Why Programming Languages Matter

Andrew P. Black

Portland State University
Portland, Oregon

Portland State University

Why Programming Languages Matter
to me and a bunch of other People

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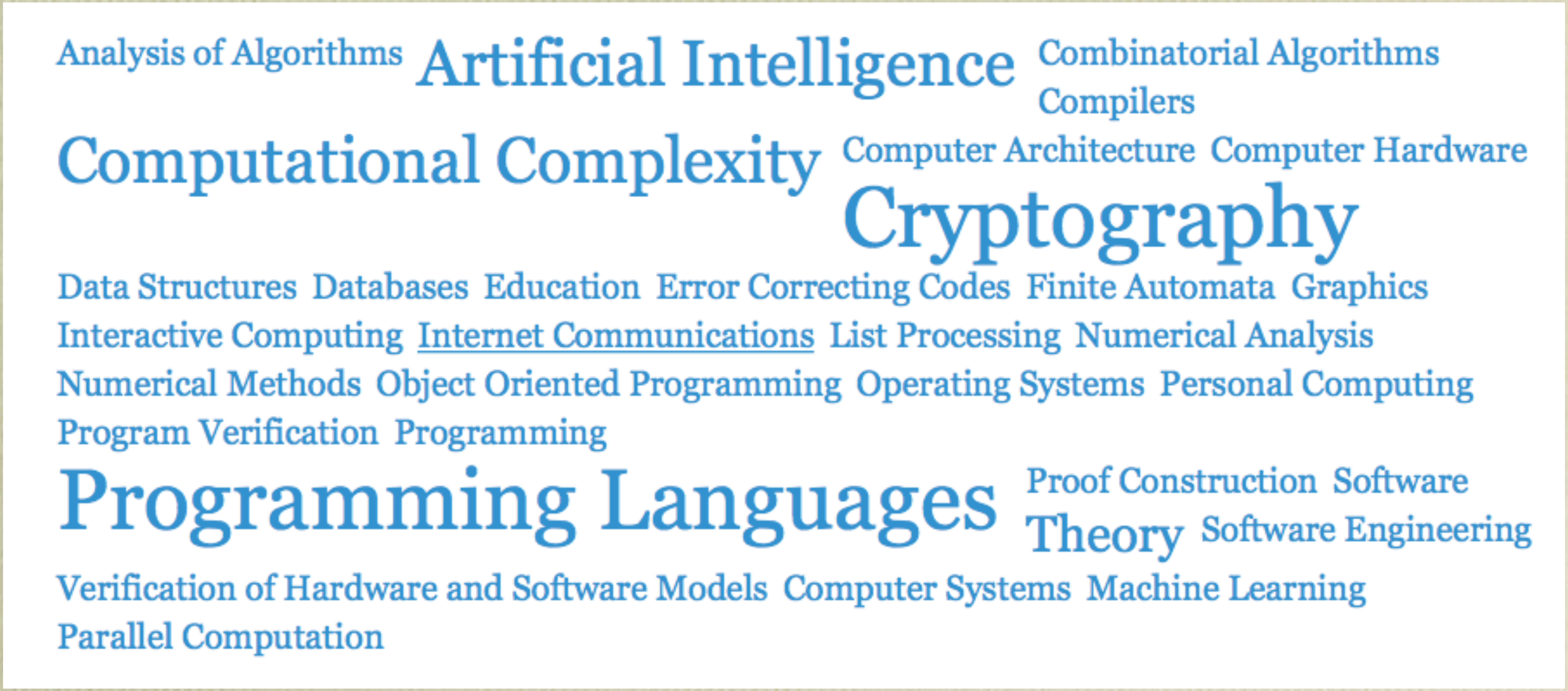
Win a Turing Award!

Win a Turing Award!



Analysis of Algorithms Artificial Intelligence Combinatorial Algorithms Compilers Computational Complexity Computer Architecture Computer Hardware Cryptography Data Structures Databases Education Error Correcting Codes Finite Automata Graphics Interactive Computing Internet Communications List Processing Numerical Analysis Numerical Methods Object Oriented Programming Operating Systems Personal Computing Program Verification Programming Programming Languages Proof Construction Software Theory Software Engineering Verification of Hardware and Software Models Computer Systems Machine Learning Parallel Computation

Turing Awards related to PL

1. Backus, John (1977)
2. Hoare, Tony (1980)
3. Iverson, Ken (1979)
4. Kay, Alan (2003)
5. Lamport, Leslie (2013)
6. Liskov, Barbara (2008)
7. Milner, Robin (1991)
8. Naur, Peter (2005)
9. Wirth, Niklaus (1984)

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But they missed ...

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12. Dijkstra, Edsger* (1972)
13. Floyd, Bob* (1978)
14. McCarthy, John * (1971)
15. Nygaard, Kristen * (2001)
16. Perlis, Alan* (1966)
17. Ritchie, Dennis M.* (1983)
18. Scott, Dana (1976)

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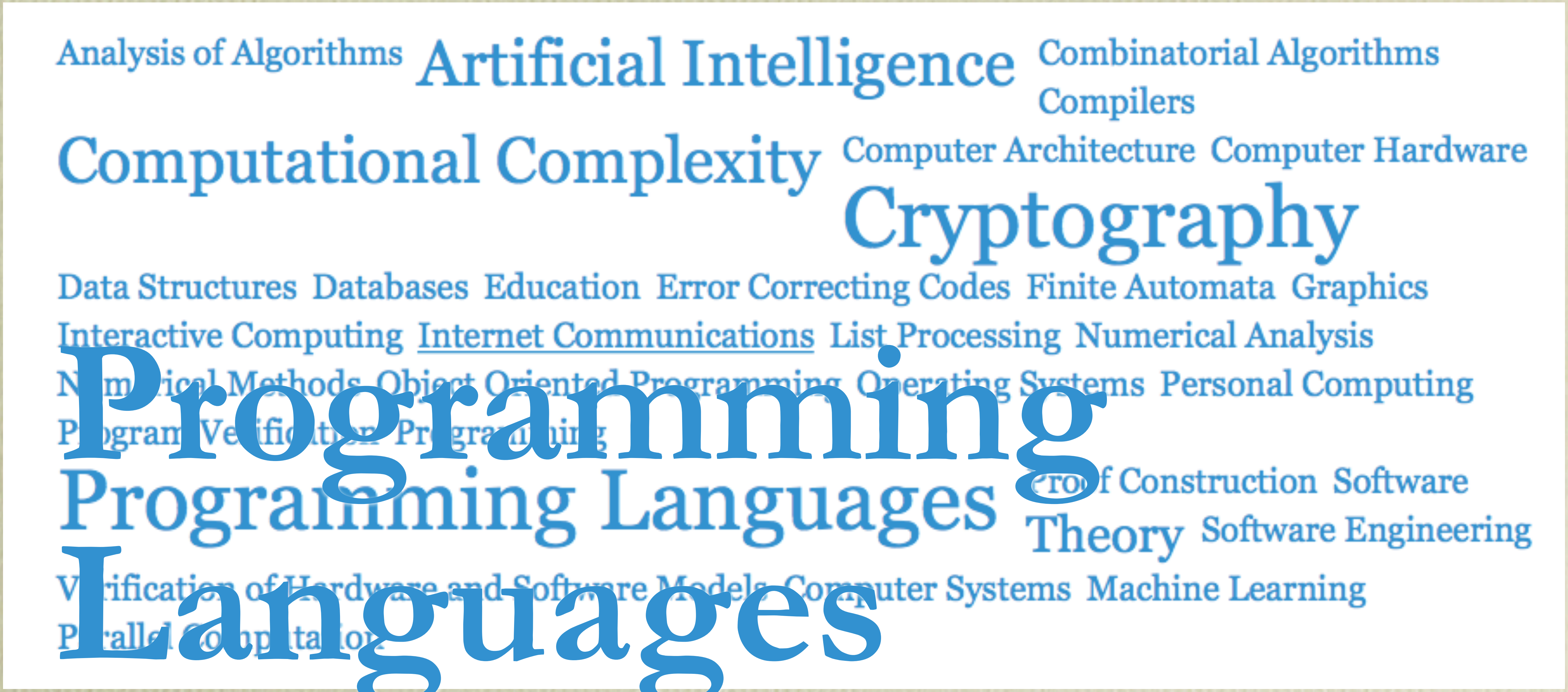

