Computer Science

A guide
for
the perplexed

Joe Armstrong

Computer science
is confusing
because it's not a science
and there are far too many
ideas floating around

The "latest stuff" is
not Computer Science

My goals

- Identify some problems worth solving
- Identify the stuff worth learning

[note: this is a very biased view]

- 50 years ago there was too little software

- 25 years ago it was about right

- Now there’s too much (sorry about that)

- The problems that Computer Scientists Study

- The problems users have

- The problems Industry solves

These are all completely different

Things we can create

Things we can understand

Things we can create

Huge Gap

Things we can understand

3N+1

- If N is odd replace it by 3N+1
- If N is even replace it by N/2

The Collatz conjecture is:
This process will eventually reach the number 1, for all starting values on N

"Mathematics may not be ready for such problems”

Paul Erdős

Part 1
Back in the 1980's
I had a plan

- How to find things
- How to store things
- How to program things

Sub-goals

- Learn emacs
- Learn unix
- Learn a programming language

What happened?

- I didn’t learn emacs
- I didn’t learn unix
- I created a programming language

Some Progress
(after 30 years)

- Finding things
  Google and friends (but we find the wrong stuff)

- Saving things
  Dropbox and friends (but it not forever, only as long as your credit card keeps up the payments)

- Programming things
  Some small improvements - nothing dramatic
  The last new thing was Prolog - no major improvements since then.

Joe Armstrong & Alan Kay - Joe Armstrong interviews Alan Kay

26,882 views 410 7 SHARE

What ideas has we forgotten?

Joe Armstrong
@joeerl

I'm interested in the forgotten ideas of computer science. Needed for a talk.

Can you post examples of great CS ideas that have been largely forgotten.

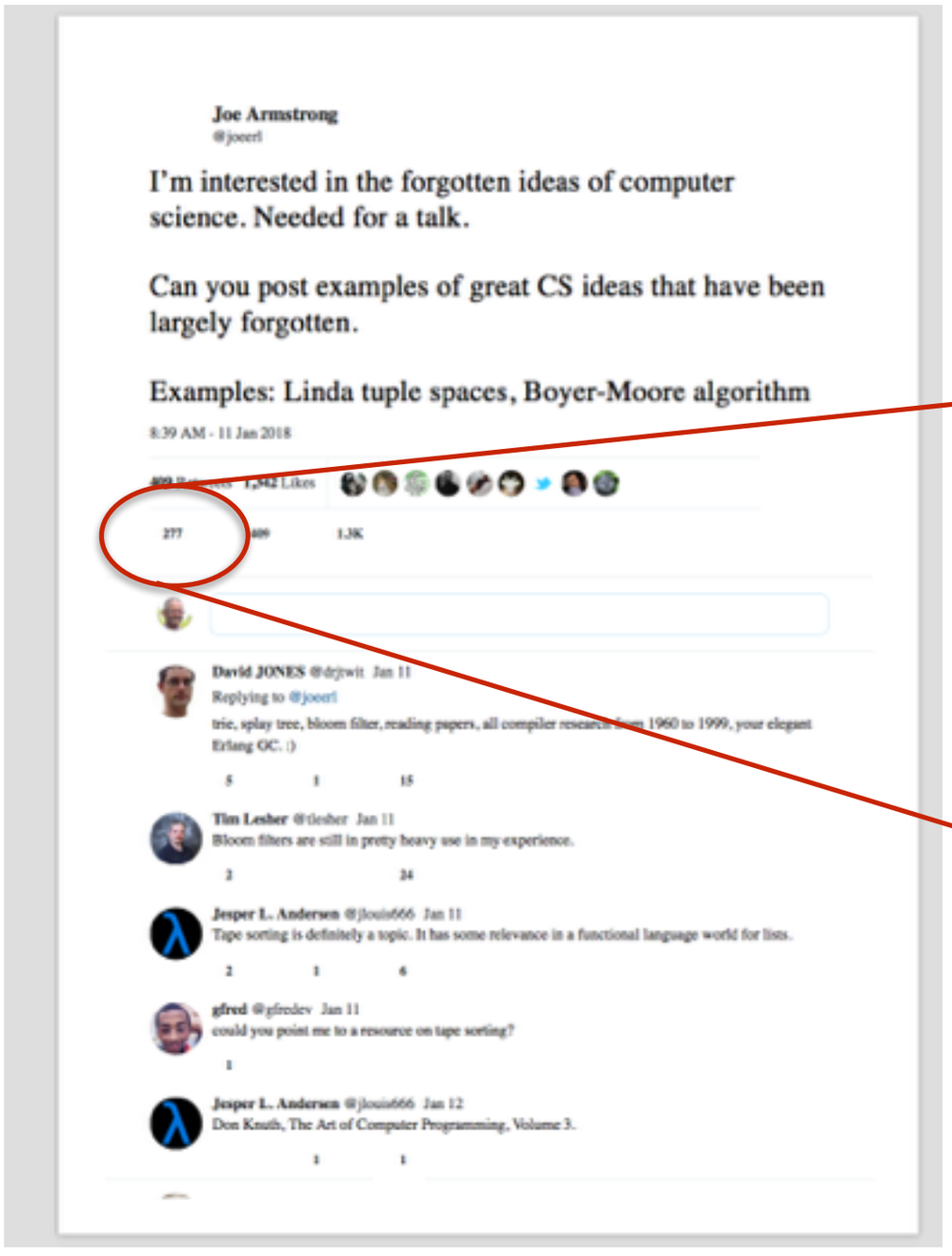
Examples: Linda tuple spaces, Boyer-Moore algorithm

