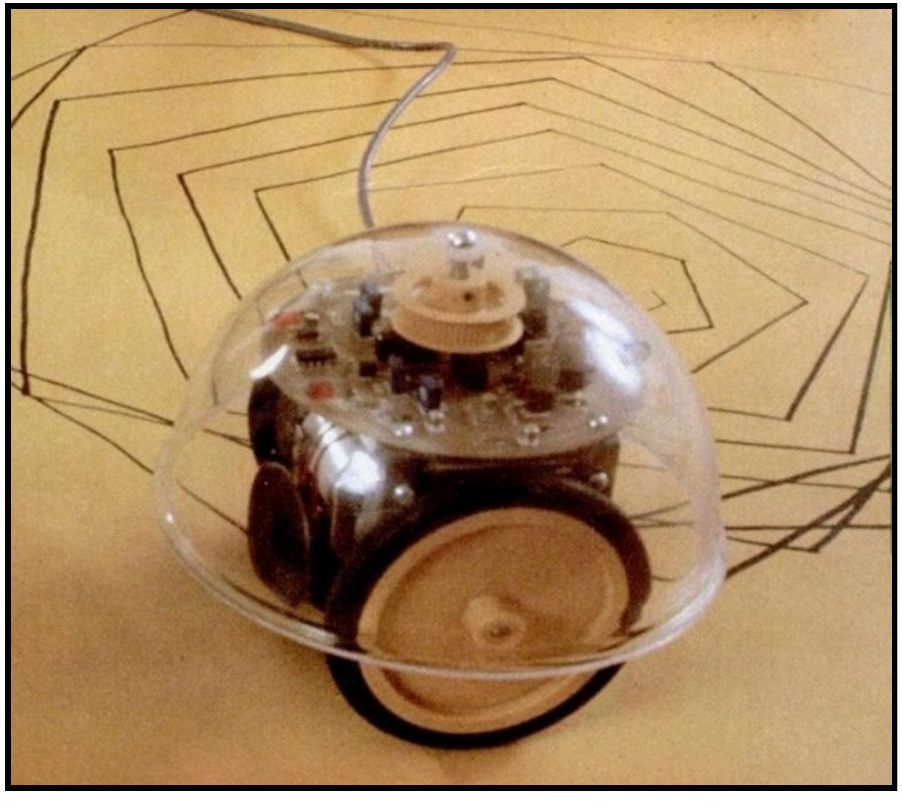
```
TO NOUN
  OUTPUT PICK [BIRDS DOGS ..]
END
TO VERB
 OUTPUT PICK [HATE BITE LOVE]
END
TO ADJECTIVE
  OUTPUT PICK [RED PECULIAR ..]
END

PRINT (SENTENCE ADJECTIVE
  NOUN VERB ADJECTIVE NOUN)
```

Microworlds

A small domain-specific language for exploring ideas

Turtle graphics is best known example

First LOGO example was for word plays



Turtle microworld

On-screen and floor robots

Great for teaching

Debug by pretending to be the turtle & follow program

Does not blame students ("the turtle has a bug")

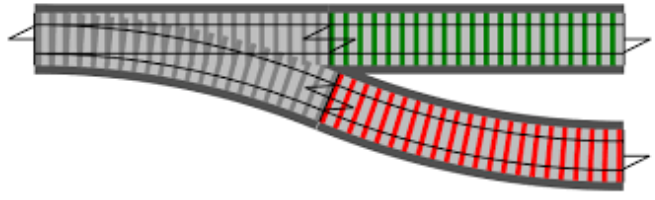
Computer science education

Teaching programming thinking today

- From 1960s idealism to 2020s pragmatism
- Focus on what we can convincingly study
- Improving teaching practices & methods
- Developing better conceptual frameworks