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Programming Languages

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My Personal Journey

• 1977–1981:	Graduate student, Oxford
• 1981–1986:	Assistant Professor, Washington
• 1986–1994:	Engineer & Researcher, Digital
• 1994–1999:	Department Head, OGI
• 2000–2004:	Professor, OGI
• 2004– :	Professor, Portland State

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  2011: Microsoft *2002: Edinburgh*

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Programming is Hard

I want to make it easier

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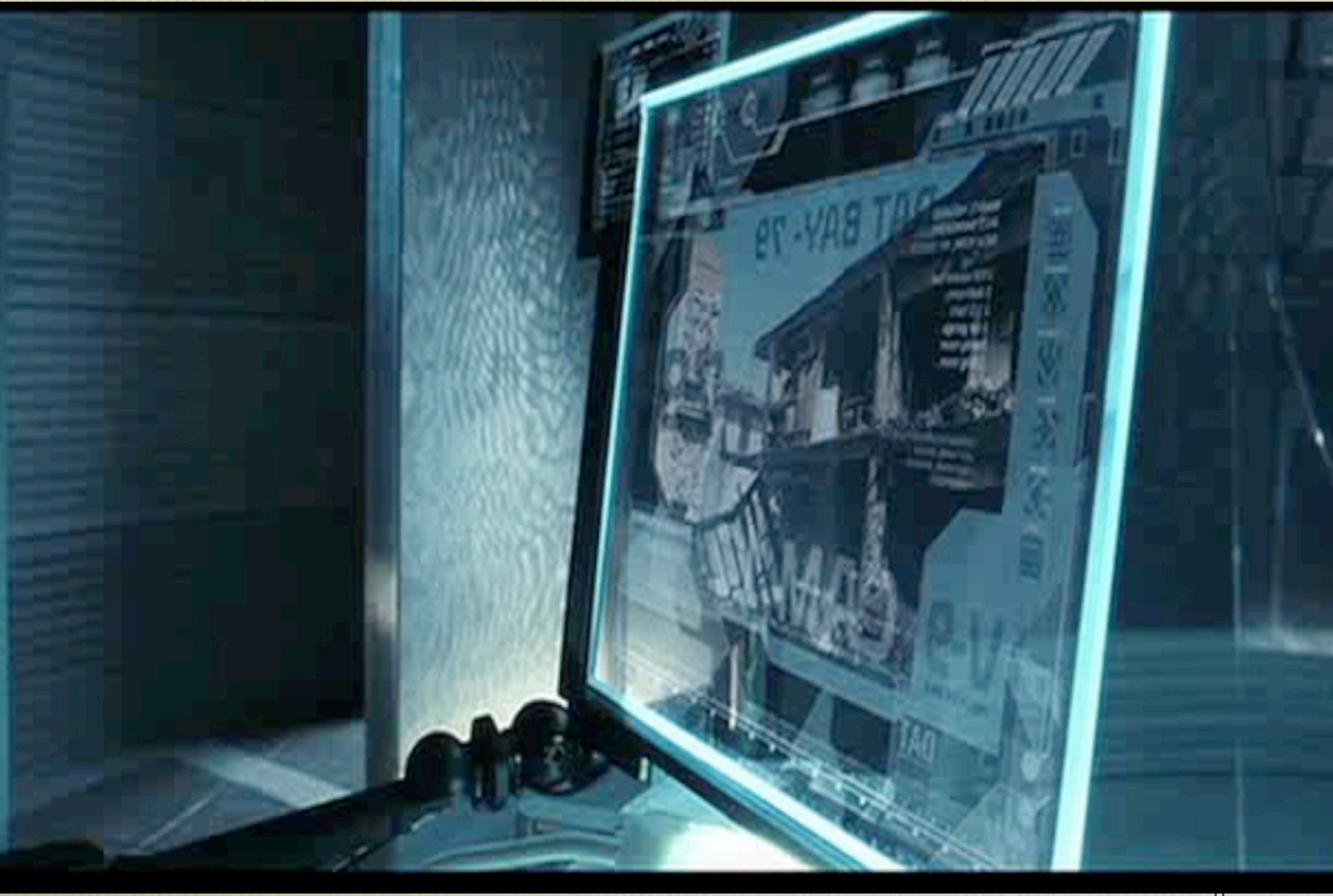

BAY-79

1978–80: 3R

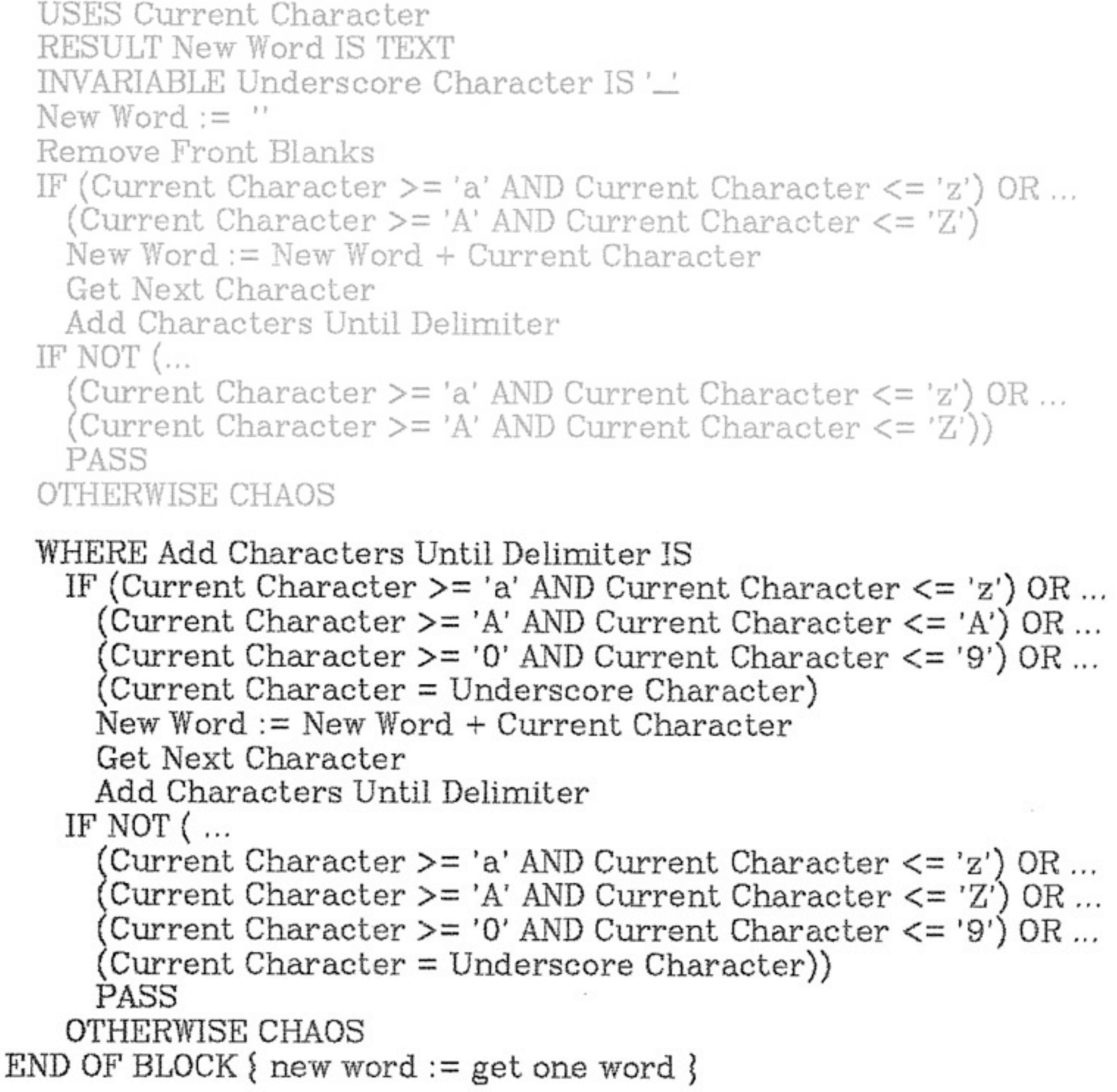
- "Reading, 'riteing, and 'rithmetic"
- Programming language designed for *readability*
  - Names made up of multiple words
  - Block (procedure) names can have arguments, e.g `delete [i]th line of page[p]`
- Flat (no nesting): *Blocks* and *Blocklets*
  - No loops, No defaults