8:39 AM - 11 Jan 2018

390 Retweets **1,268** Likes

264 390 1.3K

The next day



277

I made some lists

- Collect lots of items easy
- Assign to lists difficult
- Shorten the lists to N items (N is small) very difficult
  Throwing things away is much more difficult than collecting things - but what's left is better.

Part 2

Things to learn (the lists)

80 things to do

- 2 great papers to read
- 4 old tools to learn
- 4 really bad things
- 3 great books to read
- 7 reasons why software is difficult now
- 10 reasons why software was easier back in the day
- 1 fun programming exercise
- 8 great machines from the past

… and …

. . .

- 3 performance improvements
- 5+ YouTube videos to watch
- 6 things not to do
- 5 sins
- 4 languages to learn
- 4 great forgotten ideas
- 6 areas to research
- 2 dangers
- 4 ideas that are obvious now but strange at first
- 2 fantastic programs to try

2 great papers to read

Cybersquare

A Plea for Lean Software

Niklaus Wirth
ETH Zürich

Memory requirements of today's workstations typically jump exponentially—from several to many megabytes—whenever there's a new software release. When demand surpasses capacity, it's time to buy add-on memory. When the system has no more extensibility, it's time to buy a new, more powerful workstation. Do increased performance and functionality keep pace with the increased demand for resources? Mostly the answer is no.

About 25 years ago, an interactive text editor could be designed with as little as 8,000 bytes of storage. (Modern program editors require 100 times that much!) An operating system had to manage with 8,000 bytes, and a compiler had to fit into 32 Kbytes, whereas their modern descendants require megabytes. Has all this inflated software become any faster? On the contrary. Were it not for a thousand times faster hardware, modern software would be utterly unusable.

Enhanced user convenience and functionality supposedly justify the increased size of software, but a closer look reveals these justifications to be shaky. A text editor still performs the reasonably simple task of inserting, deleting, and moving parts of text; a compiler still translates text into executable code; and an operating system still manages memory, disk space, and processor cycles. These basic obligations have not changed with the advent of windows, cut-and-paste strategies, and pop-up menus, nor with the replacement of meaningful command words by pretty icons.

The apparent software explosion is accepted largely because of the staggering progress made by semiconductor technology, which has improved the price/performance ratio to a degree unparalleled by any other branches of technology. For example, from 1978 to 1993 Intel's 80x86 family of processors increased power by a factor of 110, transistor density by a factor of 107, and price by a factor of about 3. The prospects for continuous performance increases are still solid, and there is no sign that software's ravenous appetite will be appeased anytime soon.[1] This development has spawned numerous rules, laws, and corollaries, which are—as is customary in such cases—expressed in general terms, thus they are neither provable nor refutable. With a touch of humor, the following two laws reflect the state of the art admirably well:

- Software expands to fill the available memory. (Parkinson)
- Software is getting slower more rapidly than hardware becomes faster. (Reiser)

Uncontrolled software growth has also been accepted because consumers have trouble distinguishing between essential features and those that are just "nice to have." Examples of the latter class: those arbitrarily overlapping windows suggested by the uncritically but widely adopted

Software's girth has surpassed its functionality, largely because hardware advances make this possible. The way to streamline software lies in disciplined methodologies and a return to the essentials.