Notional machines

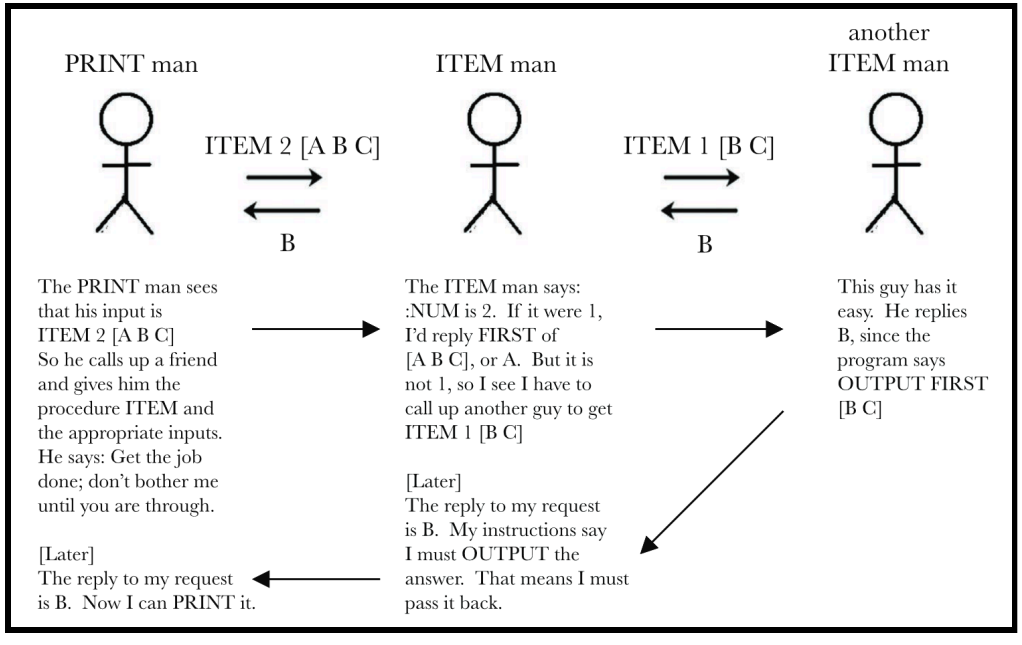
Models for thinking



- Model of a computer operation
- Helps understand computation
- A "useful lie" for teaching

Example notional machines

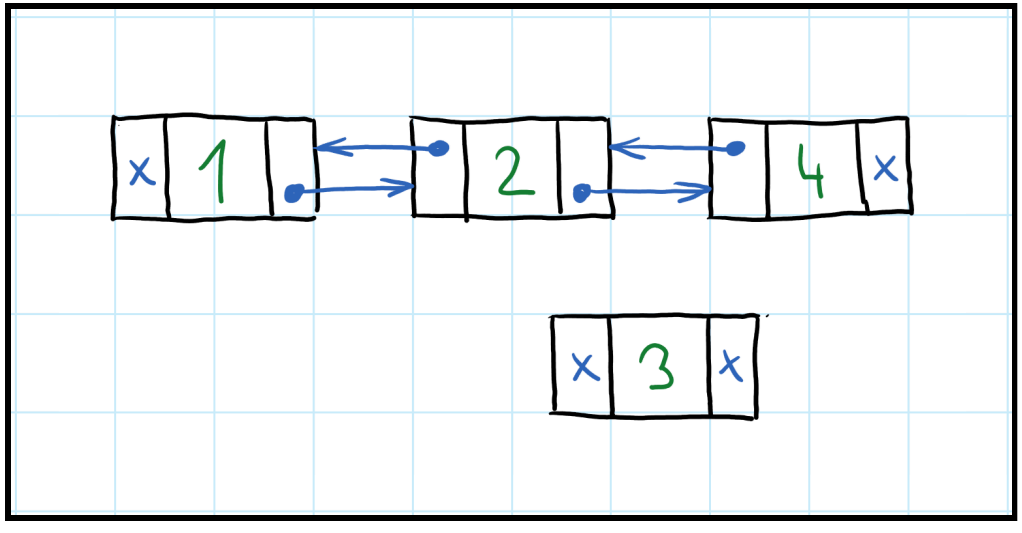
- Objects and message passing of Smalltalk
- LOGO "little people" metaphor
- Computation as railway track



Little people metaphor

A powerful idea for understanding how programs work

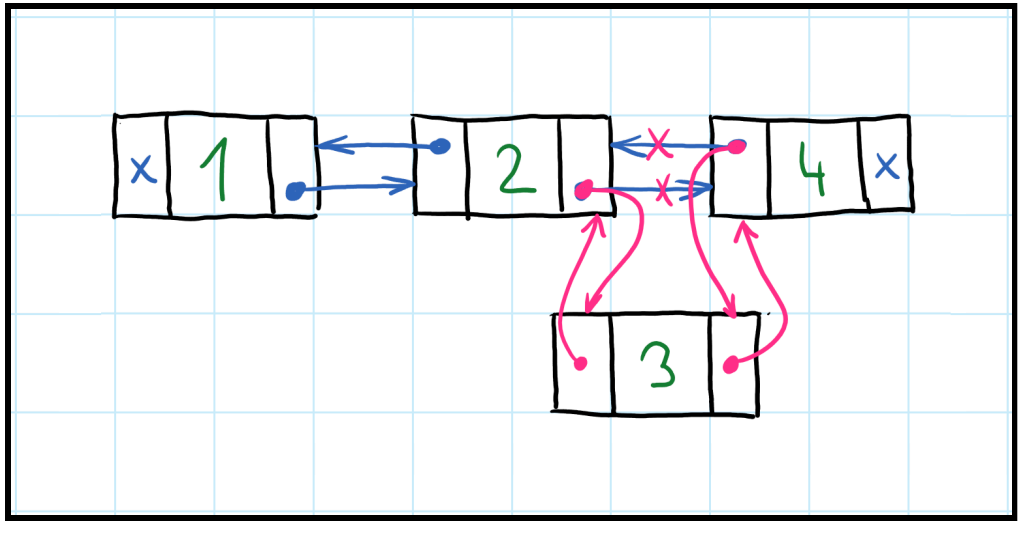
Function instantiation as a "little men" doing (one step of) work