4.5. Scanning One Word

This block scans the current line and returns the next word or perhaps a null string if one is not found. A word is a letter followed by zero or more letters, digits, or underscore characters.

```
LET New Word := Get One Word BE
  USES Current Character
  RESULT New Word IS TEXT
  INVARIABLE Underscore Character IS '_'
  New Word := ''
  Remove Front Blanks
  IF (Current Character >= 'a' AND Current Character <= 'z') OR ...
    (Current Character >= 'A' AND Current Character <= 'Z')
    New Word := New Word + Current Character
    Get Next Character
    Add Characters Until Delimiter
  IF NOT (...
    (Current Character >= 'a' AND Current Character <= 'z') OR ...
    (Current Character >= 'A' AND Current Character <= 'Z'))
    PASS
  OTHERWISE CHAOS

  WHERE Add Characters Until Delimiter IS
    IF (Current Character >= 'a' AND Current Character <= 'z') OR ...
      (Current Character >= 'A' AND Current Character <= 'A') OR ...
      (Current Character >= '0' AND Current Character <= '9') OR ...
      (Current Character = Underscore Character)
      New Word := New Word + Current Character
      Get Next Character
      Add Characters Until Delimiter
    IF NOT ( ...
      (Current Character >= 'a' AND Current Character <= 'z') OR ...
```



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    (Current Character >= 'A' AND Current Character <= 'Z') OR ...
    (Current Character >= '0' AND Current Character <= '9') OR ...
    (Current Character = Underscore Character))
    PASS