Computer

The 1980 ACM Turing Award Lecture

Delivered at ACM '80, Nashville, Tennessee, October 27, 1980

C.A.R. Hoare

The 1980 ACM Turing Award was presented to Charles Antony Richard Hoare, Professor of Computation at the University of Oxford, England, by Walter Carlson, Chairman of the Awards committee, at the ACM Annual Conference in Nashville, Tennessee, October 27, 1980.

Professor Hoare was selected by the General Technical Achievement Award Committee for his fundamental contributions to the definition and design of programming languages. His work is characterized by an unusual combination of insight, originality, elegance, and impact. He is best known for his work on axiomatic definitions of programming languages through the use of techniques popularly referred to as axiomatic semantics. He developed ingenious algorithms such as Quicksort and was responsible for inventing and promulgating advanced data structuring techniques in scientific programming languages. He has also made important contributions to operating systems through the study of monitors. His most recent work is on communicating sequential processes.

Prior to his appointment to the University of Oxford in 1977, Professor Hoare was Professor of Computer Science at The Queen's University in Belfast, Ireland from 1968 to 1977 and was a Visiting Professor at Stanford University in 1973. From 1960 to 1968 he held a number of positions with Elliot Brothers, Ltd., England.

Professor Hoare has published extensively and is on the editorial boards of a number of the world's foremost computer science journals. In 1973 he received the ACM Programming Systems and Languages Paper Award. Professor Hoare became a Distinguished Fellow of the British Computer Society in 1978 and was awarded the degree of Doctor of Science Honoris Causa by the University of Southern California in 1979.

The Turing Award is the Association for Computing Machinery's highest award for technical contributions to the computing community. It is presented each year in commemoration of Dr. A. M. Turing, an English mathematician who made many important contributions to the computing sciences.

The Emperor's Old Clothes

Charles Antony Richard Hoare
Oxford University, England

The author recounts his experiences in the implementation, design, and standardization of computer programming languages, and issues a warning for the future.

Key Words and Phrases: programming languages, history of programming languages, lessons for the future
CR Categories: 1.2, 2.11, 4.2

Author's present address: C. A. R. Hoare, 45 Banbury Road, Oxford OX2 6PE, England.

My first and most pleasant duty in this lecture is to express my profound gratitude to the Association for Computing Machinery for the great honor which they have bestowed on me and for this opportunity to address you on a topic of my choice. What a difficult choice it is! My scientific achievements, so amply recognized by this award, have already been amply described in the scientific literature. Instead of repeating the abstruse technicalities of my trade, I would like to talk informally about myself, my personal experiences, my hopes and fears, my modest successes, and my rather less modest failures. I have learned more from my failures than can ever be revealed in the cold print of a scientific article and now I would like you to learn from them, too. Besides, failures

- A Plea for Lean Software - Niklaus Wirth
- The Emperor's old clothes - ACM Turing award lecture - Tony Hoare

5. The belief that complex systems require armies of designers and programmers is wrong. A system that is not understood in its entirety, or at least to a significant degree of detail by a single individual, should probably not be built.

Wirth

7. Reducing complexity and size must be the goal in every step—in system specification, design, and in detailed programming. A programmer's competence should be judged by the ability to find simple solutions, certainly not by productivity measured in "number of lines ejected per day." Prolific programmers contribute to certain disaster.
8. To gain experience, there is no substitute for one's own programming effort. Organizing a team into managers, designers, programmers, analysts, and users is detrimental. All should participate (with differing degrees of emphasis) in all aspects of development. In particular, everyone—including managers—should also be product users for a time. This last measure is the best guarantee to correct mistakes and perhaps also to eliminate redundancies.

different. At last, there breezed into my office the most senior manager of all, a general manager of our parent company, Andrew St. Johnston. I was surprised that he had even heard of me. "You know what went wrong?" he shouted—he always shouted— "You let your programmers do things which you yourself do not understand." I stared in astonishment. He was obviously out of touch with present day realities. How could one person ever understand the whole of a modern software product like the Elliott 503 Mark II software system?

I realized later that he was absolutely right; he had diagnosed the true cause of the problem and he had planted the seed of its later solution.

