Automated Software Engineering Research Group @NCSU

Out of the Ivory Tower:
Are We There Yet on Automatic Test Data Generation?

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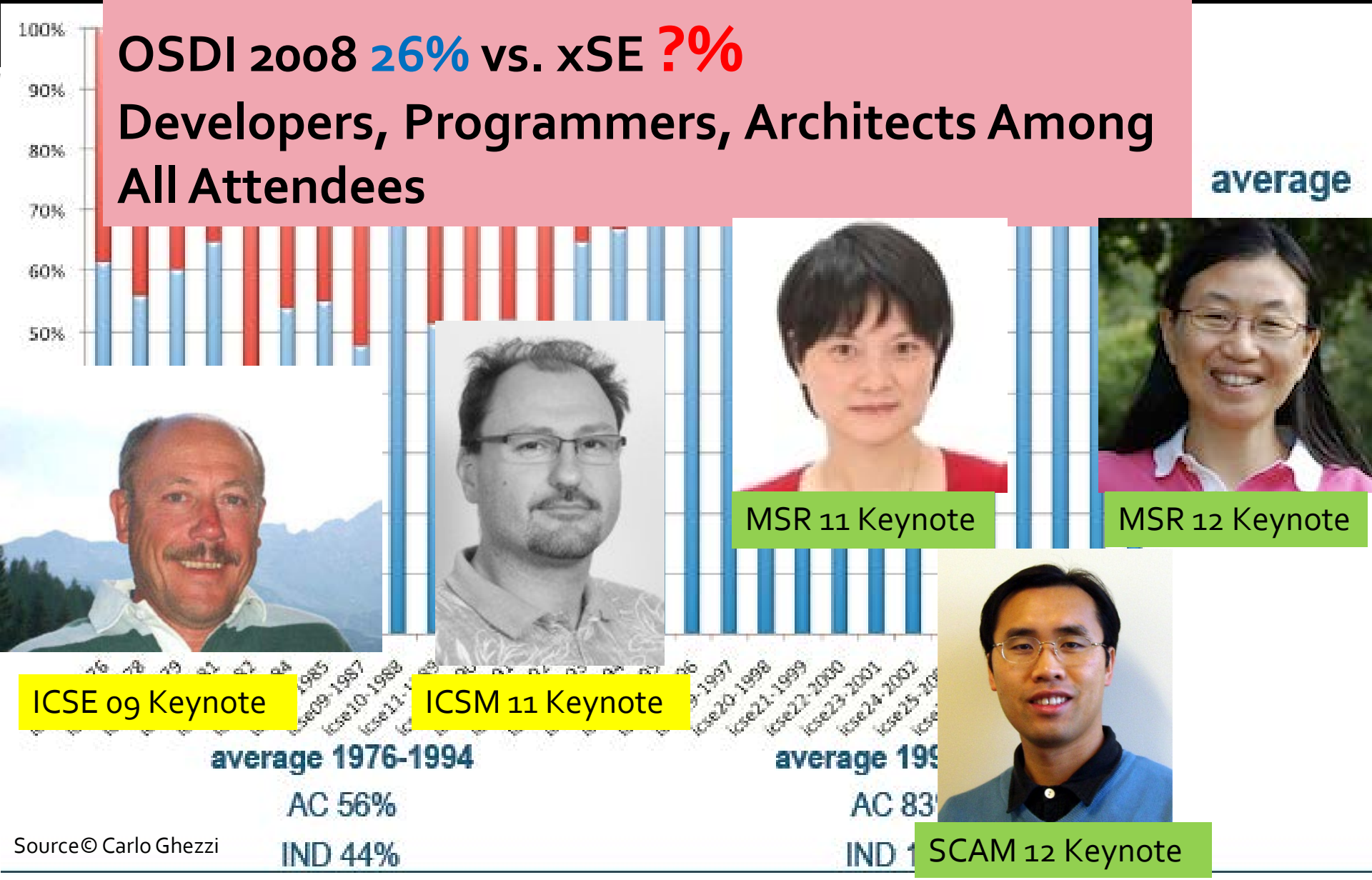
ICSE Papers: Industry vs. Academia

