Lecture 20:
Little Languages

Over-simplified history of programming languages

• 1940's	machine language	
• 1950's	assembly language	
• 1960's	high-level languages:	scripting languages:
	Algol, Fortran, Cobol, Basic	Snobol
• 1970's	systems programming: C	shell
• 1980's	object-oriented: C++	Awk
• 1990's	strongly-hyped: Java	Perl, Python, PHP, …
• 2000's	lookalike languages: C#	Javascript
• 2010's	retry: Go, Rust, Swift	Dart, Typescript

Domain-specific languages

- also called application specific languages, little languages

- narrow domain of applicability
- not necessarily programmable or Turing-complete
  - often declarative, not imperative
- often small enough that you could build one yourself

- examples:
  - regular expressions
  - parser and lexer generators: YACC, LEX, ANTLR
  - shell, Awk
  - markup languages: XML, HTML, Troff, (La)TeX, Markdown
  - data format/exchange languages: YAML, JSON, ASN.1
  - database access: SQL
  - statistics: R
  - mathematical optimization: AMPL
  - …

Example: Markup / document preparation languages

- **illustrates topics of 333 in a different setting**
  - tools
  - language design (good and bad); notation
  - evolution of software systems; maintenance
  - personal interest, research area for 10-20 years, heavy use in books

- **examples:**
  - roff and related early formatters
  - nroff (Unix `man` command still uses it)
  - troff
  - Tex / Latex
  - HTML, Markdown, etc.

Unix document preparation: *roff

- text interspersed with formatting commands on separate lines

```
.sp 2
.in 5
This is a paragraph …
```

- originally just ASCII output, fixed layout, single column
- nroff: macros, a event mechanism for page layout (Turing complete)
- troff: version of nroff for phototypesetters
  - adds features for size, font, precise positioning, bigger character sets
  - originally by Joe Ossanna (~1972); inherited by BWK ~1977
- photypesetter produces output on photographic paper or film
- first high-quality output device at a reasonable price (~$15K)
  - predates laser printers by 5-10 years
  - predates Postscript (1982) by 10 years, PDF (1993) by 21 years
  - klunky, slow, messy (chemicals!), expensive media
- complex program, complex language
  - language reflects many of the weirdnesses of first typesetter
  - macro packages make it usable by mortals for standard tasks
- troff + phototypesetter enables book-quality output
  - *..., K&R, TPOP, Go, …*

Extension to complex specialized technical material

- mathematics
  - called “penalty copy” in the printing industry
- tables
- drawings
- graphs
- references
- indexes
- etc.

- at the time, done by hand composition
  - not much better than medieval technology

- Bell Labs authors writing papers and books with all of these
- being done by manual typewriters
- how can production be mechanized?

EQN: a language for typesetting mathematics

- BWK, with Lorinda Cherry ~1974

- idea: a language that matches the way mathematics is spoken aloud
- translate that into troff commands
  - since the language is so orthogonal, it wouldn't fit directly
  - and there isn't room anyway, since program has to be less than 65KB
  - troff is powerful enough
- use a pipeline: `eqn | troff`
- math mode in TEX (1978) was inspired by EQN

EQN examples

```
x sup 2 + y sup 2 = z sup 2
```

$$x^2 + y^2 = z^2$$

```
f(t) = 2 pi int sin ( omega t ) dt
```

$$f(t) = 2\pi \int \sin(\omega t)\ dt$$

```
lim from {x -> pi / 2} ( tan x ) = inf
```

$$\lim_{x \to \pi/2} (\tan x) = \infty$$

```
x = {-b +- sqrt {b sup 2 – 4ac} over 2a}
```

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

EQN implementation

- **based on a YACC grammar**
  - first use of YACC outside mainstream compilers

- **grammar is simple**
  - box model
  - just combine boxes in various ways:
    concatenate, above/below, sub and superscript, sqrt, ...

```
eqn: box  |  eqn box
box: text  |  { eqn }  |  box over box  |  sqrt box
    |  box sub box  |  box sup box  |  box from box to box  |  ...
```

- **YACC makes experimental language design easy**

Pic: a language for pictures (line drawings)

- **new typesetter has more capabilities** (costs more too: $50K in 1977)
- **can we use troff to do line drawings?**