Hoare

plans (but not promises) to implement it. In no case would we consider a request for a feature that would take more than three months to implement and deliver. The project leader would then have to convince *me* that the customers' request was reasonable, that the design of the new feature was appropriate, and that the plans and schedules for implementation were realistic. Above all, I did not allow anything to be done which I did not myself understand. It worked! The software requested began to be delivered on the promised dates. With an

4 old tools to learn

- emacs (vi)
- bash
- make
- shell

4 really bad things

- Lack of Privacy
- Attempts to manipulate us through social media
- Vendor Lock in
- Terms and Conditions

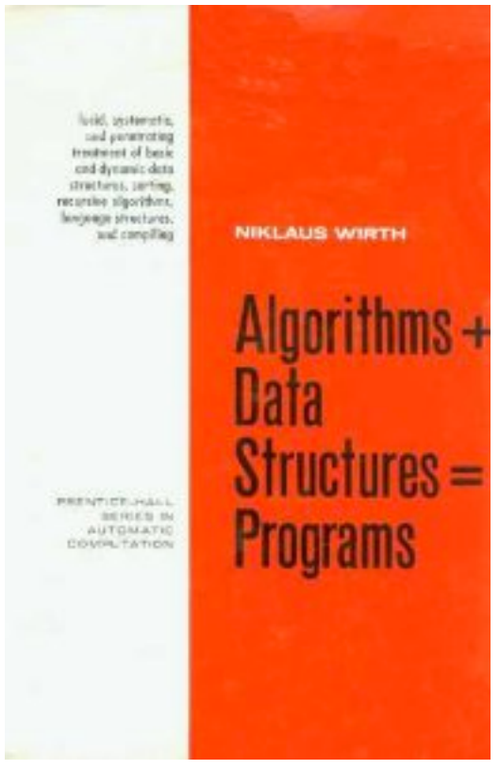
Terms and Conditions

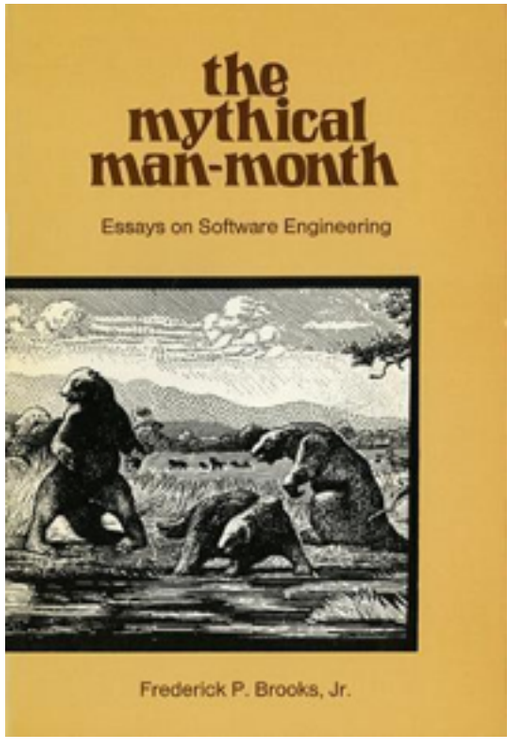
- I’ve read all the terms and conditions and understood them

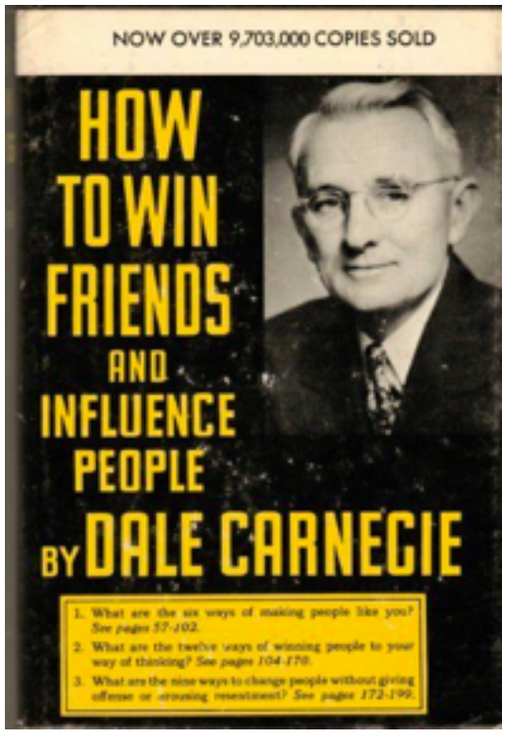
- I’ve read the terms and conditions and didn’t understand them