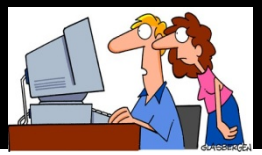
OSDI 2008 26% vs. xSE ?%

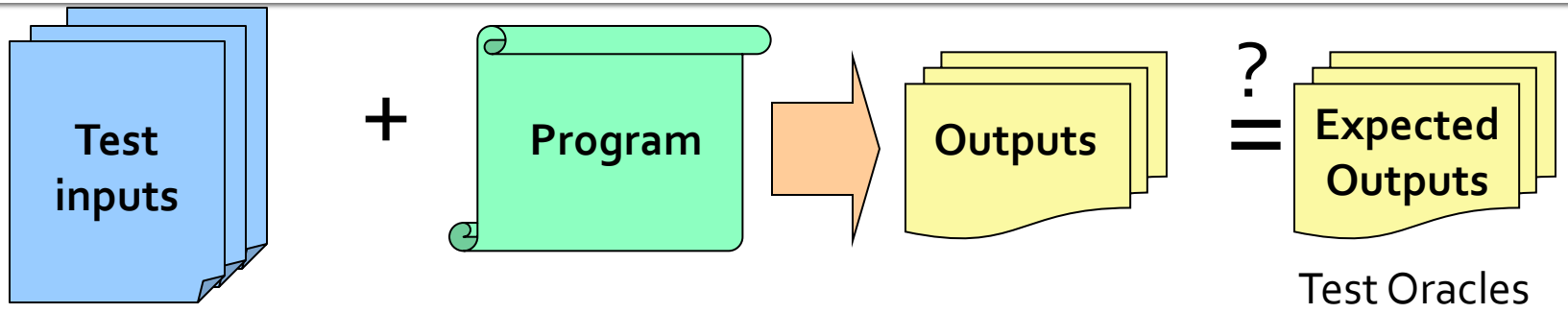
Developers, Programmers, Architects Among All Attendees