  OTHERWISE CHAOS
END OF BLOCK { new word := get one word }
```

Influences

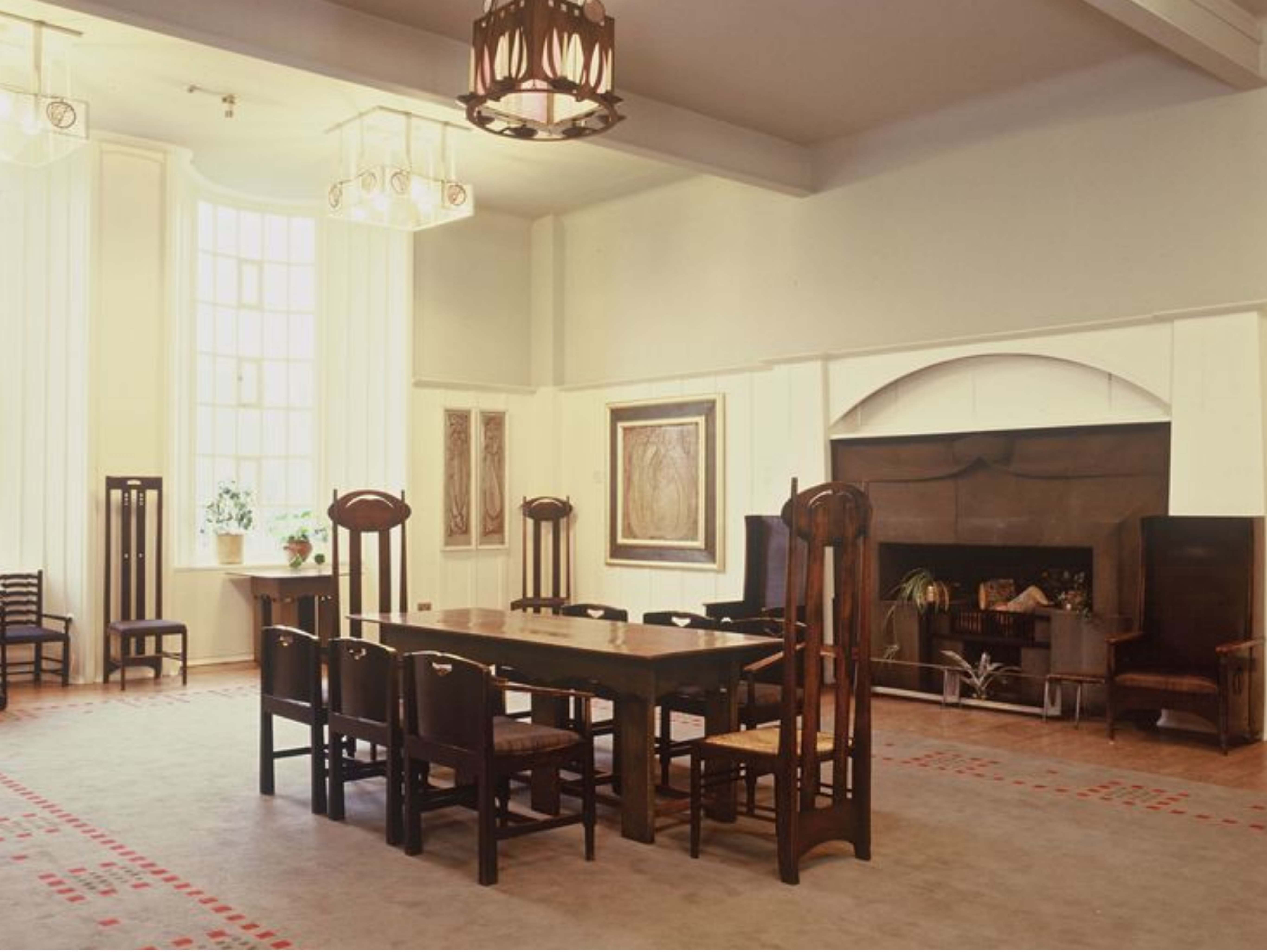
- Algol 60
- Cobol?
- Hoare Triples, Dijkstra's predicate transformers
- Top-down design
- A year at IBM
- Brian Shearing
  - *knew* that he needed a language

Reflections

"The concept of a program consisting of English text interspersed with 3R was easily grasped, but its use was more difficult than I anticipated. The main problem … is a feeling of duplicating in the English what's I've already coded in 3R … The code specif{ies} the details in a concise and comprehensible manner, {and} in a superior style."

Howard Matsuoka

Language as a Simplifier



Language as a Simplifier

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Language as a Simplifier

- Programming in Smalltalk is *also* a life-changing experience

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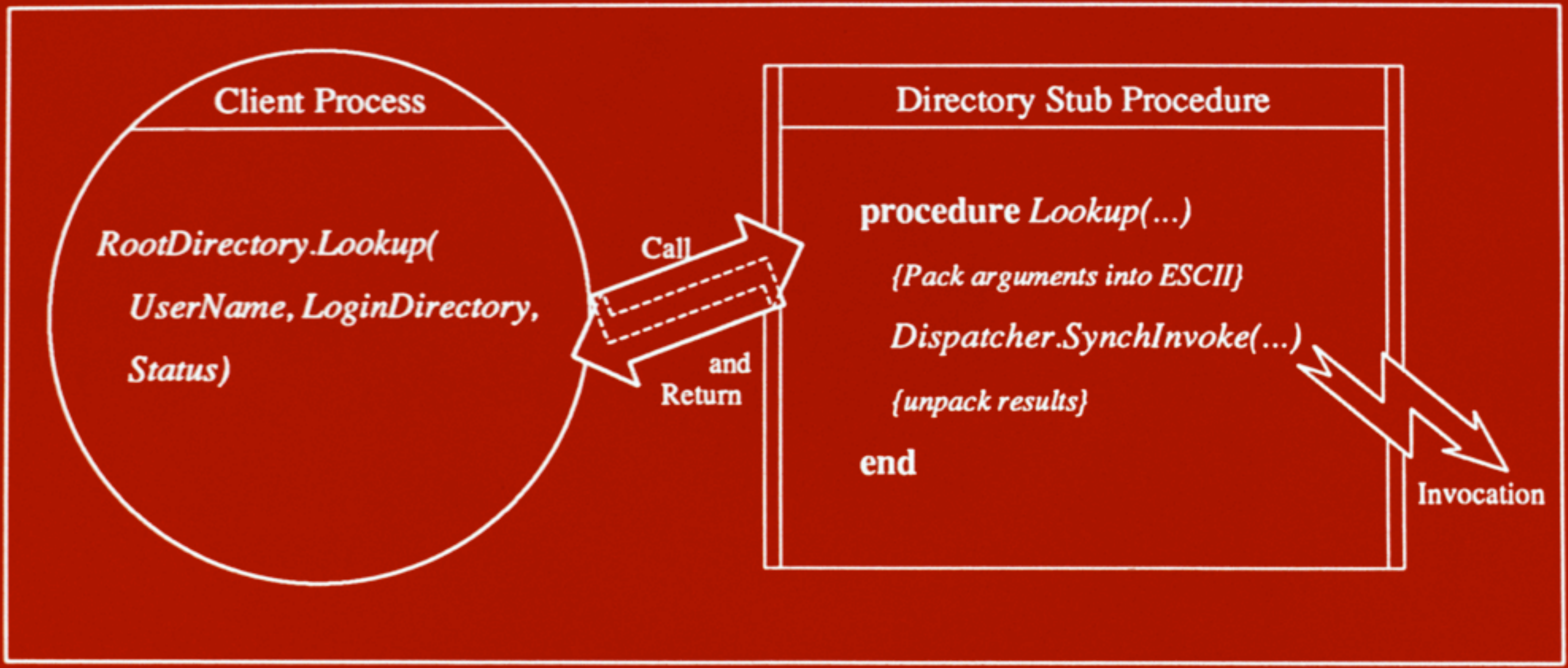
Language as a Simplifier

- Programming in Smalltalk is *also* a life-changing experience
- Once you understand how freeing it is get get rid of the junk, you will never want to go back

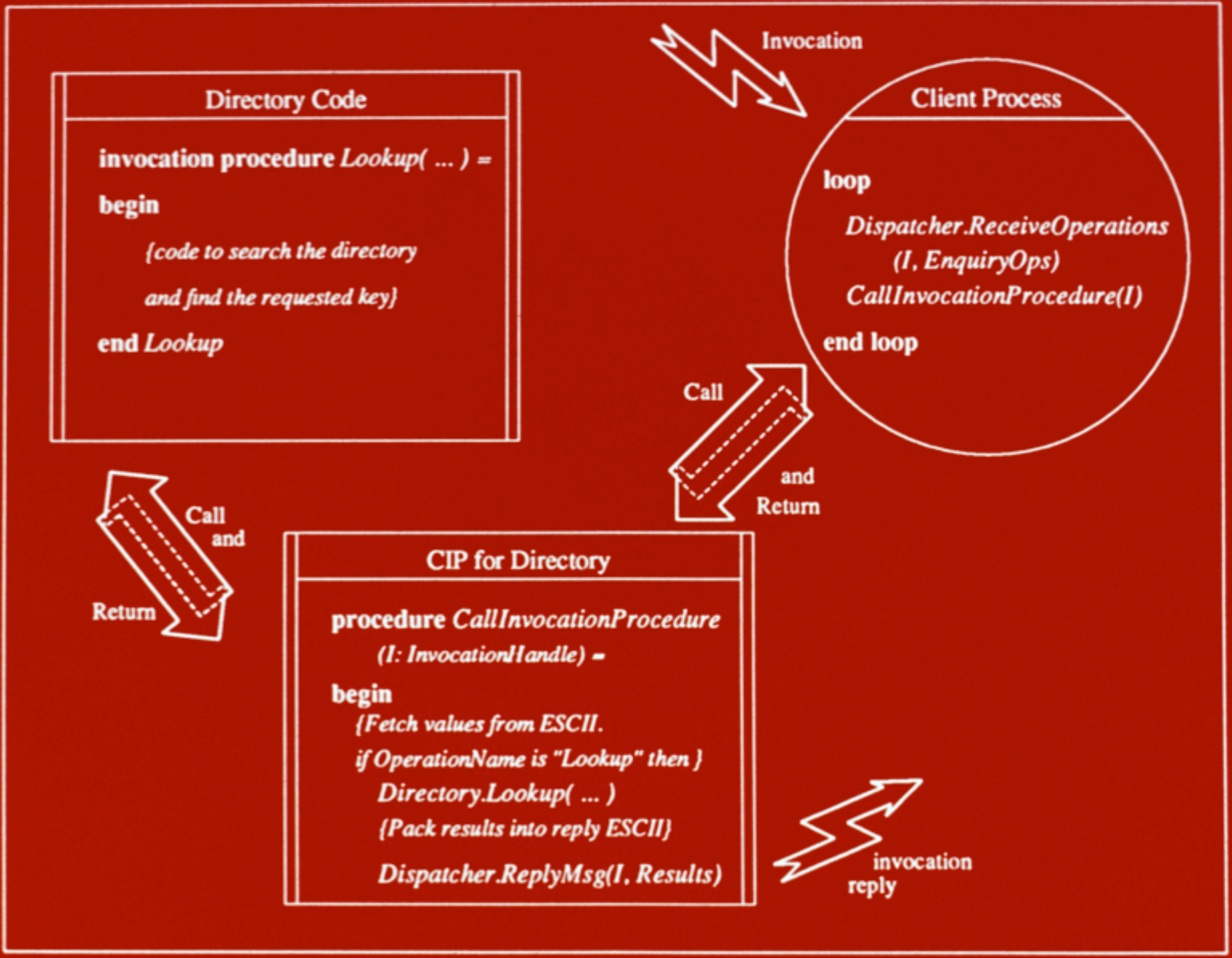
Eden Programming Language

- Eden Project (1980–1984) — early attempt to build a "distributed, integrated" computing system.
- EPL provided:
  - concurrency inside Eden objects
  - synchronous (local or remote) object invocation
  - capabilities
  - strings
- Implemented by translating to Concurrent Euclid

Sending an Invocation



Receiving an Invocation