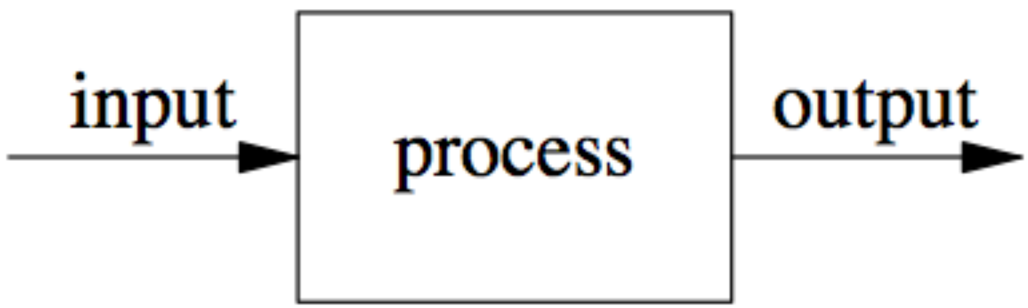
- **answer: invent another language, again a preprocessor**
  – add simple line-drawing primitives to troff: line, arc, spline

- **advantages of text descriptions of pictures**
  – systematic changes are easy, always have correct dimensions,
  – Pic has loops, conditionals, etc., for repetitive structures
    Turing complete!

- **implemented with YACC and LEX**
  – makes it easy to experiment with syntax
  – human engineering:
    free-form English-like syntax
    implicit positioning: little need for arithmetic on coordinates

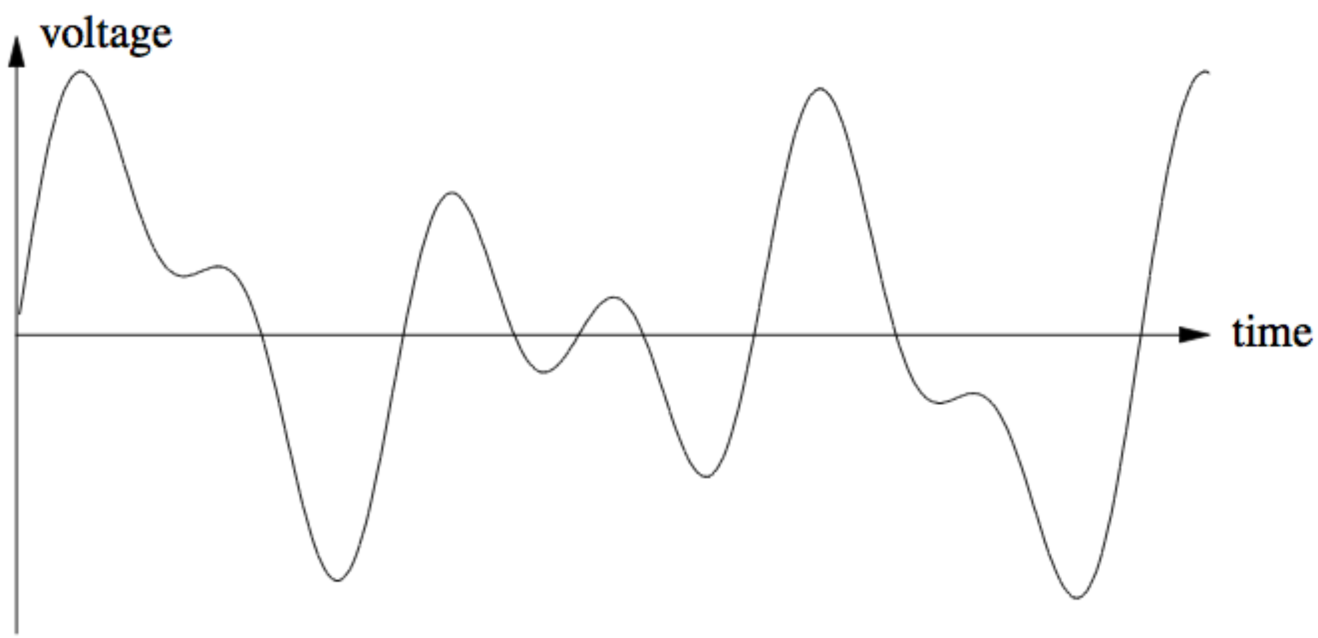
Pic examples

```
.PS
arrow "input" above
box "process"
arrow "output" above
.PE
```



Pic examples

```
.PS
V: arrow from 0,-1 to 0,1;  "  voltage" ljust at V.end
L: arrow from 0,0 to 4,0;   "  time" ljust at L.end
for i = 1 to 399 do X
    j = i+1
    line from (L + i/100, sin(i/10) / 3 + sin(i/20) / 2
     + sin(i/30) / 4) to (L + j/100, sin(j/10) / 3
     + sin(j/20) / 2 + sin(j/30) / 4)
X
.PE
```