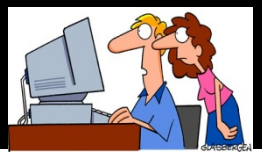
Source© Carlo Ghezzi

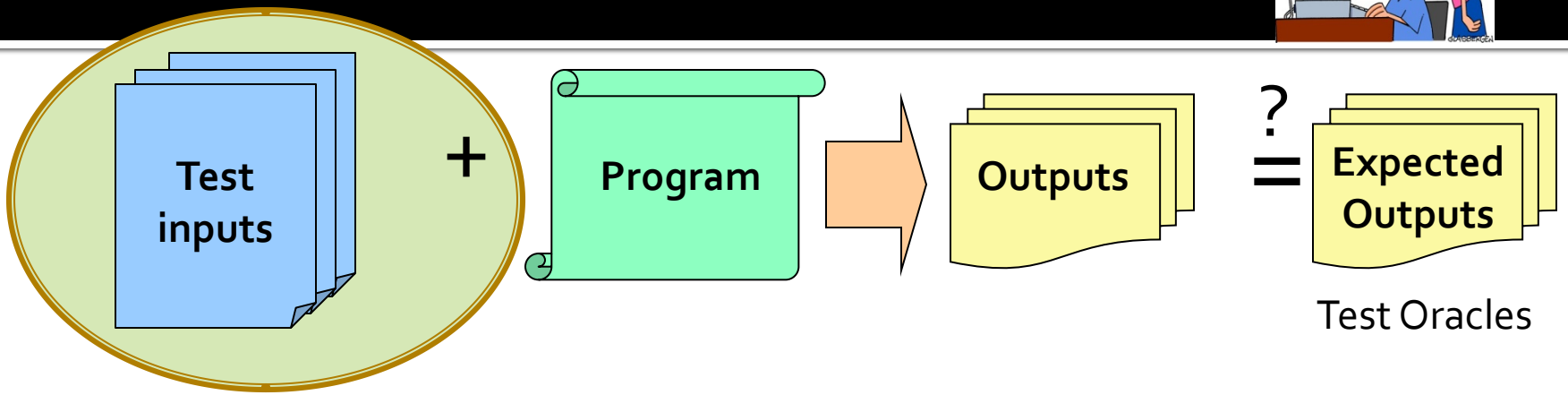
Software Testing Setup





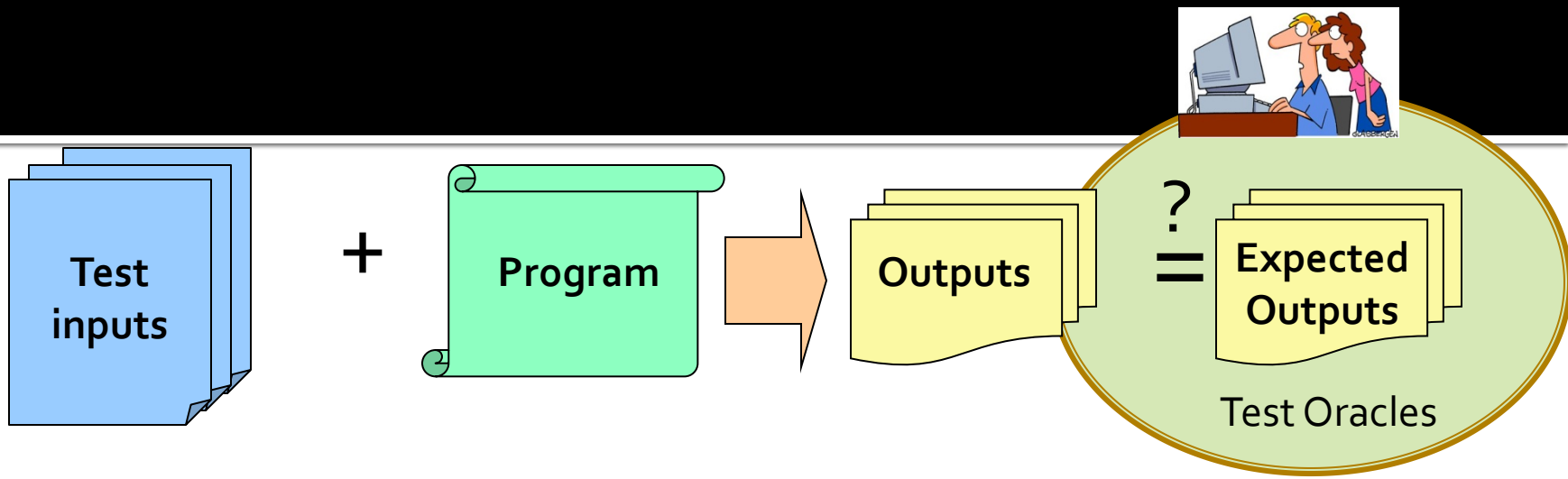
Software Testing Problems





- **Test Generation:** Generate test inputs of high quality (e.g., high structural coverage, high fault-detection capability)

Software Testing Problems



- **Test Generation:** Generate test inputs of high quality (e.g., high structural coverage, high fault-detection capability)

- **Test-Oracle Construction:** Construct test oracles of high quality (e.g., high fault-detection capability)

Research on Automatic Test Data Generation (ATDG)

- Many years of research
- Many testing researchers
- Many published papers
  - E.g., 14 papers out of 31 papers at ISSTA 2012
- Many released tools

- How well has research been transferred to industrial practice?

Tech-Adoption Evidence in Literature

- Papers on industrial studies/evaluations on applying tools on industrial code, who apply?
  - **Authors themselves instead of third parties**
  - Non-target users (such as students)
  - Target users but not developers of the industrial code
  - **Developers of the industrial code**
- Apply one-time (hit&run) or **continuous adoption**?
  - Good example on continuous industrial adoption:
    MSRA Software Analytics: StackMine [ICSE 12], XIAO [ACASC 12], …