```
loop
    Dispatcher.ReceiveOperations
        (I, EnquiryOps)
    CallInvocationProcedure(I)
end loop
```

```
invocation procedure Lookup( ... ) =
begin
    {code to search the directory
    and find the requested key}
end Lookup
```

```
procedure CallInvocationProcedure
    (I: InvocationHandle) =
begin
  {Fetch values from ESCII.
  if OperationName is "Lookup" then }
    Directory.Lookup( ... )
    {Pack results into reply ESCII}
    Dispatcher.ReplyMsg(I, Results)
```

Reflections

- Eden saw itself as *distributed systems* research
  - no one on the project knew that they needed a programming language!
- In hindsight: EPL was essential
- Partly language, partly kit of components

1983–87: Emerald

- Follow-on to EPL, but a "Real" Programming Language
  - Hides implementation choices that EPL revealed
  - Efficient (as in C) implementation

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The People

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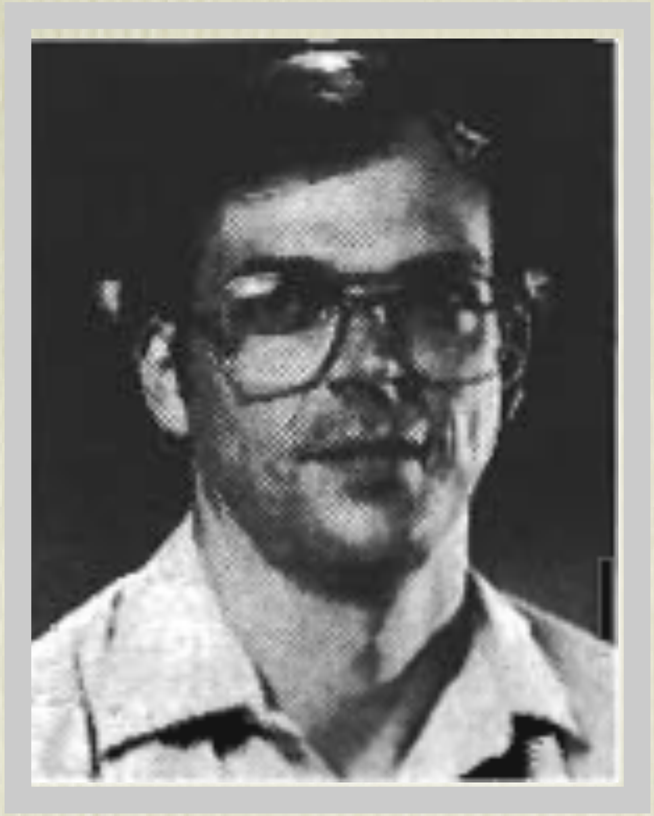
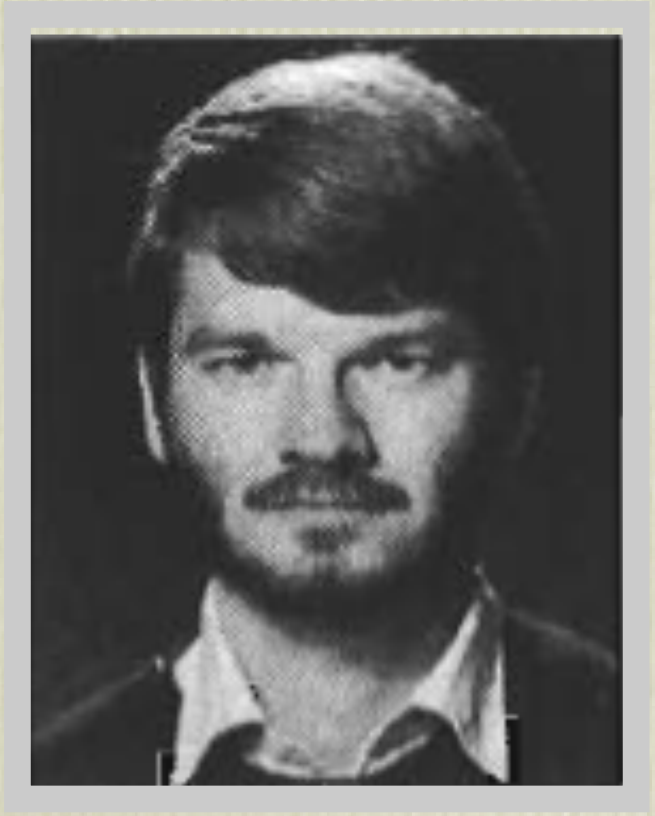
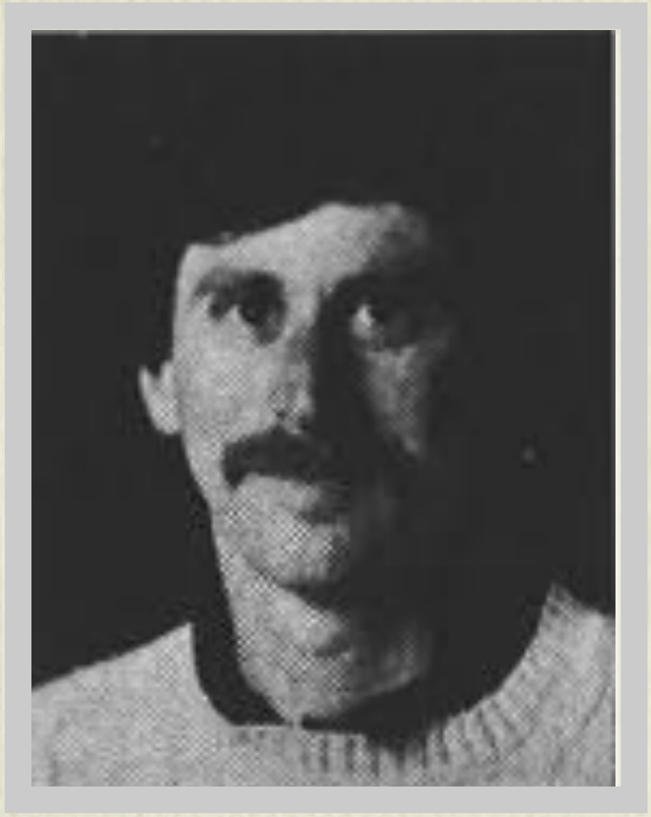
Norm Hutchinson



Eric Jul



Henry (Hank) Levy



The People

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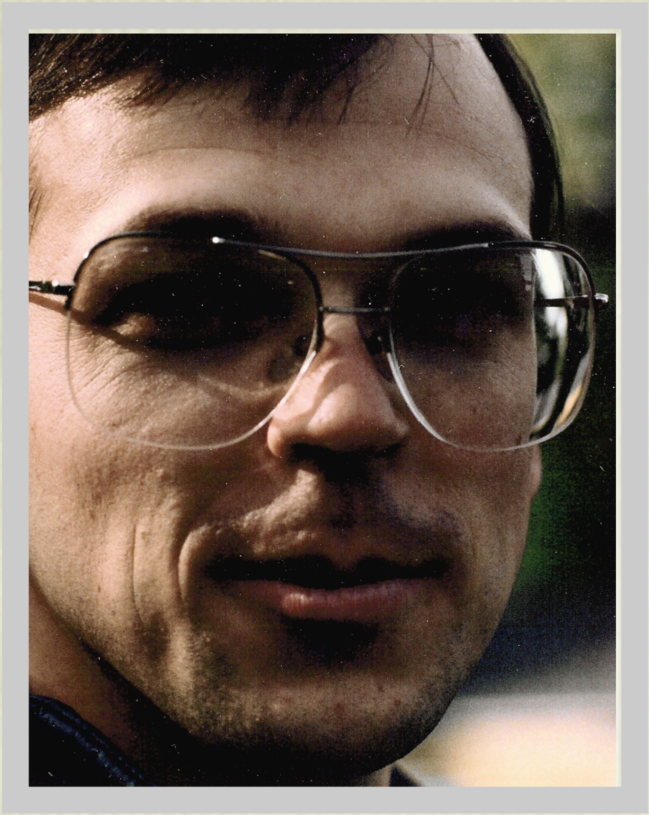

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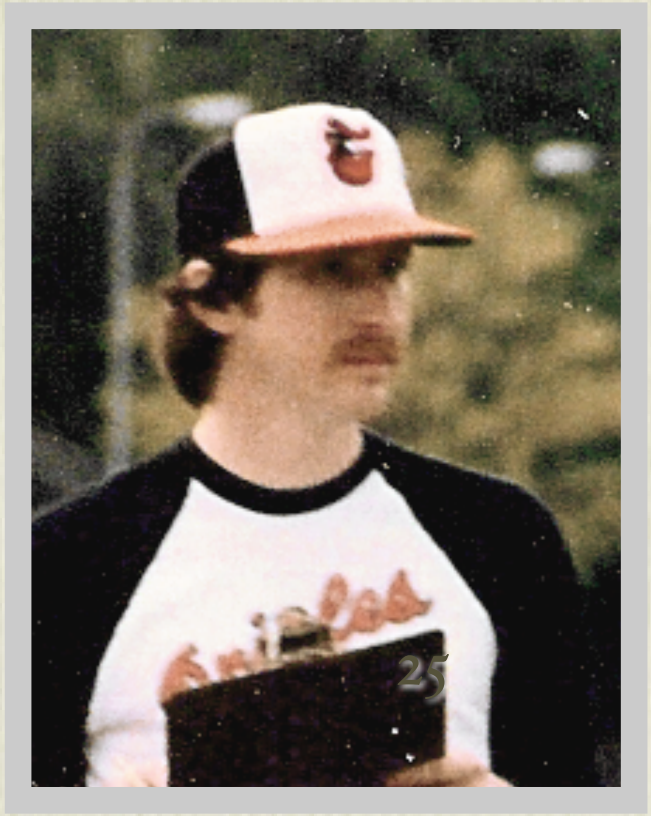

1983–87: Emerald

- Background:
  - Eric Jul (Simula 67, Concurrent Pascal),
  - Norm Hutchinson (Simula),
  - Hank Levy (Capability architectures, system-building at Digital)
- Addressed building a distributed system as a language problem
- Emerald separated "semantics" from "locatics"

Emerald Features

- Object constructors
- Concurrency
- Failure handling
- Parameterized types
- Location-independent invocation
- Compiled code about as efficient as C

```
const initialObject ← object initialObject
    const limit ← 10

    const newobj ← monitor object innerObject
        var flip : Boolean ← true      % true => print hi next
        const c : Condition ← Condition.create

        export operation Hi
            if ! flip then
                wait c
            end if
            stdout.PutString["Hi\n"]
            flip ← false
            signal c
        end hi
        export operation Ho
            if flip then
                wait c
            end if
            stdout.PutString["Ho\n"]
            flip ← true
            signal c
        end ho
        initially
            stdout.PutString["Starting Hi Ho program\n"]
        end initially
    end innerObject

    const hoer ← object hoer
        process
            var i : Integer ← 0
            loop
                exit when i = limit
                newobj.Hi
                i ← i + 1
            end loop
        end process
    end hoer

