Disruptive Programming Language Technologies

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Richard Hamming's Snare

- Richard Hamming's three questions for new hires at Bell Labs:
  1. "What are you working on?"
  2. "What's the most important open problem in your area?"
  3. "Why aren't they the same?" (Ouch!)

"You and Your Research" --- Richard Hamming (1986)

The Least Important Open Problem in Programming Languages*

Increasing program performance via compiler optimization

- Moore's Law suffices
- Algorithms and design make the big difference

- **Challenge**: Name a single significant software product that relied on compiler optimization for viability.

* The opinions expressed here are mine and mine alone. Microsoft disavows any connection to them…

The Most Important Open Problem In Programming Languages*

Increasing Programmer Productivity

- Write programs correctly
- Write programs quickly
- Write programs easily

- Why?
  - Decreases support cost
  - Decreases development cost
  - Decreases time to market
  - Increases satisfaction

*Standard disclaimer.

Language Choice Affects Productivity

- The center of the programmer's universe!
  - Core abstractions, mechanisms, services, guarantees
  - Affect how programmers approach a task (*C vs.* LISP)
  - Assumptions, expectations, patterns
    - types
    - events
    - immutable data
    - garbage collection
    - regular expressions
    - first-class functions, closures
    - ...

Language Design: *C vs. LISP*

- What's the difference between a C programmer and a LISP programmer?
  - A LISP programmer knows the value of everything and the cost of nothing.
  - A C programmer knows the cost of everything and the value of nothing.
    E.g., garbage collection, first-class functions, safety…
- The languages encourage this thinking:

```
(map fn L)  vs.  while (*d++ = *s++);
```

- Some "value investors" are reaping strong returns nowadays. (www.paulgraham.com)

Programming Language Technologies: Recent Research *vs.* Progress(!)

- Recent (perpetual?) academic research:
  - Type theory
  - Functional programming
  - Object-oriented programming
  - Parallel programming
  - Static analysis
  - Compiler optimization
- Recent adoption: Perl, Python, Visual Basic, Java
  - Almost void of innovation on type theory, functional programming, OO programming, optimization, etc!
  - Perversely hopeful development for new language design efforts.

The Innovator's Dilemma (C. Christensen)

- "… why ~~companies~~ **languages** that did everything right---were in tune with their competition, listened to their customers, and invested aggressively in new technologies---still lost their market leadership when confronted with disruptive changes in technology…"

  --- the book's back cover

- Why is C/C++ losing steam? ☺
  - Can we use the book's lessons to help future language efforts? (Not the book's intent…)

The Innovator's Dilemma: Cable-Actuated Excavators

- A "disruptive" technology — hydraulic mechanisms
  - Disadvantage in primary market — small, unreliable
  - Advantage in secondary market — safe, attaches to tractor
  - Sold in small, low-margin market — independent contractors
- Established companies concentrate and innovate on primary market; ignore secondary — capacity (for excavation)
- Timely improvements lessen disruptive technology's liabilities, increasing markets, market share, margins, etc.

The Innovator's Dilemma: C

- A "disruptive" language — safe, GC'ed interpreters
  - Disadvantage — SLOW
  - Advantage — Rapid Application Develop
  - Sold in small, low-margin market — web developers, ISV's

  (established competitor ignored market)

- Established companies concentrate on primary differentiator — SPEED

- Timely improvements lessen disruptive technology's liabilities, increasing markets, market share, margins, etc.

  Moore's Law (for free!)

  RAD enhancements

Distinguishing/Disruptive Technologies: Alleviating Real Problems

- Perl
  - Scripting with data structures ("duct tape")
  - Regular expressions
- Visual Basic
  - Drag-and-drop environment (Windows for the masses)
  - Component-friendly
- Java
  - Browser applets

Languages yield pervasive patterns and abstractions

An Opportunity!

- Languages (or language technologies) that solve real problems can succeed
  - Even if slow
  - Even with simple types
  - Even without academic significance
  - Even without rocket science
  - If useful
- Researchers need not despair
  - Golden opportunity to use disruptive technology as a Trojan Horse for disseminating research ideas

Future Disruptive Language Technologies (My Recurring Wish List)

- My criteria: technology must
  - Have disadvantages
  - Be mostly ignored by recent PLDI and POPL conferences
  - Alleviate real problems… "What does it do?"

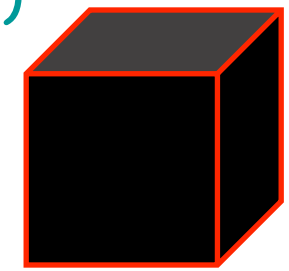
- For each candidate technology: 2 slides
  - Opportunity — what's the issue?
  - Current solutions — what's done now
  - Proposal — sketch of language solution
  - Disadvantages — why some (many?) will scoff
  - Unmet needs — benefits to adopters

Candidate: Flight Data Recorders

- Opportunity: How do you debug a program that misbehaved after the error occured?
  - Microsoft "Watson" experience
    - 50% of crashes caused by 1% of bugs.
- Current solutions
  - Ad hoc attempts to reproduce error condition
  - Examine stack trace, program state ("core dump")

Disruptive Flight Data Recorders

Add persistent, automatic "tracing" of function calls, events, I/O, etc. to the language run time. (E.g., AMOK/IDAL from IDA on CRAY-1)



- Important disadvantages
  - Will slow every program down
  - Will require storage
- Unmet needs
  - Diagnostic data available to programmer --- 1/50 rule
  - "Introspective" data available to program

Candidate: Checkpoints/Undo

- Opportunity: Programs provide checkpoint or "undo" facilities in haphazard, unreliable ways. (E.g., MS Outlook, TurboTax, almost all tiny apps.)