- I just clicked on accept

3 great books to read







7 reasons why software is difficult now

- Fast machines
- Huge memory
- Hundreds of PLs
- Distributed
- Huge programs
- No specifications
- Reuse

10 reasons why software was easier back in the day

- Small machines
- Small memory
- Few languages
- Not distributed
- No reuse of code
- No Xcode etc
- No GIT.
- Complete control
- Did not communicate
- Understandable in it’s entirety

1 fun programming exercise

META II

A SYNTAX-ORIENTED COMPILER WRITING LANGUAGE

D. V. Schorre
UCLA Computing Facility

META II is a compiler writing language which consists of syntax equations resembling Backus normal form and into which instructions to output assembly language commands are inserted. Compilers have been written in this language for VALGOL I and VALGOL II. The former is a simple algebraic language designed for the purpose of illustrating META II. The latter contains a fairly large subset of ALGOL 60.

The method of writing compilers which is given in detail in the paper may be explained briefly as follows. Each syntax equation is translated into a recursive subroutine which tests the input string for a particular phrase structure, and deletes it if found. Backup is avoided by the extensive use of factoring in the syntax equations. For each source language, an interpreter is written and programs are compiled into that interpretive language.

META II is not intended as a standard language which everyone will use to write compilers. Rather, it is an example of a simple working language which can give one a good start in designing a compiler-writing compiler suited to his own needs. Indeed, the META II compiler is written in its own language, thus lending itself to modification.

History

The basic ideas behind META II were described in a series of three papers by Schmidt,[1] Metcalf,[2] and Schorre.[3] These papers were presented at the 1963 National A.C.M. Convention in Denver, and represented the activity of the Working Group on Syntax-Directed Compilers of the Los Angeles SIGPLAN. The methods used by that group are similar to those of Glennie and Conway, but differ in one important respect. Both of these researchers expressed syntax in the form of diagrams, which they subsequently coded for use on a computer. In the case of META II, the syntax is input to the computer in a notation resembling Backus normal form. The method of syntax analysis discussed in this paper is entirely different from the one used by Irons[4] and Beatman.[7] All of these methods can be traced back to the mathematical study of natural languages, as described by Chomsky.[8]

Syntax Notation

The notation used here is similar to the meta language of the ALGOL 60 report. Probably the main difference is that this notation can be keypunched. Symbols in the target language are represented as strings of characters, surrounded by quotes. Metalinguistic variables have the same form as identifiers in ALGOL, viz., a letter followed by a sequence of letters or digits.

Items are written consecutively to indicate concatenation and separated by a slash to indicate alternation. Each equation ends with a semicolon which, due to keypunch limitations, is represented by a period followed by a comma. An example of a syntax equation is:

LOGICALVALUE = '.TRUE' / '.FALSE' .,

In the versions of ALGOL described in this paper the symbols which are usually printed in boldface type will begin with periods, for example:

.PROCEDURE .TRUE .IF

To indicate that a syntactic element is optional, it may be put in alternation with the word .EMPTY. For example:

SUBSECONDARY = '*' PRIMARY / .EMPTY .,
SECONDARY = PRIMARY SUBSECONDARY .,

By factoring, these two equations can be written as a single equation.

SECONDARY = PRIMARY['*' PRIMARY / .EMPTY] .,

Built into the META II language is the ability to recognize three basic symbols which are:

