APL: The Big Picture

Course Summary

- Programming Language Semantics
  - **Operational** – for defining program behavior
  - **Denotational** – for converting program to math
  - **Static** – for avoiding “stuck states” (bugs)
  - **Axiomatic** – for verifying program correctness
- Three styles of programming:
  - **Imperative** (programs are sequences of instructions)
  - **Functional** (programs are functions from inputs to outputs)
  - **Logic** (programs are declarative input-output relations)

Language Popularity

- Which languages are most popularly used in “real life” (i.e., industry)?
  - Unquestionably imperative ones (C/C++/Java)
- Why?
  - easy to compile (no longer a compelling reason)
  - momentum (well-developed tools, large labor pool)
  - easy to write code that almost works
- The “Software Crisis”
  - Microsoft spends >50% of its budget on testing (2008)
  - Their code still doesn’t work
  - “Find better programmers” is not the answer

Better Programming Languages (What makes a language “advanced”?)

- Correctness over efficiency! (within reason)
  - “If I want it to run faster, I’ll buy more processors.”
  - Compilers as proof-assistants
- Elegant translation from mathematical spec to code
- Separation of concerns (the “what” vs. the “how”)
- Succinctness
  - Less code = fewer bugs
  - Code-reuse (parametric polymorphism)
- Modularity
  - Object-oriented programming
  - See also: OCaml module system, Aspect-oriented programming
- *Programmer efficiency* vs. program efficiency

Should we bury C/C++/Java?

- No! C/C++ is good for certain things:
  - writing the inner loop of a matrix multiplier
  - writing device drivers (but use formal verification)
  - implementing some runtime libraries (e.g., fast string libs)
- But can we please stop implementing entire software systems with it?
- Java was/is a great step forward…
  - brought type-safe programming to the masses
  - popularized automated garbage-collection
- But it still has major weaknesses
  - uncaught exceptions are only slightly better than crashes
  - language definition defies optimization