- Current solutions:
  - Checkpoint by saving document to a file
    - Doesn't scale well to unbounded undo
  - Programmatic checkpoint by saving *select* data to file
    - Subject to judgment (and error)
  - Undo by saving operations and their inverse data
    - Tedious
    - Error-prone

Disruptive Checkpoints/Undo

Make checkpointing and undo (i.e., restore to checkpoint) primitives in the programming language. Transactions.

- Important disadvantages
  - External side-effects pose limitations (e.g., I/O)
  - Slower than hand-crafted solution
- Unmet needs
  - Simplicity
  - Automation

```
checkpoint X;
<random code>
restore/commit X;
```

Candidate: Parsing

- Opportunity: Parsing is common and difficult in general.
- Current solutions:
  - Parser generators for subsets of CFLs
  - Regular expressions ala Perl
  - Roll your own parser (and cross your fingers that nobody ever needs to maintain it)

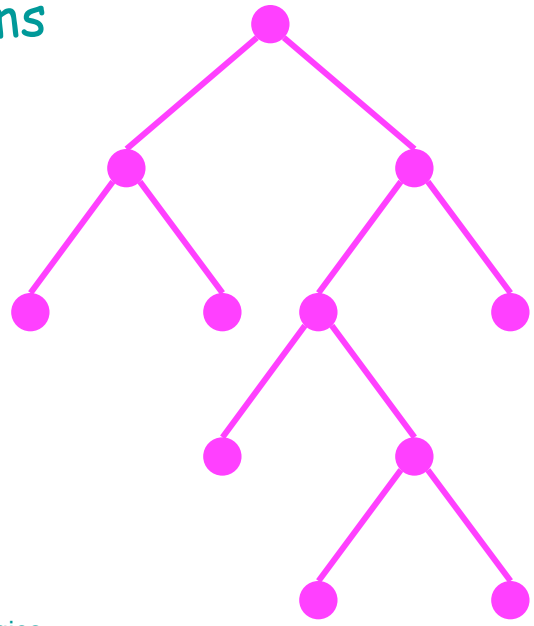
Disruptive Parsing

"Scannerless Generalized LR Parsing" (or Earley parsing) could be integrated into a language

- Important disadvantages
  - Slow
  - Ambiguity presents its own problems
- Unmet needs
  - Handle arbitrary CFL grammar
  - Spec-driven systems adapt smoothly to change
  - Confidence that parser meets spec
    - XML grammar has 80+ productions…

Candidate: Constraint Solvers

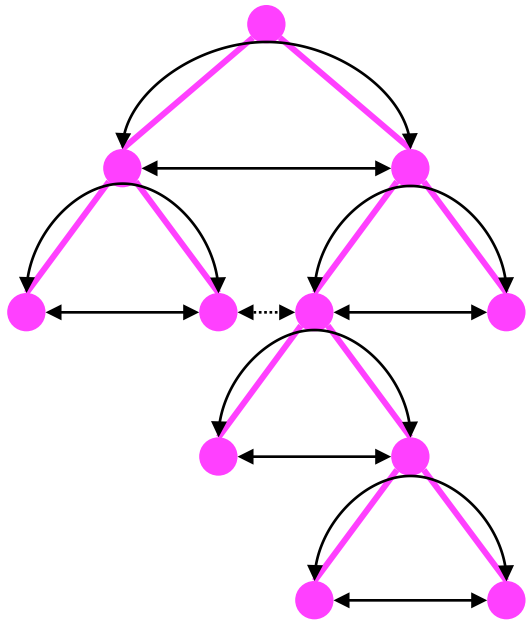
- Opportunity: Many applications have a subproblem that involves solving (or optimizing) a system subject to constraints
  - Natural fit for visual layout problems (e.g., render tree structures, resize windows, summarize maps)
  - Natural fit for optimization problems
- Current solutions
  - Hand-rolled algorithms
  - Library routines
  - Third-party solvers
  - Give up



Disruptive Constraint Solvers

Integrate linear programming constraint solver (or, better, integer programming) into a programming language

- Important disadvantages
  - Slower than tailored algorithmic solutions
- Unmet needs
  - Quick and dirty solutions
    - Visual layout (Interviews-Tk?)



Candidate: Concurrent Programming

- Opportunity: Many applications are explicitly or implicitly concurrent or distributed
  - Concurrency models many applications better than "objects," yet the world is mired in OO religion.
- Common solutions
  - OS threads, shared data, P(), V()
  - Language threads, shared data, P(), V()
  - Remote procedure calls

Disruptive Concurrent Programming

- Concurrent functional programming language (Erlang™?)
  - Lightweight processes (10,000's)
  - Message passing
    (non-blocking send, blocking receive with timeouts)
  - Higher-order functions w/ pattern-matching dispatch
  - Immutable data (except message queues)

- Important disadvantages
  - Immutable data can be slower to manipulate
  - Doesn't look like C++, not OO

- Unmet needs
  - Concurrency-Oriented Programming
    - Processes+Messages+Immutable data, which can be reasoned about

Notable Omissions:

- **Monads**
- **Continuations**
- **Lazy evaluation**
- **Complex type system**

A Final Prediction

- The next big programming language will be slower than what it replaces
- Why?
  - The incumbent language will have been optimized relentlessly
  - To replace it, the new language must offer something new that will be valuable even if slow.

Shameless Self-Interest

- I manage the Programming Language Systems group in Microsoft Research
  - We work on programming language design and implementation
  - We appreciate small, simple solutions
  - We're a small group: Chris Fraser, Dave Hanson and me
  - **We're recruiting! (Full-time researchers and interns)**
- Email: toddpro@microsoft.com

The End