Microsoft® Research

FacultySummit 2011

Cartagena, Colombia | May 18-20 | In partnership with COLCIENCIAS

# Future Trends in Software Engineering

**Wolfram Schulte**

RiSE Research in Software Engineering

Reinventing Software Development

# Software Engineering (SE)

NATO SE Conference 1968

*“Produce high quality software with a finite amount of resources to a predicted schedule”*

# Agenda

Analytics for software development

- *Many known programs: Branch analysis*

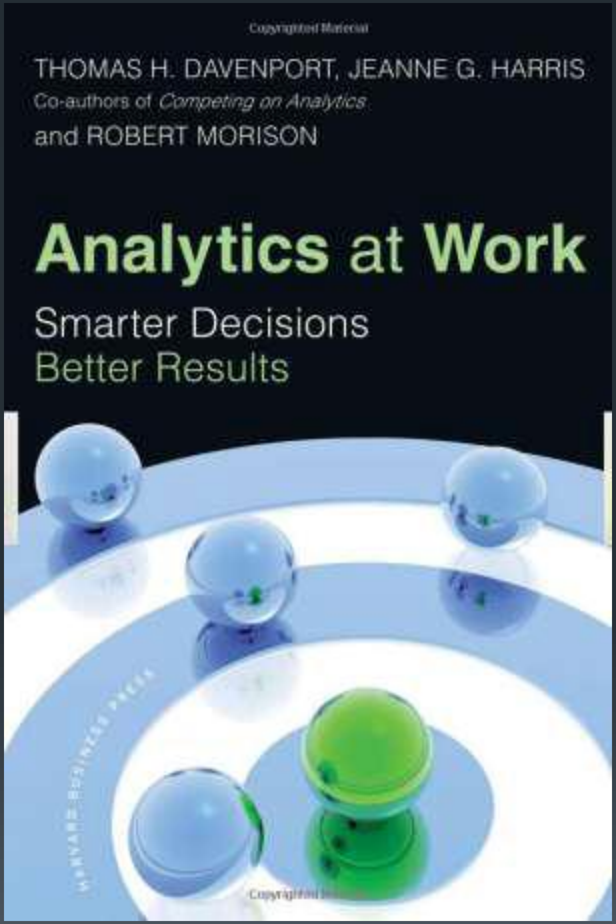
Logic-based tools

- *Two known programs: Equivalence checking*

Future platforms, future developers

- *One known, one unknown pgm: Coding duels*

# Analytics



“Use of analysis, data, and systematic reasoning to make decisions”

- Financial services
- Manufacturing
- Health care
- Search
- And more…

# Analytics

| | Past | Present | Future |
|---|---|---|---|
| Information | What happened?<br>**(Reporting)** | What is happening now?<br>**(Alerting)** | What will happen?<br>**(Extrapolation)** |
| Insight | How and why did it happen<br>**(Modeling)** | What’s the best next action?<br>**(Recommendation)** | What’s the best/worst that can happen?<br>**(Prediction)** |

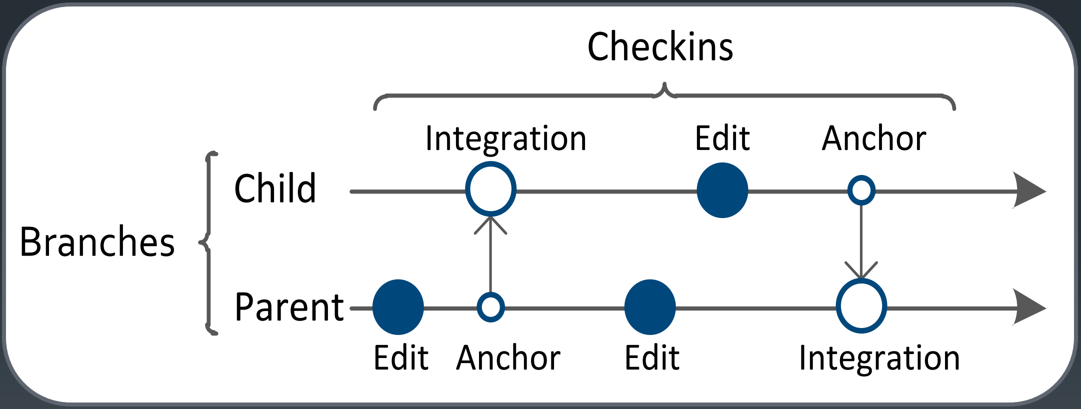
*From Davenport et al. “Analytics at Work”.*