    process
        var i : Integer ← 0
        loop
            exit when i = limit
            newobj.Ho
            i ← i + 1
        end loop
    end process
end initialObject
```

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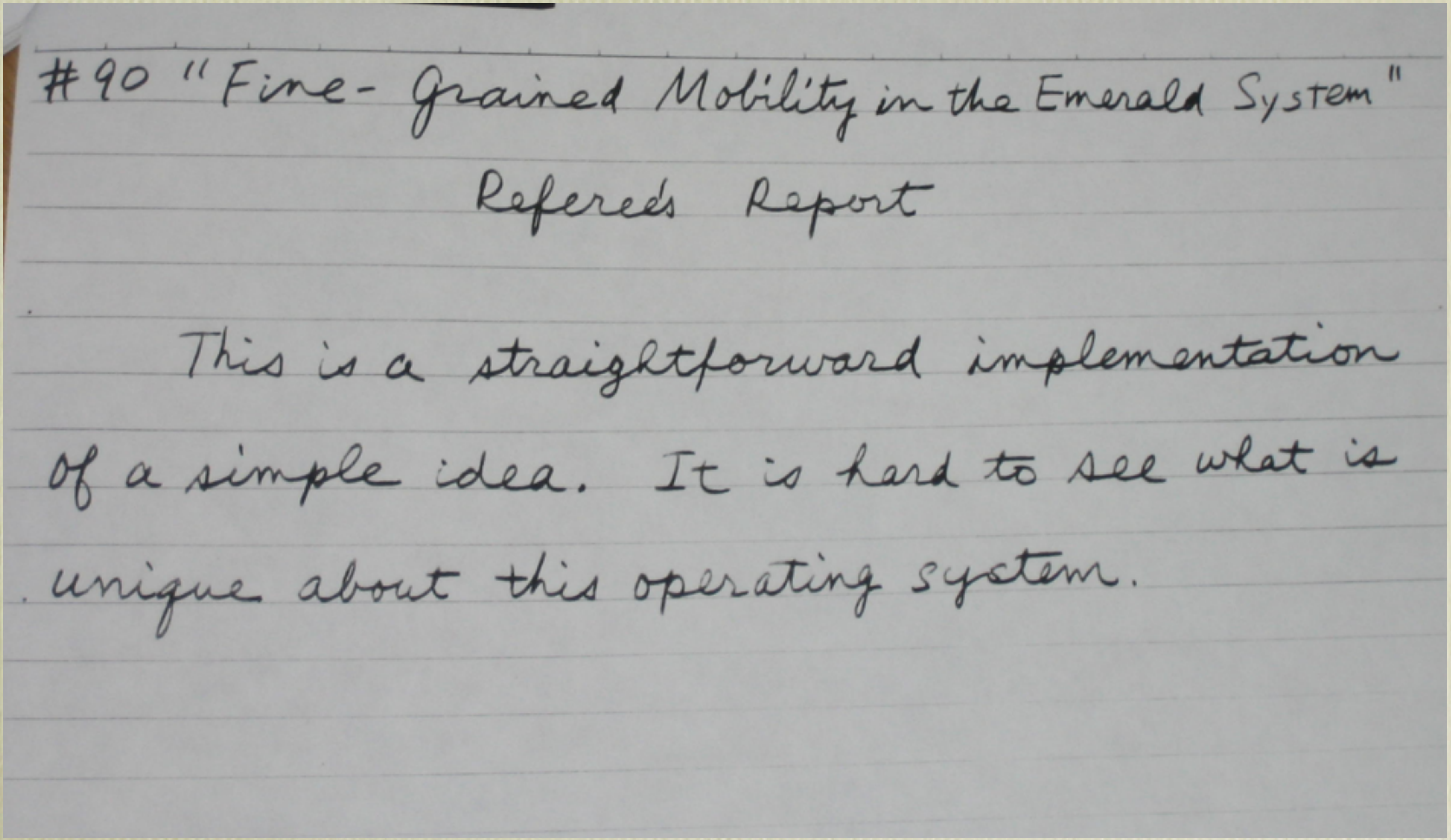
Reflections

- About 20 years before its time
  - NSF called it “unimplementable”
  - Still generating PhDs in 2006

SOSP Referee's didn't agree...



#90 "Fine-Grained Mobility in the Emerald System"

Referee's Report

This is a straightforward implementation of a simple idea. It is hard to see what is unique about this operating system.

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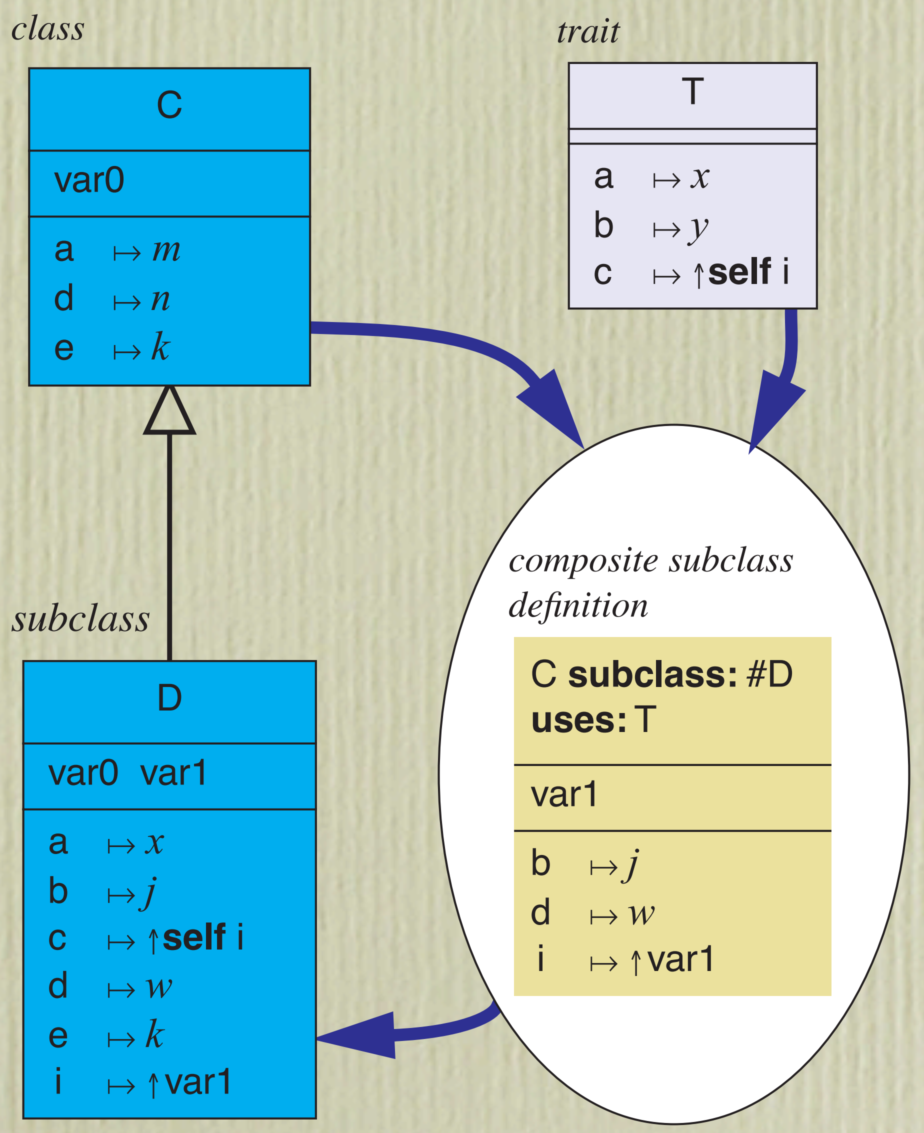
Reflections

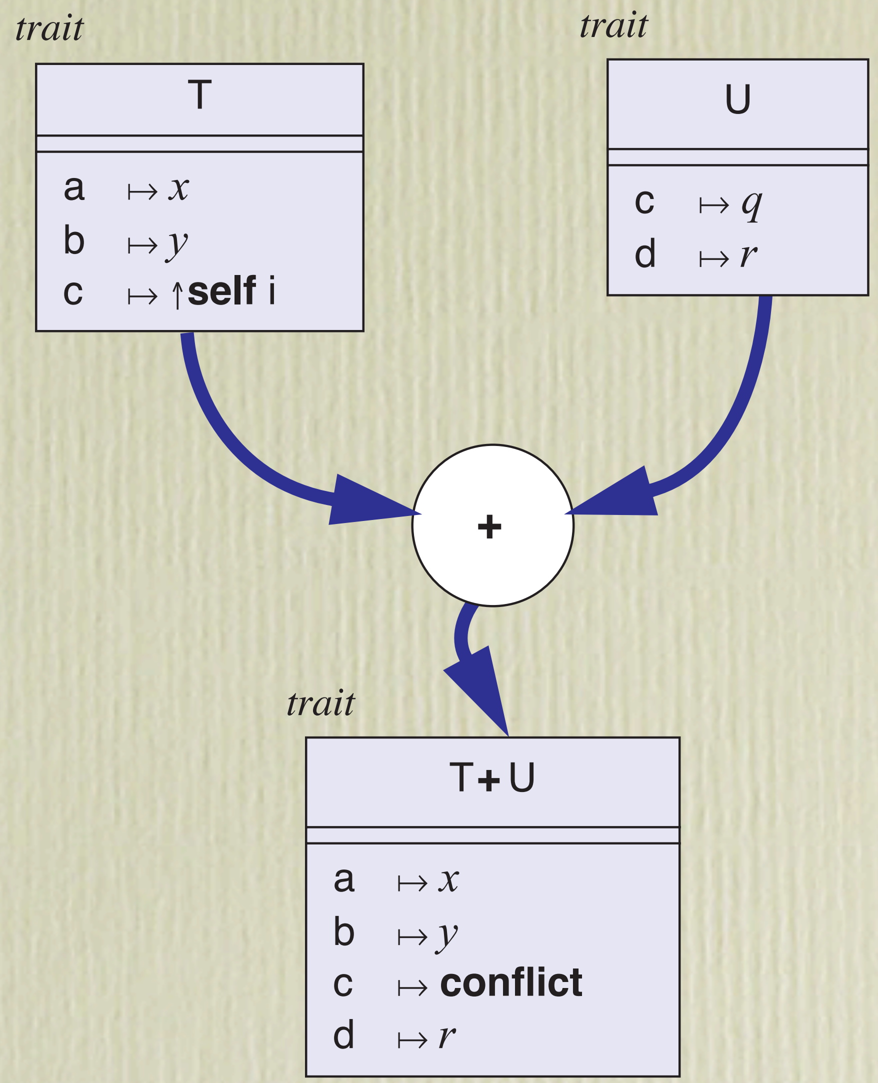
- About 20 years before its time
  - NSF called it "unimplementable"
  - Still generating PhDs in 2006
- Not widely used, but widely influential
  - ANSA DPL, OMG CORBA, INRIA's *Guide*, Birrell et al.'s Network Objects, the ANSI Smalltalk standard
- We were our own customers. *We* realized that we needed a language ...

2001–present: Traits

- a language feature, not a language
- a *Trait* is a Smalltalk class without any slots
- traits can be
  - combined with +,
  - modified with @ (alias) and – (exclusion)
  - *used* in other traits and classes.

- Trait = set of methods, without instance vars
- *Sum*, *alias, exclude* and *uses* as combinators





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Influences

- Deep experience with Smalltalk
- The sad history of multiple inheritance

  "multiple inheritance is good, but there is no good way to do it"

  Steve Cook channeling *Alan Snyder*

- Nathanael Schärli, who cut the gordian knot
- A little lattice theory
- Excellent toolbuilding environment & skills

Reflections

- *Smallest* contribution
- Largest impact?
  - Pearl 6, Java, Pharo, Visualworks, Fortress, Racket, Ruby, C#, Scala, Joose, PHP, ActionScript, ...
- We underestimated the importance of programming tools
  - many of the properties we claimed for traits depended also on tool support

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2010–present: *Grace*

- Simple O-O language for teaching
  - block-structured
  - dialects.
  - optional, gradual types
  - indentation matters
- An effort at *consolidation*, not *innovation*
- Open-source implementation

Linked List