http://research.microsoft.com/en-us/groups/sa/

Agitar AgitarOne – Developer Testing

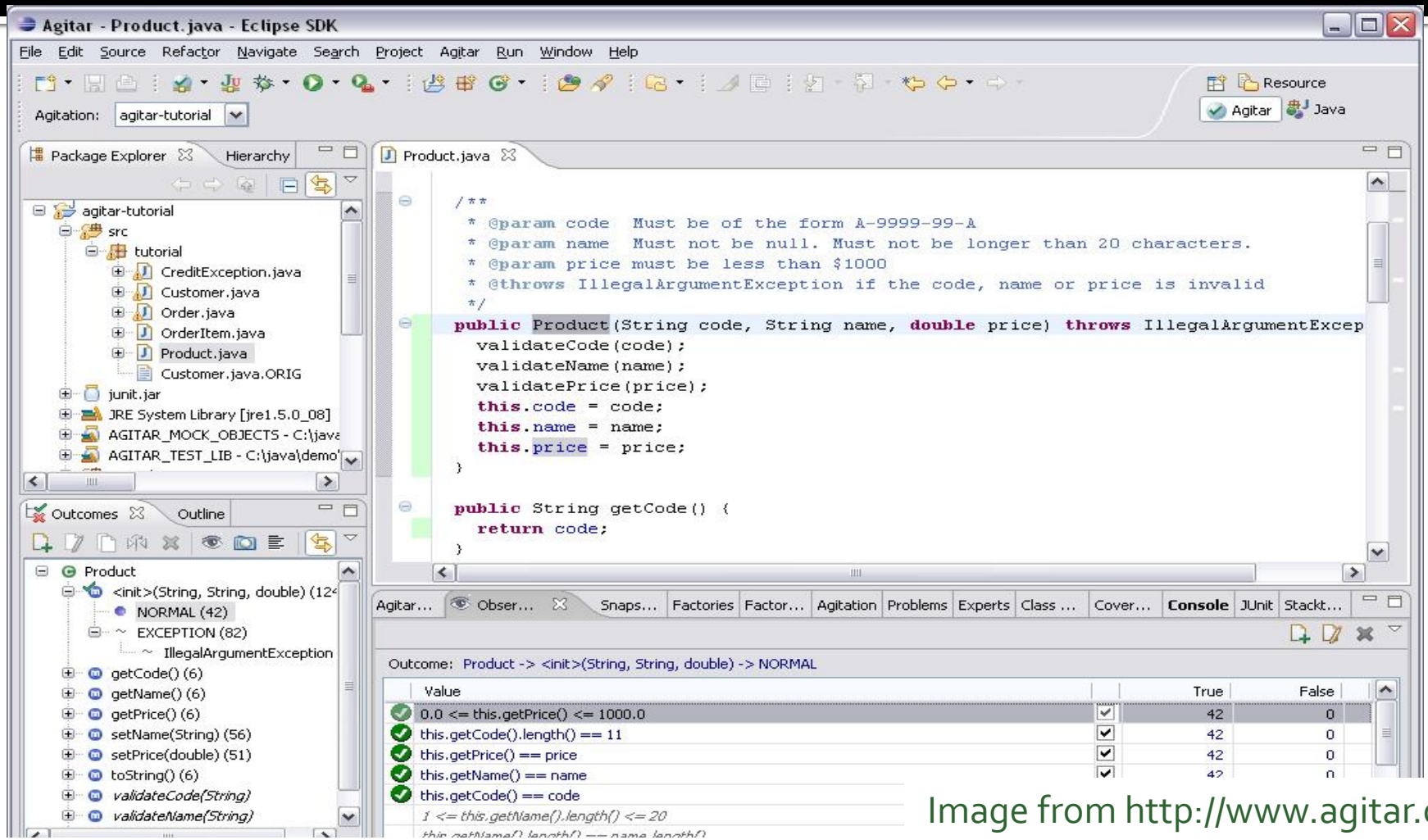


Image from http://www.agitar.com/

Boshernitsan, Doong, and Savoia. **From Daikon to Agitator: lessons and challenges in building a commercial tool for developer testing**. ISSTA 2006.

Microsoft Research : SpecExplorer
Protocol Doc Interoperability Testing

- 222 protocols/technical documents tested
- 22,847 pages studied and converted into requirements
- 36,875 testable requirements identified and converted into test assertions
  - 69% tested using Model-Based Testing
  - 31% tested using traditional test automation
- 66,962 person days (250+ years)
  - Hyderabad: 250 test engineers
  - Beijing: 100 test engineers

From talk slides by Yiming Cao

http://cacm.acm.org/magazines/2011/7/109908-microsofts-protocol-documentation-program/fulltext