Linked lists (1/2)

Boxes with pointers as connecting arrows

Let's insert 3 in the list between 2 and 4...



Linked lists (2/2)

Boxes with pointers as connecting arrows

Let's insert 3 in the list between 2 and 4...

Useful but does not explain everything that pointers can do!

Computing education

Basic disagreements about the problem

- Computational thinking & algorithms for all?
- Creativity as with LOGO and Sonic Pi?
- History and philosophical problems?
- How to best teach present-day technology?

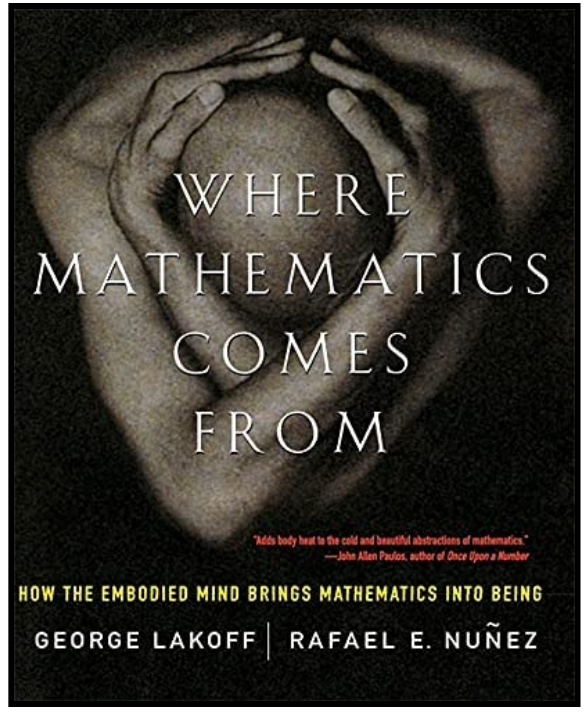
Metaphors

Thinking about programming

Metaphors for programming

Essence of human thought?

- Time as resource, Up as positive, ...
- Apparent through our language
- Basic for constructing mathematics?
- Each has fits and misfits



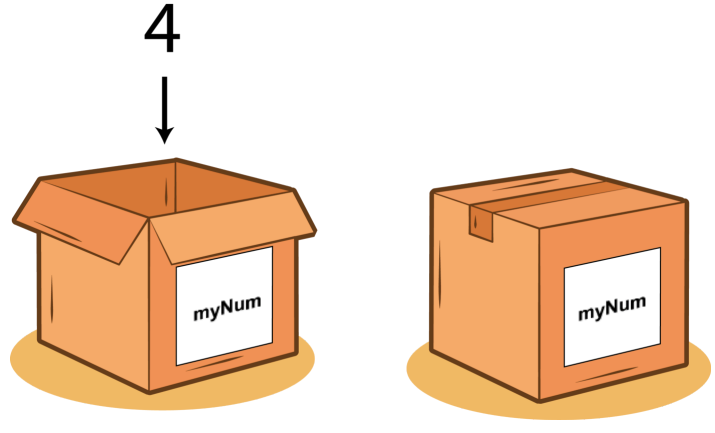
Metaphors for programming

- Notional machines (LISP, Smalltalk)
- Thinking about variables, monads

Two metaphors for variables

Variable as a box

- You store value in a box
- Variable "contains" a value
- What is stored in a **`name`**?



Variable as a label

- Label you place on a value
- Variable "is" a value
- What is a **`name`**?

Misconceptions

Does the metaphor for variables matter?


What is the meaning of multiple assignment?


Box can contain multiple values!