# Branching in Source Control Management (SCM) Systems

Coordinating the work of 100’s of developers is difficult

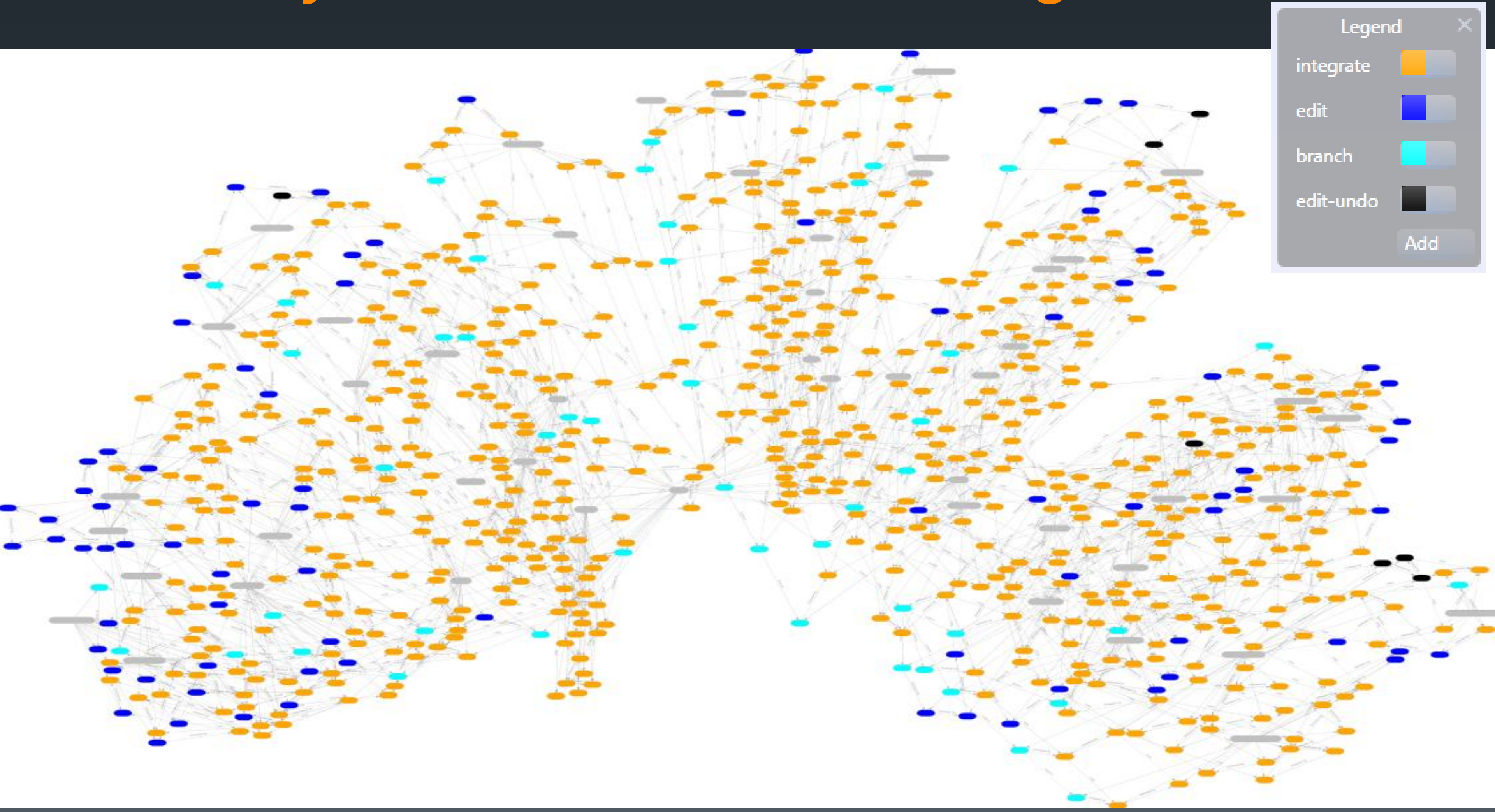
A common solution is to **use branches in SCM** systems

- Benefits: Isolating concurrent work during times of instability



- Cost: Increase the time that changes per-colate through the system (Code Velocity)