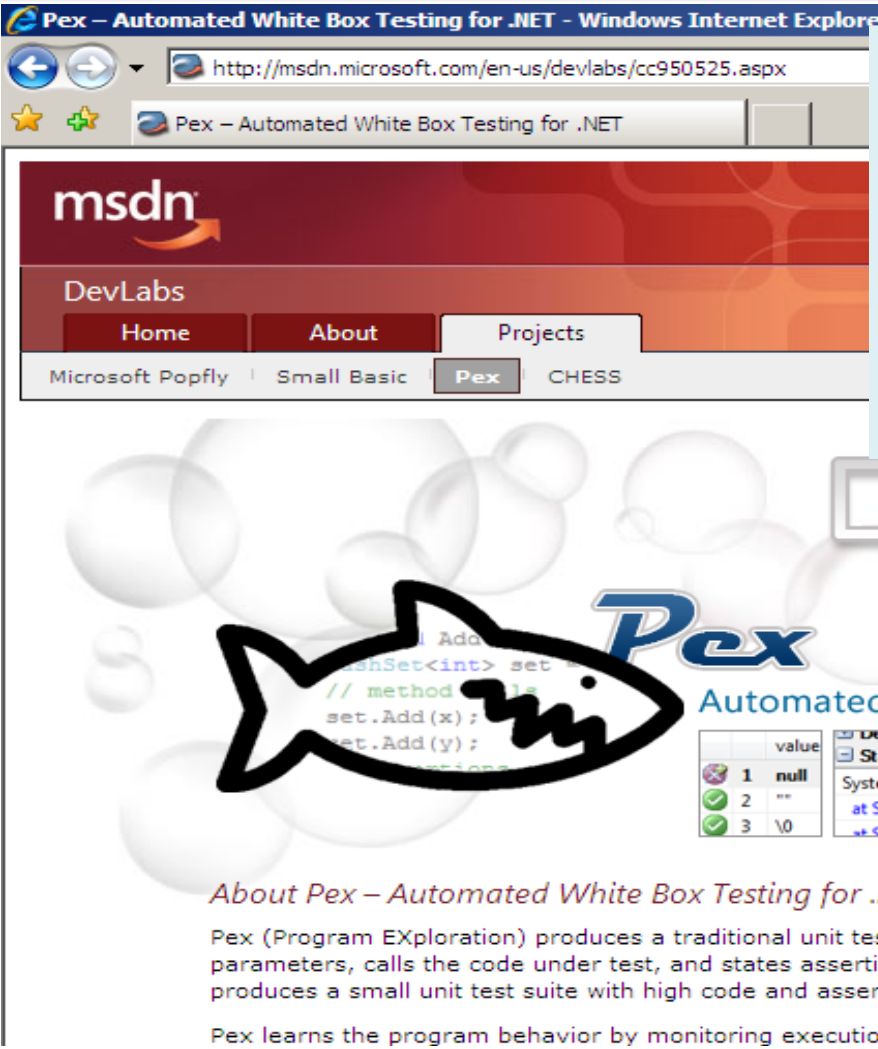
Microsoft Research SAGE – Security Fuzz Testing

- Since April 2007 1st release: many new security bugs found (missed by blackbox fuzzers, static analysis)

- Example: Windows Client Security team for Win7
  - Dedicated fuzzing lab with 100s machines □
  - 100s apps (deployed on 1 billion+ computers)
  - ~1/3 of all fuzzing bugs found by SAGE

From http://research.microsoft.com/en-us/um/people/pg/public_psfiles/talk-tap2011.pdf

Microsoft Research
Pex/Fakes - Developer Testing



Pex download counts (20 months)
(Feb. 2008 - Oct. 2009)