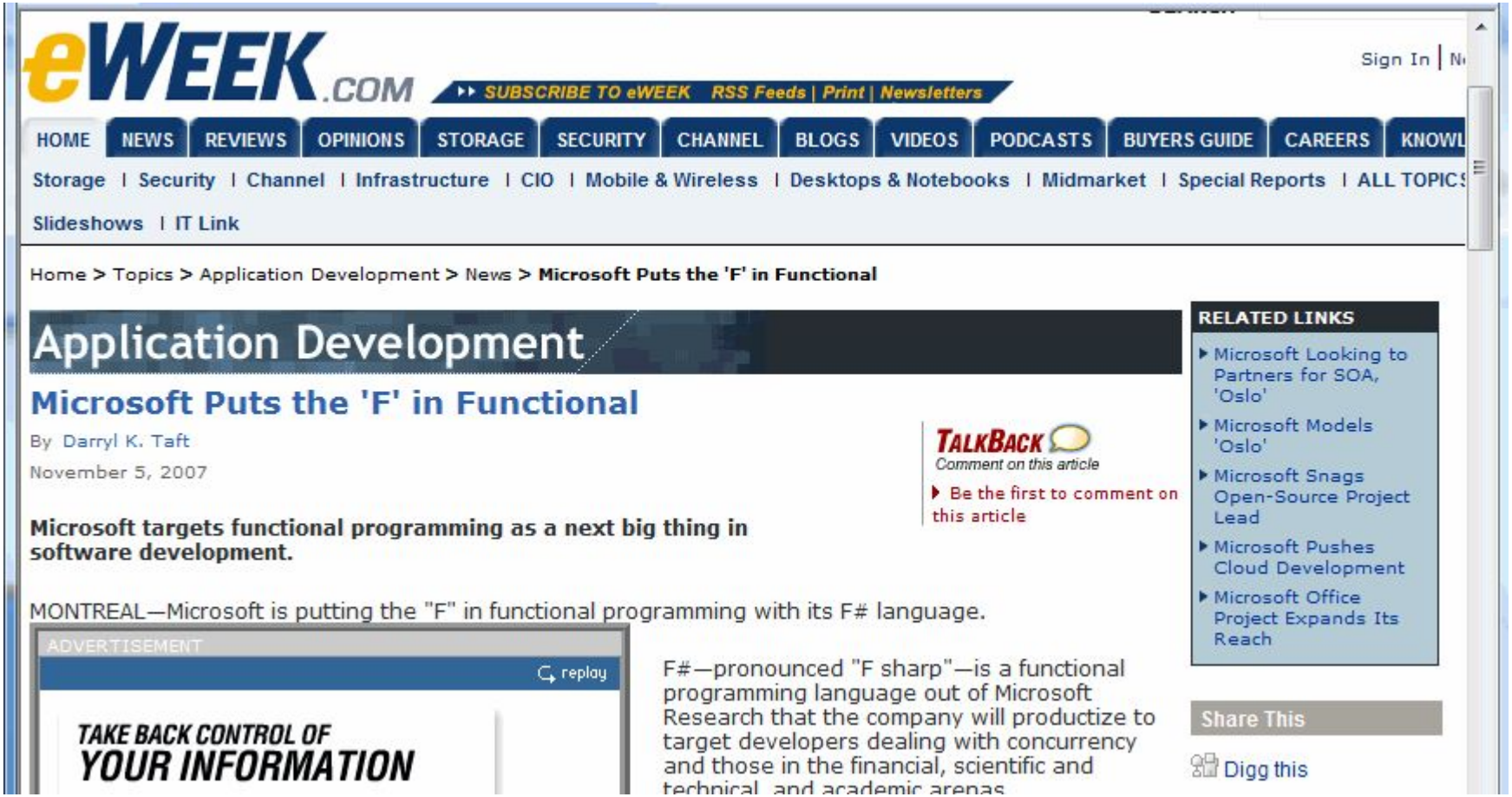
Grand Challenges

- What kind of language might segue the imperative programming world toward functional/declarative programming?
  - Example: F# [Syme et al., 2001]
- Can we use modern PL theory to debug/correct/analyze legacy codes?
  - Example: REINS [Wartell, Mohan, Hamlen, Lin; ACSAC 2012]
- Can we use PL theory to solve security problems like data confidentiality enforcement?
  - Example: Java Information Flow [Myers, POPL 1999]
- How can we create verified, highly parallelized software?
  - Example: *Verification of Parameterized Concurrent Programs By Modular Reasoning about Data and Control* [Farzan & Kincaid, POPL 2012]

Relevance/Usefulness

- Practical right now
  - Functional Programming
  - Operational/Denotational Semantics for compiler design and analysis
  - Type-checker design & implementation
- Not practical in itself, but fundamental for understanding real-world software verification
  - Lambda calculus
  - Hoare Logic
  - Structural Induction
- Learning how to write formal, rigorous proofs
  - essential if you want to do science, and not just programming
  - infrequently taught at the undergraduate level
  - if you can't prove easy things, you can't program hard things
    - every program is a constructive proof (Curry-Howard)
    - Example: if you can't reason inductively, you can't program recursively

Microsoft's Functional Language: F# (OCaml for Visual Studio .NET)



Facebook's New Polymorphic, Statically-typed Web Dev Language

WIRED GEAR SCIENCE ENTERTAINMENT BUSINESS SECURITY DESIGN OPINION MAGAZI

Facebook Introduces 'Hack,' the Programming Language of the Future

BY CADE METZ 03.20.14 | 12:00 PM | PERMALINK

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Next Steps

- CS 6353 Compiler Construction
  - we learned how to design and analyze a language
  - 6353 teaches how to build a compiler for a language
- CS 6374 Computational Logic
  - learn about automated theorem proving
  - tools for doing formal software verification
- CS 6301-005 Language-based Security (shameless plug)
  - type theory for security analysis & enforcement
  - information flow, access control, etc.
- Independent study research
  - Dr. Gupta: logic programming
  - Me: language-based security

Course Evaluations

- Online
  - Please provide (constructive!) feedback
  - Non-anonymous feedback is even more helpful!
    - I never allow student comments (negative or positive) to affect the student's grade, so please don't worry about that.
- Some issues of interest…
  - Topics you wish had been included but weren't?
  - Homework/exam difficulty level
  - Helpfulness of instructor/TA
  - No textbook (make Winskel a required text?)

Questions?
Feedback?