CS 603: Organization of Programming Languages

What should a programming language do?

Express computations

- **precisely**
- **at a high level**
- **in a way we can reason about them**

What's it all for?

Make it easier to write programs that really work

Why study programming languages?

New ways of thinking about programming

Writing programs is fundamental

Language can help or hinder

Become a sophisticated, skeptical consumer

Why do people actually like this stuff?

Language is the way to write code

- **write code that's elegant**
- **write code that's cool**

CS 603 Agenda

Intellectual tools **to understand & evaluate languages**

- **Language features**
- **Questions with answers**

Learn the *notations of the trade*

- **Precise way to model languages**
- **Foundation for further study**

Learn by doing

- **Write lots of (mostly short) programs**
- **Many difficult programs (thought required)**
  (High difficulty per line of code)

Study of Language $\equiv$ Study of Features

Language features influence code

Choose abstractions (languages) to fit needs

Build your vocabulary (add to your toolbox)

- Higher-order functions
- Polymorphism (reuse)
- Pattern matching for symbolic computing
- Data for symbolic computing: lists, tables, sets
- Abstract datatypes, encapsulation
- Objects and subtyping
- Modules, parameterization
- Searching and backtracking

How to use Features

From the definition of Scheme:

> **Programming languages should be designed not by piling feature on top of feature, but by removing the weaknesses and restrictions that make additional features appear necessary.**

Larry Wall (inventor of Perl) and Bjarne Stroustrup (inventor of C++) might not agree.

Why study “weird” features?

Some languages more powerful than others

Mistake to use any but the most powerful

- Except for: compatibility, libraries

Problem: habit blinds us to power

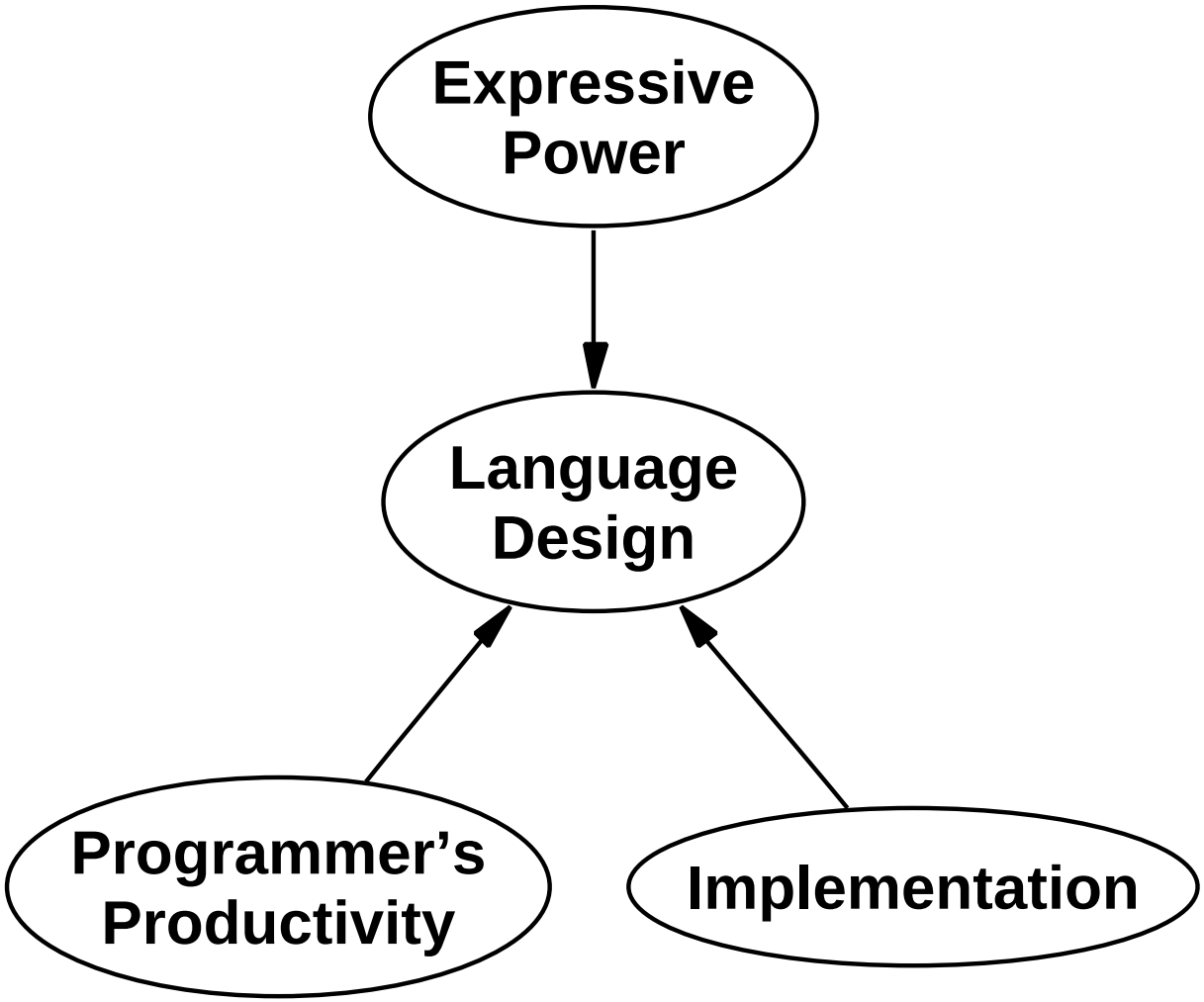
Happy user of *Blub*: beats Cobol, machine code