1. Identifiers -- represented by .ID,
2. Strings -- represented by .STRING,
3. Numbers -- represented by .NUMBER.

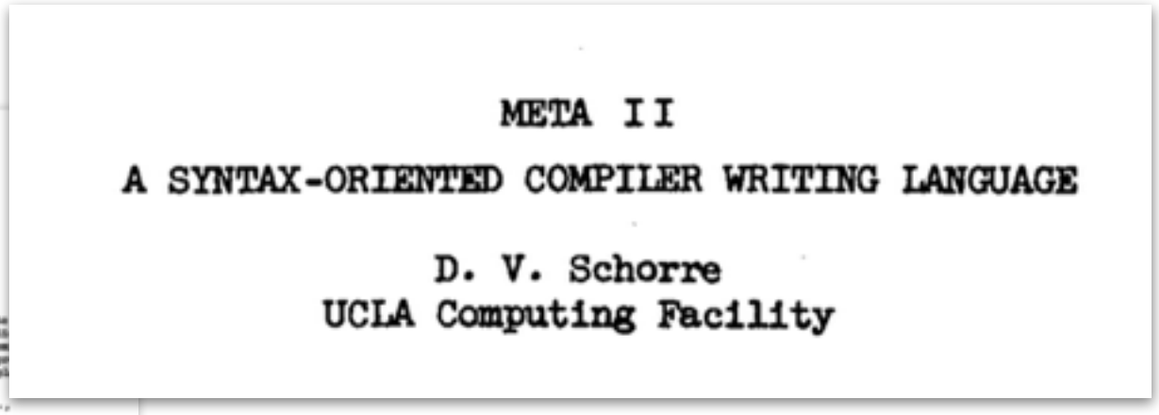
The definition of identifier is the same in META II as in ALGOL, viz., a letter followed by a sequence of letters or digits. The definition of a string is changed because of the limited character set available on the usual keypunch. In ALGOL, strings are surrounded by opening and closing quotation marks, making it possible to have quotes within a string. The single quotation mark on the keypunch is unique, imposing the restriction that a string in quotes can contain no other quotation marks.

The definition of number has been radically changed. The reason for this is to cut down on the space required by the machine subroutine which recognizes numbers. A number is considered to be a string of digits which may include imbedded periods, but may not begin or end with a period; moreover, periods may not be adjacent. The use of the subscript 10 has been eliminated.

Now we have enough of the syntax defining features of the META II language so that we can consider a simple example in some detail.

The example given here is a set of four syntax equations for defining a very limited class of algebraic expressions. The two operators, addition and multiplication, will be represented by + and * respectively. Multiplication takes precedence over addition; otherwise precedence is indicated by parentheses. Some examples are:

B1.3-1



META II

A SYNTAX-ORIENTED COMPILER WRITING LANGUAGE

D. V. Schorre
UCLA Computing Facility

Serious fun - might cause your brain to melt

8 great machines from the past

- Baby SSEM
- PDP11
- Vax 11/750
- Cray 1
- IBM PC
- Raspberry PI
- iPhone/iPad
- Nvidia Tesla P100

3 performance improvements

- Better algorithms (x 6) (Interpreter -> Compiler)
- Better Programming language (x50) (Prolog -> C)
- Better Hardware (x1000 per 10 years)

5+ YouTube videos to watch

- The computer revolution has not happened yet
  Alan Kay

- Computers for Cynics
  Ted Nelson

- Free is a lie (Aaron Balkan)

- How a handful of tech companies control billions of minds every day Tristan Harris (TED-Talk)

- Matt Might - Winning the War on Error: Solving Halting Problem, Curing Cancer - Code Mesh 2017

6 things not to do

- Backdoors
- Violate privacy
- Put microphones in everybody's houses
- Hijack our attention system
- Hijack our social systems
- Sell crap that we don’t want or need

5 sins

- Crap documentation
- Crap website
- Crap dependencies
- Crap build instructions
- Group think

4 languages to learn

- C
- Prolog
- Erlang
- Javascript

4 great forgotten ideas

- Linda Tuple Spaces - David Gelernter and Nicholas Carriero.
- Flow based programming - John Paul Morrison.
- **Xanadu - Ted Nelson**
- Unix pipes

Pipes

- **The output of my program should be the input to your program**

- A | B | C
- Text-flows across the boundary
- **Killed by GUIs** and Apps (Apps are not pipeable)

Apps

- Pads - Tablets - Phones
- Human can interact with Apps
- Apps can’t interact with each other
- You are locked inside your Apps. They all do different things with a varying degree of success.