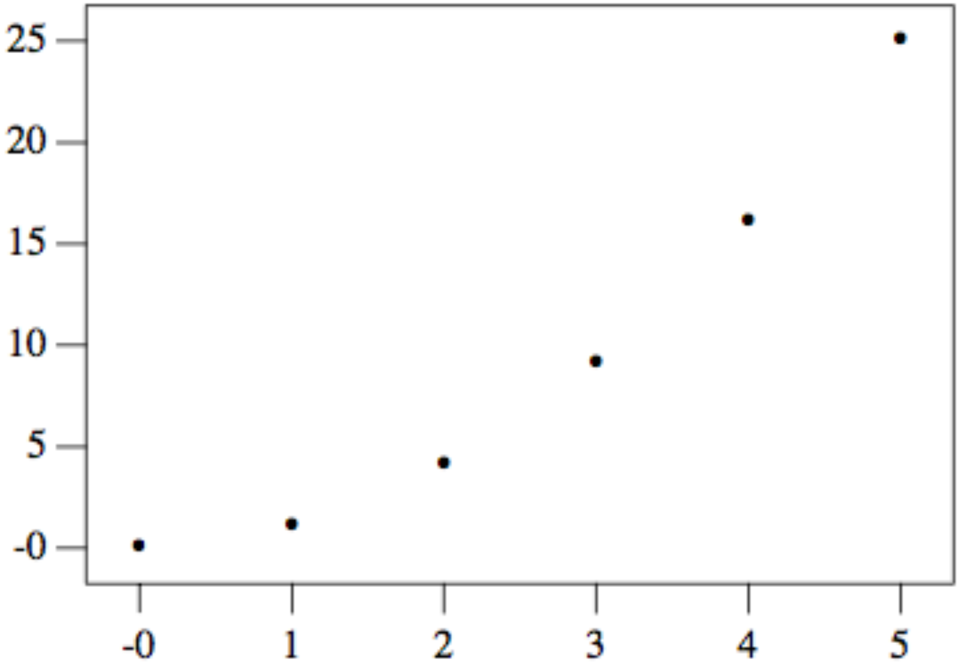


Grap: a language for drawing graphs

- line drawings, not "charts" in the Excel sense
- with Jon Bentley, ~1984

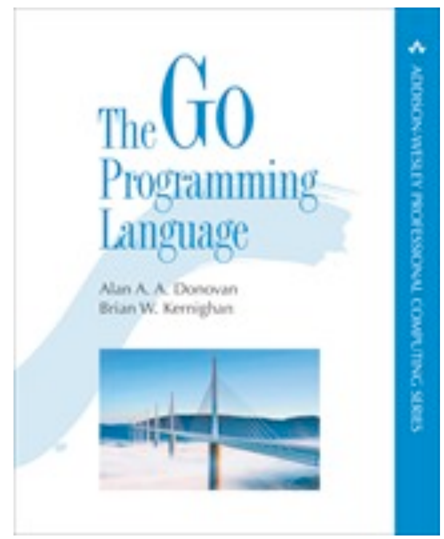
- a Pic preprocessor: **`grap | pic | troff`**

```
.G1
0 0
1 1
2 4
3 9
4 16
5 25
.G2
```



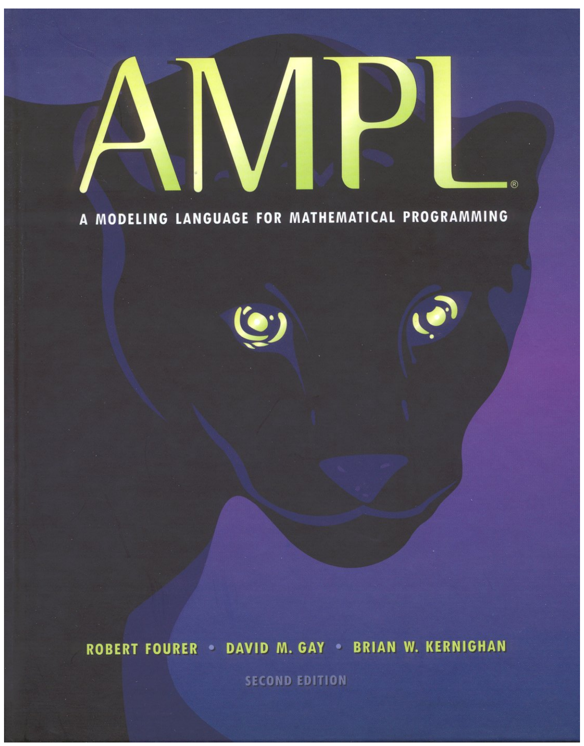
The Go Programming Language experience

- **started with Markdown**
  - very good for simple documents
- **doesn't scale to books**
  - too many special cases if material is complicated (e.g., fonts, layout)
  - very slow
- **Alan Donovan wrote a version in Go**
  - better, but still too many special cases
- **LaTeX?**
  - it's complicated, inflexible and uncontrollable
- **convert book text to XML, process by a Go program**
  - about 20 tags, with attributes
  - a nuisance to type, but many fewer special cases
  - generates HTML for proofing and ultimately ebooks
  - generates Troff for paper version
  - still lots of special-purpose shell scripts, e.g., indexing, special chars