Academic: **17,366**

Devlabs: **13,022**

Total: 30,388

Fakes

Visual Studio®

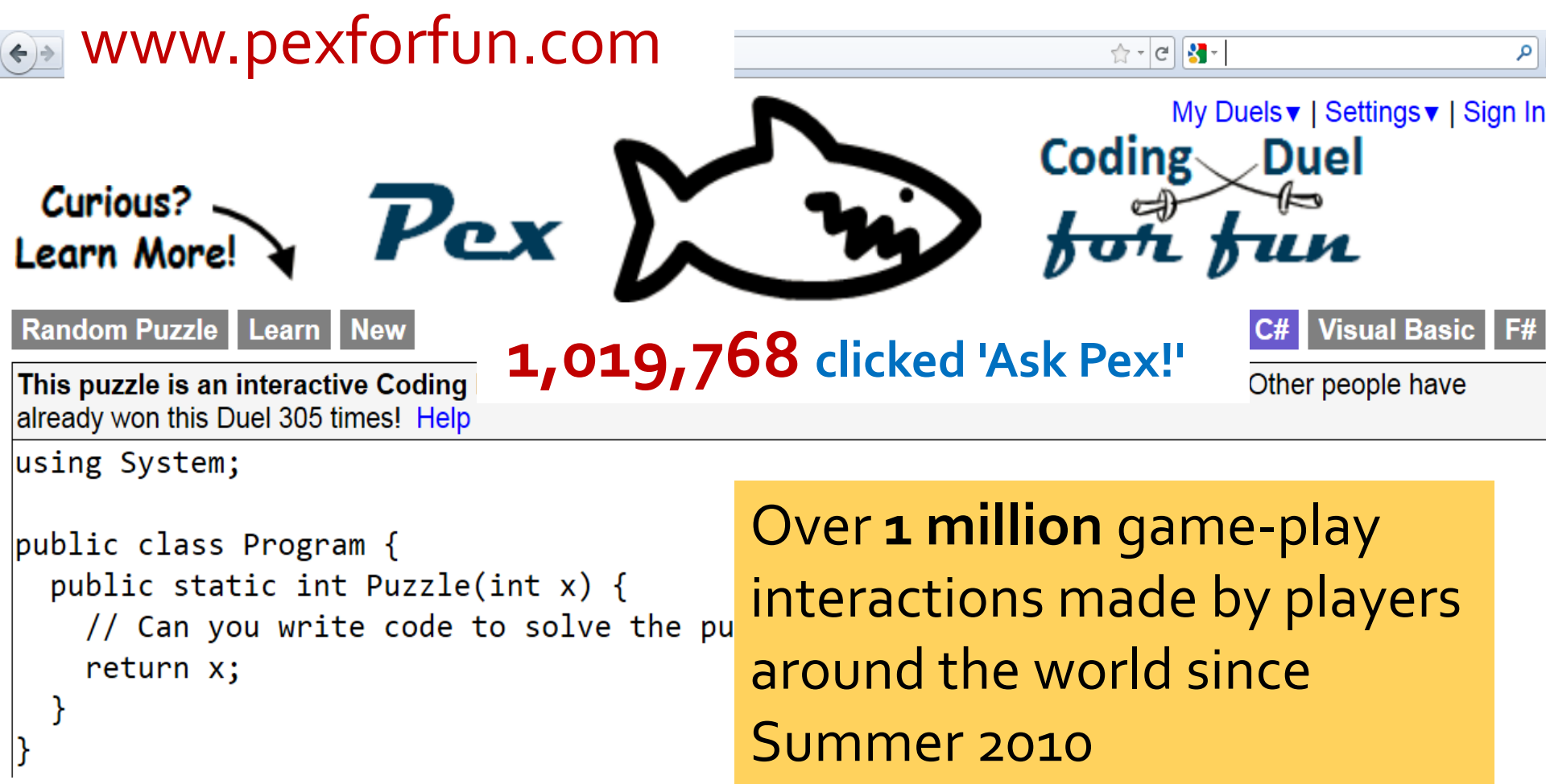
Premium & Ultimate 2012 Overview

http://research.microsoft.com/projects/pex/

Microsoft Research Pex for Fun

Teaching/Learning CS via Interactive Gaming

www.pexforfun.com



Over **1 million** game-play interactions made by players around the world since Summer 2010

Non-Success Factors?

- Unavailability of tools in the public domain
  - TOSEM papers 2001-2006 (60% refer to a tool, only 20% **installable**) [Ghezzi ICSE 09 keynote]
- Evaluation subjects (scalability)
  - Toy examples (prior 2000) → hand-picked isolated complex data structures [Korat ISSTA 02] → open source real-world code [MSeqGen/Seeker FSE 09/OOPSLA 11]
- Self referentiality
  - E.g., compare proposed X-type test-gen technique within only other X-type test-gen techniques w/o comparing with other test-gen techniques (X: random, evolutionary, DSE, …)
- Usability ignored (assuming human not in the loop)
- Company/practitioner culture in practice

Summary

- Status of SE research community (e.g., ICSE)
- Zoom in: seeking evidence of tech adoption of ATDG in practice
- Some success stories with varied levels of extent
- Some non-success factors

- What to do next to deal with the gap issues? …
  - Panel discussion next session

Thank you!