# Status quo:
# Many branches for little change



**Code Velocity for this file is particularly bad…**

# Branch Analytics

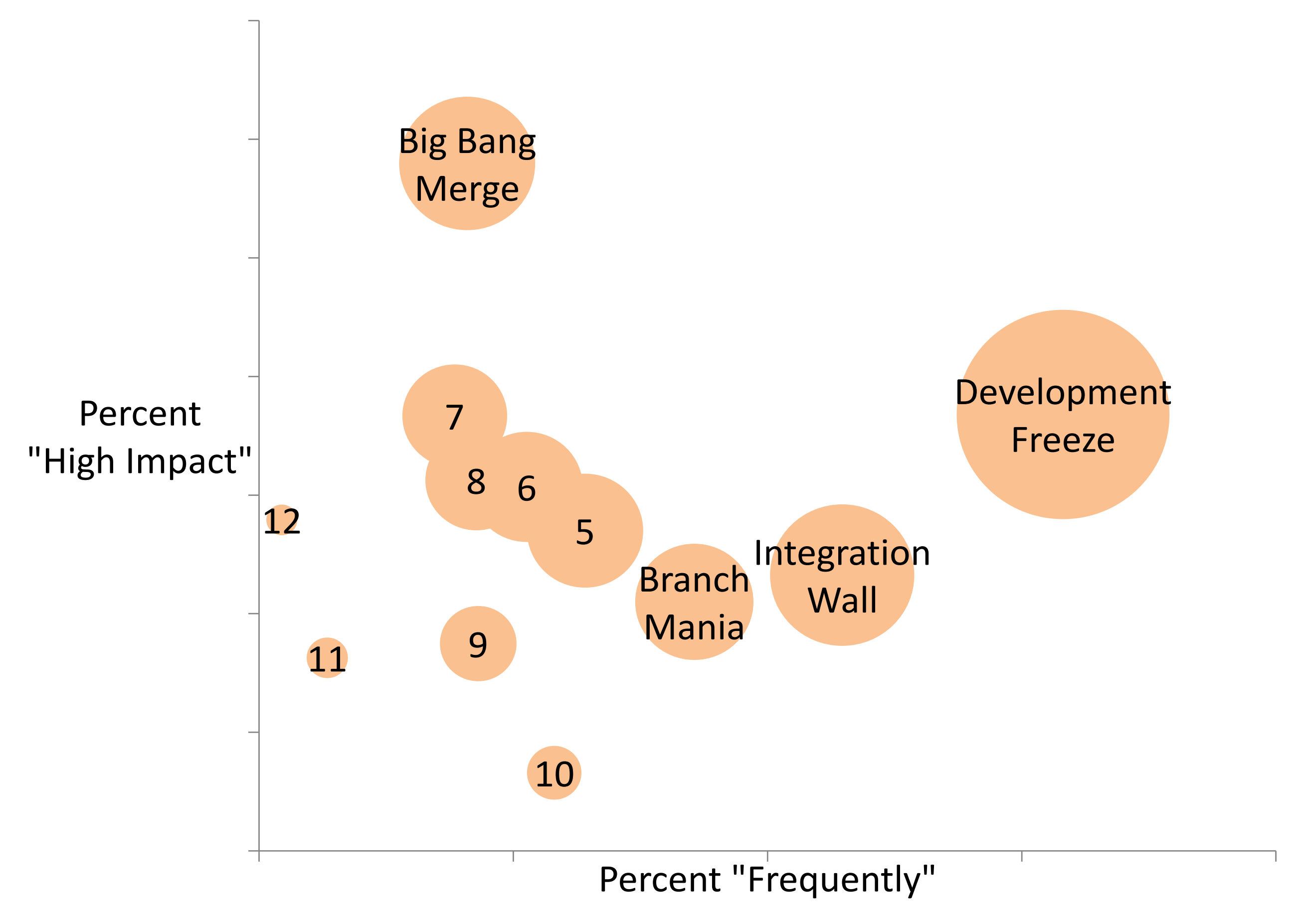
Techniques:

- **Survey** devs to understand their problems with branching
- **Mine** dev. data for relationship of teams and branches
- **Simulate** benefits and cost of alternative branch structures

Actions/Tools:

- **Alert** users about possible conflicts
- **Recommend** branch structure, e.g. del., add, merge etc.
- **Perform** semi-automatic branch refactoring

# Survey: Branching Problems



- **Big Bang Merge:** merge all branches simultaneously
- **Development Freeze:** stop work while merging
- **Integration Wall:** using branches between people, instead of dividing work
- **Branch Mania:** creating too many branches
- ...