6 areas to research

- Robotics
- AI
- Progammer productivity
- Energy efficiency
- Precision Medicin
- Security

2 dangers

- Group think

- Bubble think

4 ideas that are obvious now but strange at first

- Indentation
- Versioning
- Hypertext across machine boundaries
- Pipes

2 fantastic programs to try

- TiddlyWiki
- SonicPI

Part 3
Important non computer science things

learn to write

- A program with excellent documentation is not going to go anywhere
- …

3 rules at work

- If you get a bad boss move immediately
  do not try to change your boss

- The relationship comes first (Jane Walerud)

- Engage with management
  just because they do not understand what you are saying is no reason not to talk to them - and whose fault is it anyway (that they don’t understand you)

7 distractions

- Open plan offices
- The latest stuff
- Twitter/Facebook (social media)
- Notifications (turn ‘em off)
- Links (don’t click on them)
- Ban Scrum etc.
- We can only do one thing at a time
  Our brains are terribly bad at context switching

6 ways to get your boss to <program in XXX>

- Do things that gain trust
- Tell success stories
- Reduce fear of failure
- Introduce on a small scale - for a part of the problem
- Network with XXX folks
- Make a prototype at home
- (don’t bother - quit and form a company)

1 thing to look for when applying for a new job

- Look at their balance sheet
  a company with a positive cash flow and increasing profits is good to work for - a company that makes a loss is not good to work for

3 general laws

- Software complexity grows with time (because we build on old stuff)
- Bad code crowds out good (Gresham's law)
  bad money drives out good (clipping)
- Bad code contaminates good code

Laws of Physics and maths

3 laws of physics

- A computation can only take place when the data and the program are at the same point in space time => get all the data + program to the same place (can be client OR server or someplace in-between) (problem - easy to move data - difficult to move programs) **This is why PHP is good :-)**

- Causality - Effect follows cause. We don't know how stuff **is** we know how it **was** (the last time it told us)

- 2'nd law thermo dynamics - Entropy (disorder) always increases

Entropy

- Early Unix (1970) had a very small disk so programs that were not used were thrown away (decreases entropy - natural selection)

- Git keeps all old versions (increases entropy - cancer)

- https://en.wikipedia.org/wiki/Unix_philosophy

Trust and Responsibility

Trust is transitive

- I trust the SW written by Robert
- Robert wrote X
- => I trust X

Can I trust X?

- I need a program to do X
- I find X in github
- I do not know who wrote X
- Can I trust X?

Responsibility

- I reuse X in program P
- I ship program P to custom A
- A reports an error in P
- I am responsable
- => I must trust that P is correct

User’s Problems

6 common problems

- Does not know how to delete files - when the system runs out of space they buy a new computer
- No idea of what MBytes, Mbits, Bbits/sec quad cores etc means
- If the app doesn’t work immediately gives up
- Does not Google for fixes - or does and does not understand the answers
- Does not want to try the latest things
- Uses a method that works (not the best) - ie to copy
  a file open word - read the file in then writes it out with a new name

5 more Problems

- The UI changes
- Passwords
- Stuff doesn’t work
- Terms & Conditions
- … non reproducible errors

Helping your non-technical neighbour

- Tell them “it’s not your fault”
- Tell them “it’s crap software”
- Tell them “I don’t understand this crap either”
- Tell them “computers can’t do everything”

Part 4
Important half forgotten BIG ideas

Things can be small

- Forth OS 24 KB
- Forth compiler 12KB
- IBM PC DOS < 640KB
- USCD Pascal
- Turbo Pascal
- Turbo C

The old truths

- Keep it simple
- Make it small
- Make it correct
- Fight complexity

Learning

- Kids can learn computing
- OAPs can learn computing
- Everybody can learn computing
  It was easy to learn BASIC back in the 80's so why is it more difficult now?

Web is broken

- It’s not symmetric
  Users read data but write very little

- Can every page be changed?

- Can I make new data by combining fragments from other data in a flexible manner? - no

- The Web is dominated by a small number of companies (Amazon, Apple, Goole, Facebook) using huge data centers, it should be controlled from the edge network.

- The original vision was a Web controlled by “citizen programmers” (Google “Ted Nelson talks”)

Xanadu

- Like the web but better
- No broken links
- No difference between readers and writers
- Never loose any data
- All copyright and attribution correct
- Complete knowledge of parents and children

Problems

- Solve the “404 - Not found” problem
- Make sure we don’t loose all our history
- Think Joules not $
- We are responsible for the negative side effects of our technology

Part 5

What we can do

- Unbreak the web
  Make it read/write symmetric

- Bring computation to the edge network

- Ensure that all personal data is owned by the individual and not by large corporations

- Make computing easy again

- Build Apps so they can communicate with each other

Don’t reuse code
rewrite it

Write code that is
correct forever

Reduce

Entropy

Write less code
not more

Throw old code
away

A program that is not secure and cannot be remotely controlled should not be written

We've given millions of people supercomputers - so let them use them and …

It’s your turn next