Questions ?

https://sites.google.com/site/asergrp/

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Behind the Scene of Pex for Fun

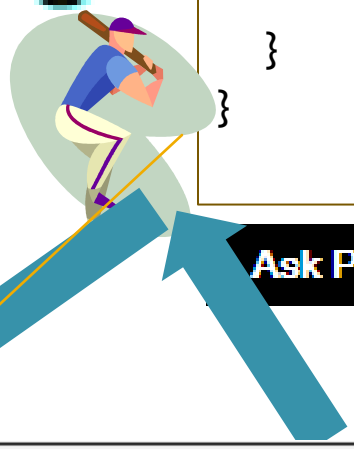
Secret Impl behavior== Player Impl

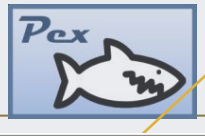
Secret Implementation

```
class Secret  {
    public static int Puzzle(int  x) {
      if (x <= 0) return 1;
      return x * Puzzle(x-1);
    }
}
```

Player Implementation

```
class Player {
    public static int Puzzle(int  x) {
          return x;
    }
}
```






```
class Test {
public static void
  if (Secret.Puzzl
     throw new Ex
  }
}
```

	x	your result	secret implementation result	Output/Exception
✓	1	1	1	
✓	2	2	2	
✗	3	3	6	Mismatch

What Make Tech Transfer Difficult?

- Scalability
- Complexity
- Applicability
- Usability (human in the loop)
- Cost-Benefit Analysis

Scalability

- Academia
  - Rarely ask "When scale is up, will my solution still work?"
  - Tend to focus on small or toy scale problems
- Real-world (e.g., search engine, code analysis, …)
  - Often demand a scalable solution
- Ideal: sophisticated and scalable solution
  - But in practice, simple solution tends to be scalable (performance, maintenance, …)
  - Academia tend to value sophistication > simplicity
- Ex: Test prioritization@Microsoft [ISSTA 2002], Klee [OSDI 2008]

Complexity

- Academia
  - Tend to make assumptions to simplify problems, or one at a time (indeed relaxing assumptions over time)
  - May not be able to assess the relevance/feasibility of assumptions in practice; not consult/work w/ industry
- Real-world
  - Often has high complexity, violating these assumptions
- Example: OO Unit Test Generation
  - Isolated simple classes → Isolated complex data structures → Real world classes as focused by our recent work [ESEC/FSE 2009, OOPSLA 2011]

Applicability

- Academia
  - Tend to focus on a solution optimized for one of many situations (likely worse for others) vs. comprehensive solution
  - May not enable to tell ahead of time whether a given case would fall into applicable scope of the solution
- Real-world
  - Need a comprehensive solution that would work generally (at least not compromising too much other situations)
- Examples
  - Integration of our Fitnex in Pex [DSN 2009]
  - Coverity [CACM 2010] vs. MSRA XIAO/PatternInsight
  - Industry adoption of open source tools

Usability

- Academia
  - Tend to leave human out of loop (involving human makes evaluations difficult to conduct or write)
  - Tend not to spend effort on improving tool usability
    - tool usability would be valued more in HCI than in SE
    - too much to include both the approach/tool itself and usability/its evaluation in a single paper
- Real-world
  - Often has human in the loop (familiar IDE integration, social effect, lack of expertise/willingness to write specs,…)
- Examples
  - Agitar [ISSTA 2006] vs. Daikon [TSE 2001]
  - Debugging user study [ISSTA 2011]

Cost-Benefit Analysis

- Academia
  - Tend to focus on one or a few dimensions of measurement (e.g., analysis cost, precision and/or recall)
- Real-world
  - Consider many dimensions of measurement
    - Cost, e.g., human cost
    - Benefit, e.g., bug severity
- Example
  - FindBugs experience at Google [ISSTA 2009]

Suggestions

- Value engineering creativity
- Find killer apps, e.g.,
  - MSR SLAM: Device driver verification
  - MSR Sage: Security testing of binaries
  - PatternInsight/MSRA Xiao: Known-bug detection
- Engage practitioners
  - Get research problems from real practice
  - Get feedback from real practice
  - Collaborate across disciplines
  - Collaborate with industry

Industry Academia Collaboration

- Academia (research recognitions, e.g., papers) vs. Industry (company revenues)
- Academia (research innovations) vs. Industry (likely involving engineering efforts)
- Academia (long-term/fundamental research) vs. Industry (short-term research or work)
- …
- Industry: problems, infrastructures, data, evaluation testbeds, …
- Academia: educating students, …