```
method with(*a) {
    def result = empty
    a.do { each -> result.add(each) }
    return result
}

class empty {
    class node(d, n) {
        var data is public := d
        var next is public := n
        method asString { "{data}|{next}" }

        method insert(value) {
            next := node(value, next)
        }
    }

    def null = Singleton.named "⏚"
    def top = node("header", null)
    var lastNode := top
```

```
method size {
    // returns the number of elements in self
    var result := 0
    var current := top
    while { current.next ≠ null } do {
        current := current.next
        result := result + 1
    }
    return result
}

method do(action:Block1) {
    // applies action to each element of self
    var current := top
    while { current.next ≠ null } do {
        current := current.next
        action.apply(current.data)
    }
}

method search(needle) ifAbsent(action) {
    // searches for needle in self.  Returns the first node
    // containing needle if it is found; otherwise, applies action.
    var current := top
    while { current.next ≠ null } do {
```

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Influences

- Teaching with inappropriate languages
  - Java: mixes paradigms, verbose, complex
  - Python: stupid defaults, objects are an afterthought
  - Smalltalk: no types, no interfaces

Reflections

- The *consumer* is a novice student
  - but the *customer* is an instructor in a introductory programming course
- ~~Surprisingly~~ challenging to please both
  - e.g., clean object model *or* existing practice?
- Design skills ⇄ implementation skills
- http://www.gracelang.org

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Meta-Reflections

- I've had a lot of fun over the last 35 years
  - Maybe I've also had some impact
- But programming is still too hard
- The (recent) focus on Programming *Languages* rather than Programming *Systems* hasn't helped
  - less science and more engineering?

What keeps me coming back?

- I like *fixing things*
  - there's plenty to fix in programming!
- Programming languages are an *enabler*
  - for others (3R, EPL)
  - for programmers (Traits)
  - for students (*Grace*)
- Programming languages are about communication
  - still refining my writing and communication skills
  - in English, and in program

Why is progress so slow?

- Programming languages are central to everything that we build
  - You would be crazy to build a 100 kloc system with an untested language.
- Tooling and libraries are as important, or more important, than the language
  - they take time to build and evolve

Why else?

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Why else?

- A programming language is not just a means for programmers to communicate with *computers*

Why else?

- A programming language is not just a means for programmers to communicate with *computers*
- It is also a means for programmers to communicate with *programmers* —

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- It is a *social*, as well as a *technical*, enabler

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- It is a *social*, as well as a *technical*, enabler
  - social change is slow

Why else?

- A programming language is not just a means for programmers to communicate with *computers*
- It is also a means for programmers to communicate with *programmers* —
- It is a *social*, as well as a *technical*, enabler
  - social change is slow
  - but enjoys the "100th monkey" effect

What about others?

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What about others?

A quick survey of the members of IFIP WG 2.16 on language design ...

What about others?

A quick survey of the members of IFIP WG 2.16 on language design …

… revealed a lot of passion

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Creating

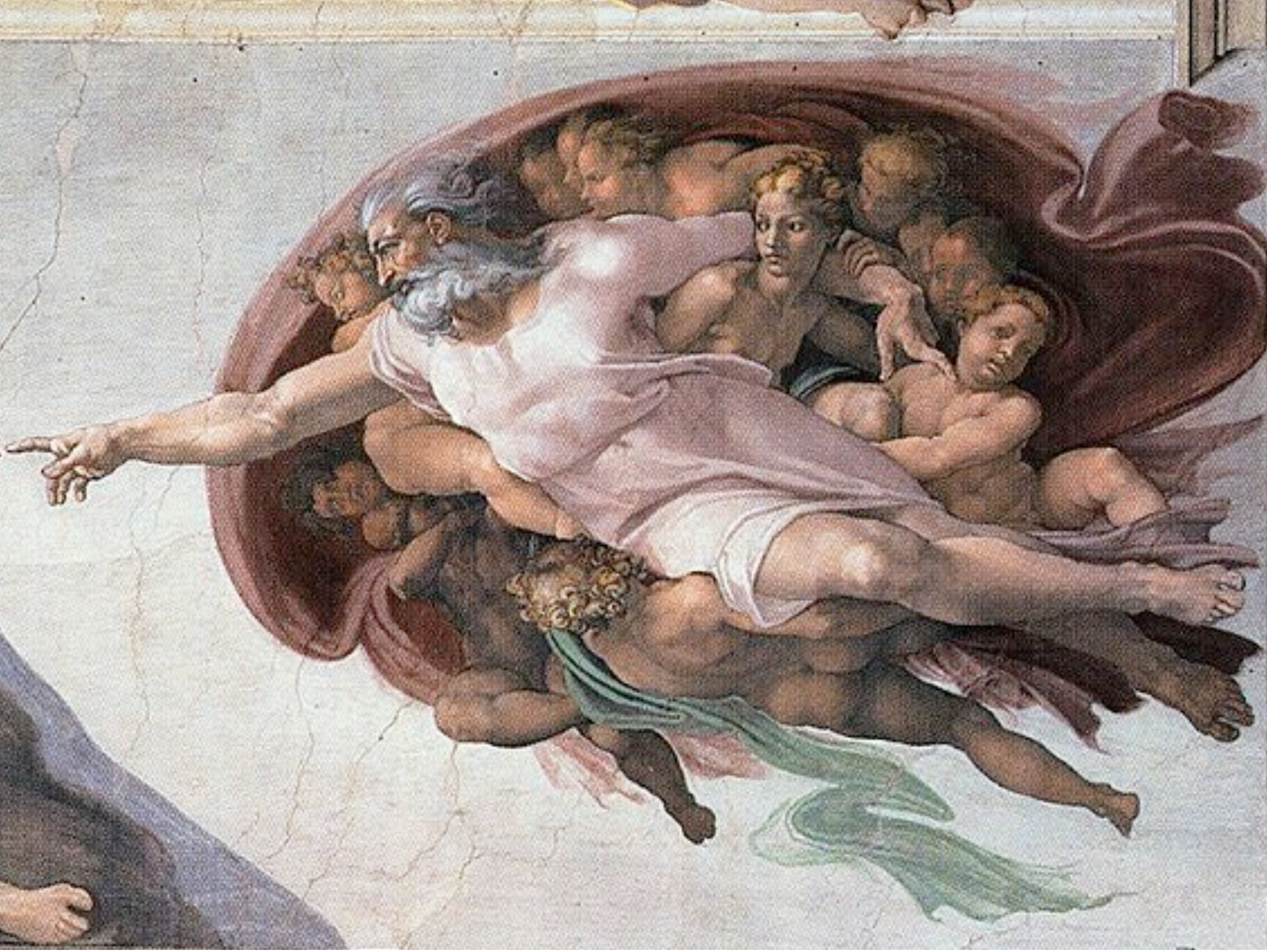
“The power to create out of pure thought”

Jonathan Edwards

“A universal tool”

“In the beginning was the word”