Label will be for computation or addition


Box metaphor wins, but beware of misfits

```
class Monad m where
 (>>=)  ::
  m a -> (a -> m b) -> m b
 return ::
  a -> m a
```

Metaphors for monads

Interface capturing a class of computations

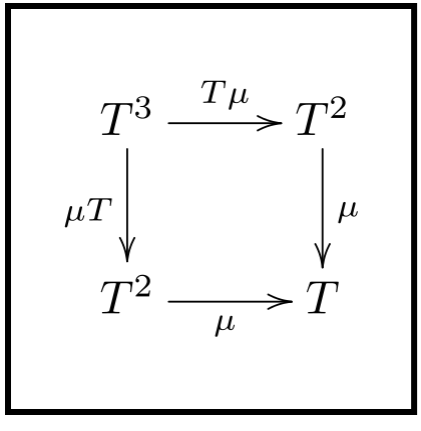
Used for effectful computations in Haskell

How programmers think about them?

Three metaphors for monads

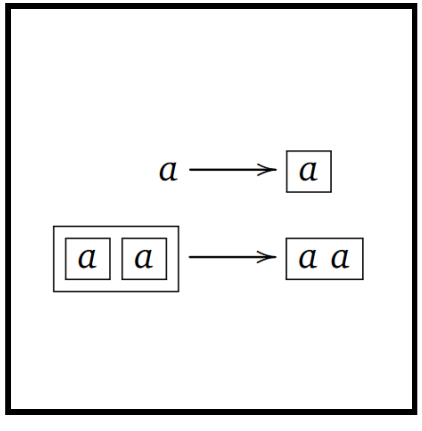
Symbolic

Meaningless symbolical entity satisfying laws



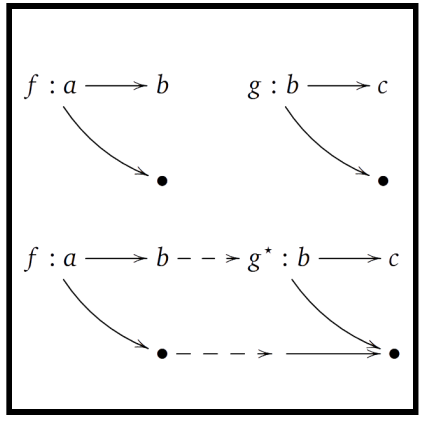
Box

Container that can be transformed and un-nested



Track

Computation that can proceed in multiple ways



Misconceptions

Common errors in thinking


Loops terminate when condition turns false


Sequential statements do not wait


Variable name has effect on its behaviour


Missing else branch stops program

Conclusions

Easier and learnable

Thank you!

Please do keep in touch!

- Do a final project (and get credit as a bonus)
- Sign-up for a follow-up seminar
- Get in touch about MSc or PhD projects

Tomáš Petříček, 204 (2nd floor)

petricek@d3s.mff.cuni.cz

https://tomasp.net | @tomaspetricek

https://d3s.mff.cuni.cz/teaching/nprg075

References (1/3)

End-user programming

- UNIVAC FLOW-MATIC (1957). Introducing a new language for automatic programming. Sperry Rand Corporation
- Bonnie A. Nardi (1993). A Small Matter of Programming. MIT
- Blackwell, A. F. (2002). First Steps in Programming: A Rationale for Attention Investment Models. VL/HCC
- Blackwell, A.F., Burnett, M. (2002). Applying Attention Investment to End-User Programming. VL/HCC

Spreadsheets

- Marasoiu, M. et al. (2019). Cuscus: An End User Programming Tool for Data Visualisation. IS-EUD

References (2/3)

Programming by demonstration

- Smith, D. C. (1977). Pygmalion: A Computer program to Model and Stimulate Creative Thought. ISR
- Kandel, S., et al. (2011). Wrangler: Interactive Visual Specification of Data Transformation Scripts. CHI
- Cypher A (ed.) (1993). Watch What I Do: Programming by Demonstration. MIT

Programming by example

- Gulwani, S. et al. (2016). Programming by Examples. DSSE
- Vu Le, Gulwani S. (2014). FlashExtract: A Framework for Data Extraction by Examples. PLDI

References (3/3)

Programming education

- Solomon, C. et al. (2020). History of LOGO. HOPL
- Papert S. (1980). Mindstorms: Childern, Computers and Powerful Ideas. Basic Books
- Fincher, S. A. & Robins A. V. (eds.) (2019). The Cambridge Handbook of Computing Education Research. Cambridge

Metaphors & misconceptions

- Lakoff, G. & Nunez, R. (2001). Where Mathematics Come From
- Petricek, T. (2018). What we talk about when we talk about monads
- Hermans, F. et al. (2018). Thinking out of the box: comparing metaphors for variables in programming education. WiPSCE
- Swidan, A. et al. (2018). Programming Misconceptions for School Students. ICER