Programming Languages

- As difficult to discuss rationally as religion or politics.

- Prone to extreme statements devoid of data.

  Examples:

  > "It is practically impossible to teach good programming to students that have had a prior exposure to BASIC; as potential programmers they are mentally mutilated beyond hope of regeneration." (Dijkstra)

  > "The use of COBOL cripples the mind; its teaching should, therefore, be regarded as a criminal offence." (Dijkstra)

- Like anything else, decision making should be a rational process based on the priorities and features of the project.

Some Decision Factors

- Features of application:

  Hard real time?
  - Not just efficiency
  - Predictability (need to guarantee deadlines will be met)

  High assurance?
  Portability?
  Maintainability?
  Others?

- Features of development environment:

  Availability of programmers, compilers, development tools?
  Schedule constraints?
  Others?

Relationship between PL and Correctness

- Decreasing emphasis as an explicit design goal and research topic.

- Masterability

  - Not complex: programmers understand it in its entirety

    The most important decisions in language design concern what is to be left out." (Wirth)

  - Powerful features OK only if easy to use correctly.
    - Balance against need to keep language simple

  - "Natural"
    - Language should not surprise us in any of its effects.

    - Should correspond to our experience with natural languages, mathematics, and other PLs

Relationship between PL and Correctness (2)

- Error Proneness

    - Language design should prevent errors.

        Should be difficult or impossible to write an incorrect program.

    - If not possible, then allow their detection (as early as possible)

    - Need for general principles and hypotheses so can predict error-prone features and improve language design.

    - Some hypotheses and data about:

        Go to
        Global variables
        Pointers
        Selection by position (long parameter lists)
        Defaults and implicit type conversion
        Attempts to interpret intentions or fix errors

    - Meaning of features should be precisely defined (not dependent on compiler.

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Relationship between PL and Correctness (3)

- Understandability

    - "The primary goal of a programming language is accurate communication among humans."

    - Readability more important than writeability.

        - Well "punctuated" (easy to directly determine statement types and major subunits without intermediate inferences)

        - Use of distinct structural words (keywords, reserved words) for distinct concepts (no overloading, e.g., = for equal, assignment)

        - Avoidance of multiple use of symbols unless serve completely analogous functions (e.g., commas as separators, parentheses for grouping).

    - Necessary to be able to see what is being accomplished at a higher level of abstraction.

        - Permit programmers to state their "intentions" along with instructions necessary to carry them out.

Relationship between PL and Correctness (4)

- Maintainability

  - Locality -- possible to isolate changes.

  - Self-documenting

    - Programming decisions should be recorded in program, independent of external documentation.

    - Good comment convention, freedom to choose meaningful variable names, etc.

    - User-defined types and named constants

      e.g., type direction=(north, south, east, west)

  - Explicit interfaces

    - Should cater to construction of hierarchies of modules

Relationship between PL and Correctness (5)

- Checkability

    - Every error should transform a correct program into one whose errors are detectable by the system.

    - All error detection based on redundancy (but some forms can cause errors).

        Examples of userful redundancy:
            type declarations and type checking
            declarative redundancy
            invariance conditions or assertions

    - Run-time assertions, exception handling

        checking subscripts vs. array bounds
                case selector vs. case bounds

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Relationship between PL and Correctness (6)

- General

    - High-level languages take many decisions out of programmer's hands.

        - One reason they are so fiercely resented by experienced programmers.

        - Language should restrict programmer to decisions that really matter.

        - Decisions should be recorded in program independent of external documentation.

    - Simplicity of language less important than ability to write conceptually simple programs.

Can programming language influence correctness?

- Languages affect the way we think about problems:

    *"The tools we use have a profound (and devious) influence
    on our thinking habits, and, therefore on our thinking abilities?"*

    Dijkstra, 1982

- Additional experimental evidence:

    – C130J software written in a variety of languages by a variety
    of vendors.

    – All certified to DO–178B standards (FAA).

    – Then subjected to a major IV&V exercise by the MoD

    - Significant, safety–related errors found in Level A certified
    software

    - Residual error rate of Ada code on aircraft was one tenth
    that of code written in C.

    - Residual error rate of SPARK code (Ada subset) one tenth
    that of the Ada code.

Green: Design and Use of PLs

"Clarifying the psychological processes of using programming languages will, I believe, clarify the requirements of language design and of environmental support."

Some examples of structured programming hypotheses:

- Control structures should be hierarchical. Thus they should be nested, rather than allowed to have arbitrary branching. In this way, successive layers of detail can be added.

- The comprehensibility of hierarchically constructed programs will be easier, since they can be understoof by a reverse process -- understand the outer layer, then the inner layers, etc.

- These programs will be easy to modify because the inter-relations between parts will be simple.

Have accepted these hypotheses but have never been validated.

Green: Program Comprehension

- Cites experiments ("atheoretical") that evaluate only current programming practice.

- More interesting question: Can we elucidate underlying psychological principles to allow generalization of results to other classes of information structure in programming?

  - Hypothesis 1: If one language is better than another, it is always better, whatever the context.

  - Hypothesis 2: Every notation highlights some type of information at the expense of others; the better notation for a given task is theone that highlights the information that given task needs.

- More generally, the comprehensibility of a notation may depend on the number and complexity of mental operations required to extract needed information.

Green: Program Comprehension (2)

- Cites results supporting second hypothesis better than first.
  Not predicted by arguments of structured programming,
  which are based solely on presence or absence of good structure.

  - Programmers were not simply decoding programming structure
    top down into some undescribed mental representation. Were
    reworking one structure into another.

  - Difficulty of answering questions depended not only on source
    structure but also on relation between source and target structures.

- Observes that result "appears to raise insuperable difficulties
  for those simple-minded computer scientists who attempt to
  measure 'psychological complexity' of a program by means
  of a single number, such as McCabe."

Statement of Problem:

Fry: everything that is juicy but not hard
Boil: everything that is hard
Chop and roast: everything that is neither hard nor juicy

if hard go to L1
if juicy go to L2
chop roast stop
L2: fry stop
L1: boil stop
	if hard then
	  begin boil end
	else
	  begin
	  if juicy then
	    begin fry end
	  else
	    begin chop roast end
	  end
		if hard: boil
		not hard:
		  if juicy: fry
		  not juicy: chop roast
		  end juicy
		end hard

Using Dijkstra's guarded command:

if hard: boil
if not hard, juicy: fry
if not hard, not juicy: chop roast

Green: Program Creation

- Programs as plans.

- Role expressiveness: Outcome of a programmer's effort
  is a structure in which each part plays some role vis-a-vis
  the programmer's original intention.

  - Easy program comprehension and creation requires role expressiveness.

    - Rapid chunking into components

    - Visible or easily inferred purposes for each part

    - Visible or easily inferred relationships between
      each part and the larger structure.

  - Important to alleviate mismatches between programmer's task
    and program structure.

  - Hypothesis that role expressiveness tends to detract from reusability
    of program fragments.

    "When a program fragment makes its role and purpose very clear,
    it is probably not easy to transport it unchanged to a new
    environment, because its role may be slightly but significantly different.

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Green: Program Creation (2)

- Linguistic consistency

  - Metarules vs. BNF (simplified syntax rules)

    Not the number of rules that counts but the consistency between the form of the rules.

  - Similar roles should be indicated by similar syntax: syntax should map roles consistently.

- Significant omissions (defaults)

- Perceptual cues

  - Humans not good at discerning structure of a string of arbitrary symbols but good at differentiating shapes, spatial positions, and other perceptual cues.

  - Dangling else: use of indentation the best solution

    Green asks: "Why did it take so long to find the solution?