Cristina Lopes



Magic

Programmers are like wizards ... except that the magic is real!

PLs are "spell systems"

Sean McDirmid

"Any sufficiently-advanced technology is indistinguishable from magic"

Arthur C . Clarke

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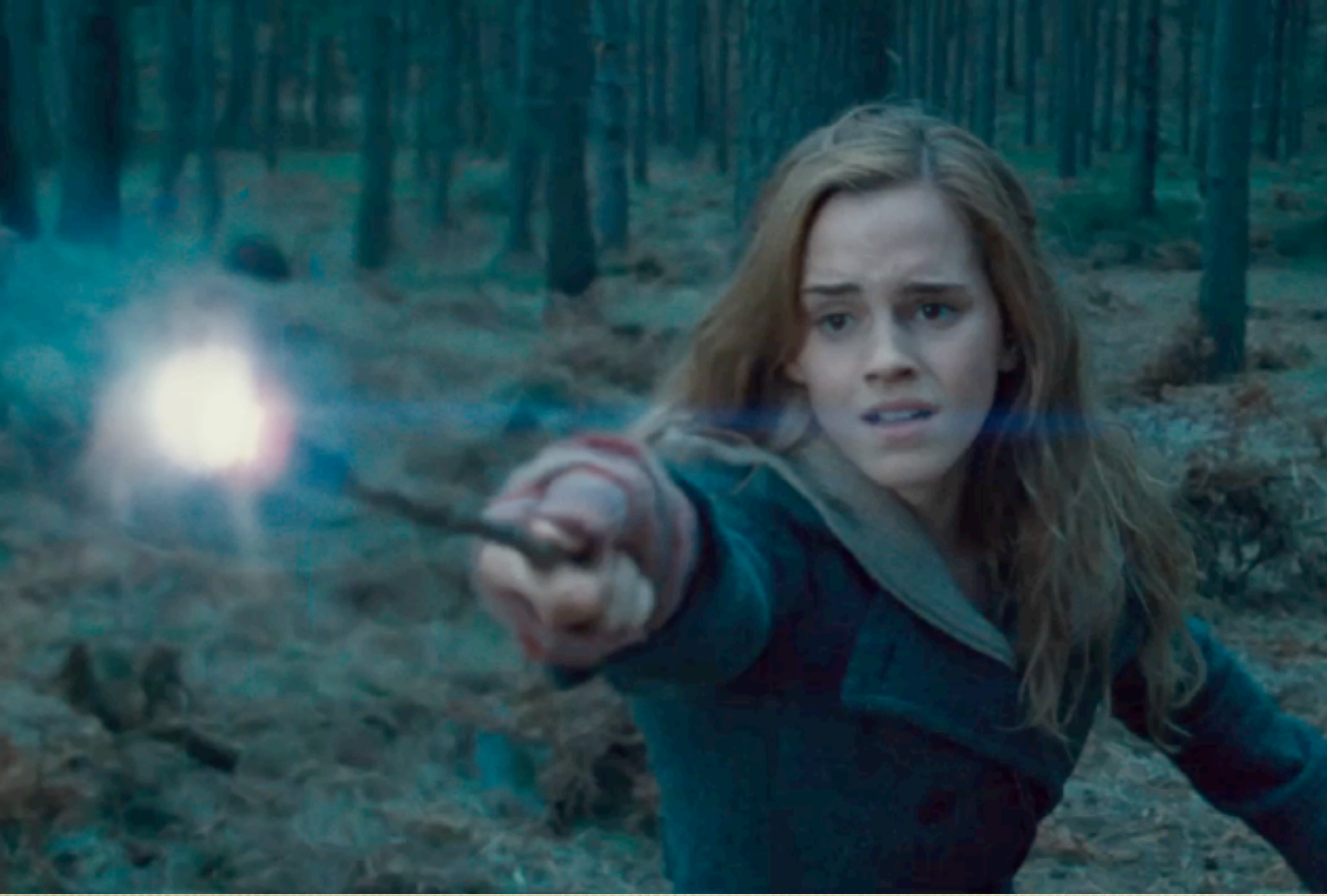

Foundational

- Software is the most important infrastructure for ... basically everything
- Software is totally dependent on programming languages
- Programming languages are the most important infrastructure for writing software ... and thus for anything and everything!

James Noble

Fun

Building things is fun!

Building things *that build things* is doubleplus fun!

Jonathan Aldrich

Are we there yet?

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Are we there yet? No!

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Are we there yet? No!

Since Fortran, people have been saying that we don't need new languages.

Yet, languages continue to evolve … and few of us would want to go back to Fortran.

Roberto Ierusalimschy

Language as "Law Enforcement"

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Language as “Law Enforcement”

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Language as "Law Enforcement"

Language as "Law Enforcement"

"Law" of Physics

Language as “Law Enforcement”

Language as “Law Enforcement”

The value of a language can be in what it *prevents* you from doing

Hence: libraries are not the answer

Language as "Law Enforcement"

The value of a language can be in what it *prevents* you from doing

Hence: libraries are not the answer

- No library is ever going to ensure that there are no race conditions in my Java program

Languages shape thought

Languages shape thought

Whorfianism, or “Linguistic Relativity”

Languages shape thought

Whorfianism, or "Linguistic Relativity"

Learning a new language "changes the path of least resistance"

Tom van Cutsem

Languages shape thought

Whorfianism, or “Linguistic Relativity”

Learning a new language “changes the path of least resistance”

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Languages shape thought

Languages shape thought

Languages shape thought

"You can't trust the opinions of others, because of the Blub paradox: they're satisfied with whatever language they happen to use, because it dictates the way they think about programs."

Paul Graham

Languages shape thought

Languages shape thought

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Languages shape thought

“A language that doesn’t affect the way you think about programming,
is not worth knowing”

Alan Perlis

Languages shape thought

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Languages shape thought

My Recommendation:

Languages shape thought

My Recommendation:

- *Do* program in a pure functional language

Languages shape thought

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- *Do* program in a pure functional language
- *Do* program with pure objects (Smalltalk)

Languages shape thought

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Languages shape thought

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- *Do* program with pure objects (Smalltalk)
- *Do* program with CSP
- *Do* try Logic Programming (but not Prolog!)

Languages shape thought

My Recommendation:

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- *Do* program with pure objects (Smalltalk)
- *Do* program with CSP
- *Do* try Logic Programming (but not Prolog!)

Use them for a serious project

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PL Reading List

1. *Notation as a tool of thought*. Iverson
2. *Programming as Theory-building*. Naur
3. *Beating the Averages*. Graham (and commentary thereon at c2.org)
4. *The Development of the Emerald Programming Language*. Black *et al*. HoPL III
5. *The Algol 60 Report*. Naur *et al*
6. *Smalltalk*. BYTE Magazine, August 1981
7. *Lisp: Good News, Bad News, How to Win Big*. Gabriel
8. *Babel-17*. Delany