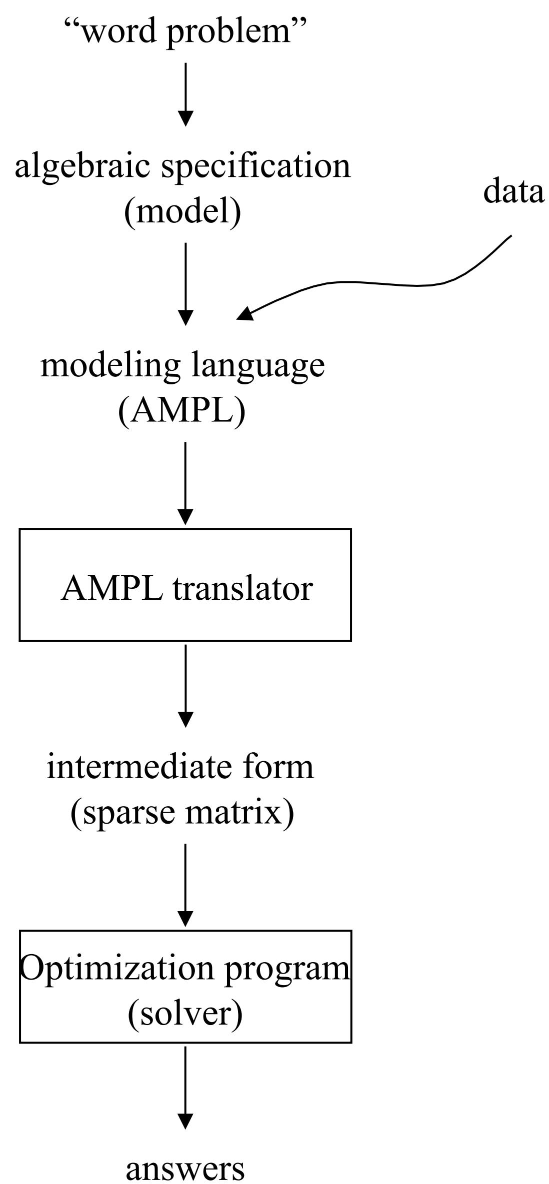


AMPL: A big DSL that got bigger

- a language and system for
  - describing optimization problems in a uniform, natural way
  - compiling descriptions into form needed by solver programs
  - controlling execution of solvers
  - displaying results in problem terms



Robert Fourer
David Gay
Brian Kernighan



Cost minimization: a diet model

- **Find a minimum-cost mix of TV dinners that satisfies requirements on the minimum and maximum amounts of certain nutrients.**
- **Given sets and parameters:**

  F, a set of foods

  N, a set of nutrients

  a_{ij} = amount of nutrient i in a package of food j

  c_j = cost of package of food j, for each $j \in F$

  f_j^- = minimum packages of food j, for each $j \in F$

  f_j^+ = maximum packages of food j, for each $j \in F$

  n_i^- = minimum amount of nutrient i, for each $i \in N$

  n_i^+ = maximum amount of nutrient i, for each $i \in N$
- **Define decision variables:**

  X_j = packages of food j to buy, for each $j \in F$
- **Minimize objective:** $\sum_{j \in F} c_j X_j$
- **Subject to constraints:**

  $n_i^- \leq \sum_{j \in F} a_{ij} X_j \leq n_i^+$, for each $i \in N$

  $f_j^- \leq X_j \leq f_j^+$, for each $j \in F$

AMPL version of the diet model

```
set FOOD;
set NUTR;

param amt {NUTR,FOOD} >= 0;
param cost {FOOD} > 0;
param f_min {FOOD} >= 0;
param f_max {j in FOOD} >= f_min[j];
param n_min {NUTR} >= 0;
param n_max {i in NUTR} >= n_min[i];

var Buy {j in FOOD} >= f_min[j], <= f_max[j];

minimize total_cost:  sum {j in FOOD} cost[j] * Buy[j];

subject to diet {i in NUTR}:
   n_min[i] <= sum {j in FOOD} amt[i,j] * Buy[j] <= n_max[i];
```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Why languages succeed

- **solve real problems effectively**
- **culturally compatible and familiar**
  - familiar syntax helps (e.g., C-like)
  - easy to get started with
  - portable to new environments
- **environmentally compatible**
  - don't have to buy into an entire new environment to use it
  - e.g., can use standard tools and link to existing libraries
  - open source, not proprietary
- **weak competition**
- **good luck**

Why languages fail to thrive

- **niche or domain disappears**
- **poor engineering**
  - too big, too complicated, too slow, too late
  - incompatible with environments
- **poor philosophical choices**
  - ideology over functionality
  - single programming paradigm
  - too "mathematical"
  - too different, too incompatible