- Use Haskell, Lisp, or Icon? No! Equivalent to *Blub*, plus weird stuff nobody uses

Blub looks good enough because I think in *Blub*

CS 603: tour of power in languages

Course orientation: Language Design



The search for expressive power

Functions

Types

Pattern matching

Context-free grammars

Making the programmer more productive

Programming methodologies, software engineering

Goals:

- **fewer bugs, more easily isolated**
- **reuse code**

Techniques:

Abstract data types

Modules (including “generics”)

Objects and inheritance (reuse)

Separate compilation/smart recompilation

Influence of Implementation

- Techniques
  - Parser generators
  - Attribute-grammar systems
  - Memory allocation
  - Garbage collection
  - Runtime typing/tagging
  - Efficiency concerns
    - fast execution
    - fast compilation
    - fast program construction

(Compiler implementation is primarily a topic for CS 614)

Describing it all precisely

Formal semantics:

- **Operational semantics (tool of the trade)**
- **Denotational semantics (for mathematicians)**
- **Axiomatic semantics**
- **Predicate transformers**

Some design dimensions

Typing

- strong vs. weak (ill-defined terms)
- static vs. dynamic
- monomorphic vs. polymorphic

First-class values

- structures?
- procedures? (funarg problem)
- are built-in types different?

More design dimensions

Safety

- no *unexplained* core dumps (and more. . .)

Control flow

- stack-based
- heap-based, closures & continuations
- logic programming (Prolog, unification)
- backtracking (Icon)

Non-dimensions:

- "Simplicity," "Orthogonality," "Readability"
- . . .

Administrivia — Grading

Weight of grades:

3 midterm exams	45% to 60%
final exam	20% to 35%
projects	10%
homework	10%

Administrivia — Working together

Collaborate! (Up to a point)

- what professionals do
- vital to your success
- discuss problems, techniques, ideas
- for team assignments: collaboration is fine with members of your team
- for individual assignments: discussion only, no sharing of code or written answers

Administrivia — Policies, procedures

Policies and procedures

- **handed out in class**
- **on the web**

Know what is expected

Prerequisites

You must enjoy programming

You must also like math

C (or C++ or Java)

Ability to learn new languages quickly: Scheme, ML, Smalltalk, Prolog

Windows and/or Unix

Algorithms, data structures

Basic mathematics (set theory, logic, induction)

Course of Study

Work hard, learn a lot

Focus on

- **semantics, not syntax**
- **the unusual, not the common (weird but powerful)**
- ***answerable* questions**

Methods of study

Case studies of interpreters

- **Learn foundations of languages by studying and modifying implementations**
- **Study abstracted "essentials" of languages**
- **(Mostly) uniform implementation framework**

Supplement by

- **Descriptive tools of the professionals:**
  - **operational semantics**
  - **type systems**

- **Work with real languages**

Readings

Ramsey and Kamin

Programming Languages: An Interpreter-Based Approach

- **distilled essence of languages**
- **uniform syntax, implementation framework**
- **available in Ferguson Center supply store**

Topics

Unit/Language	*Concepts*
Imperative Core	environments, bindings, ASTs, operational semantics
Scheme	S-expressions, recursion and lists, programs as data, first-class & higher-order functions
ML	type inference
Smalltalk	object-oriented programming
Prolog	logic programming, unification