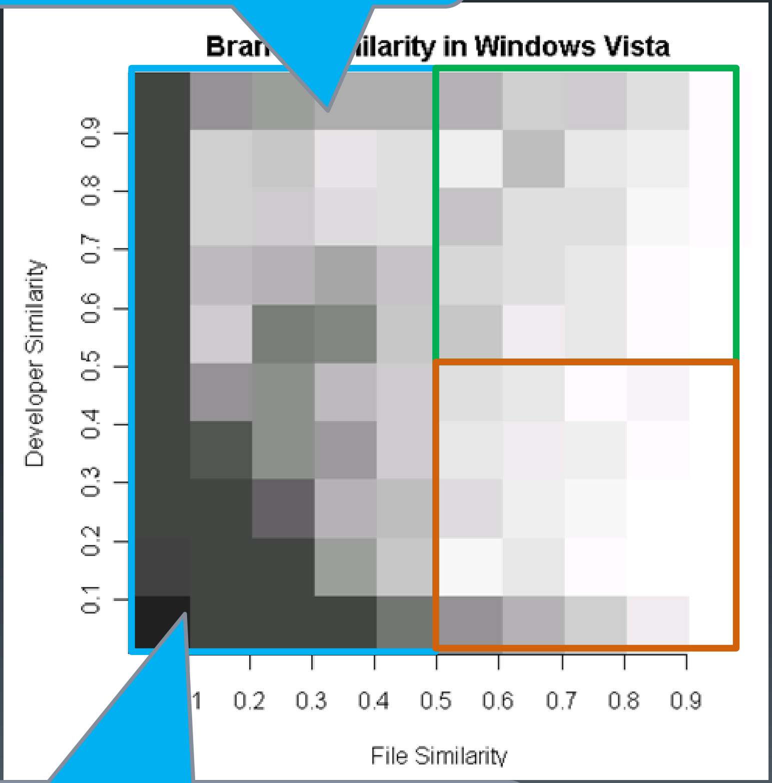
*Anti-patterns from [Streamed Lines: Branching Patterns for Parallel Software Development] and [Branching and Merging Primer].*

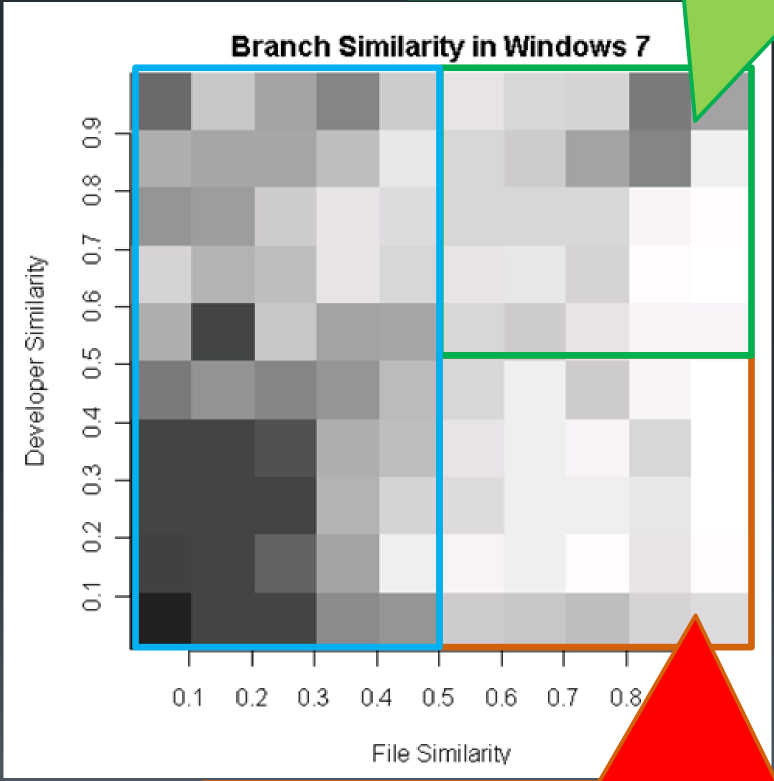
# Mine “File Similarity” / ”Developer Similarity”

Dark areas mean many branch pairs in that area.

Same devs working on different things is OK

Same files should mean same people





Most pairs of branches are not similar

Same files, but different team means possible problems

# Simulate Cost-Benefit of Alternative Branch Structures

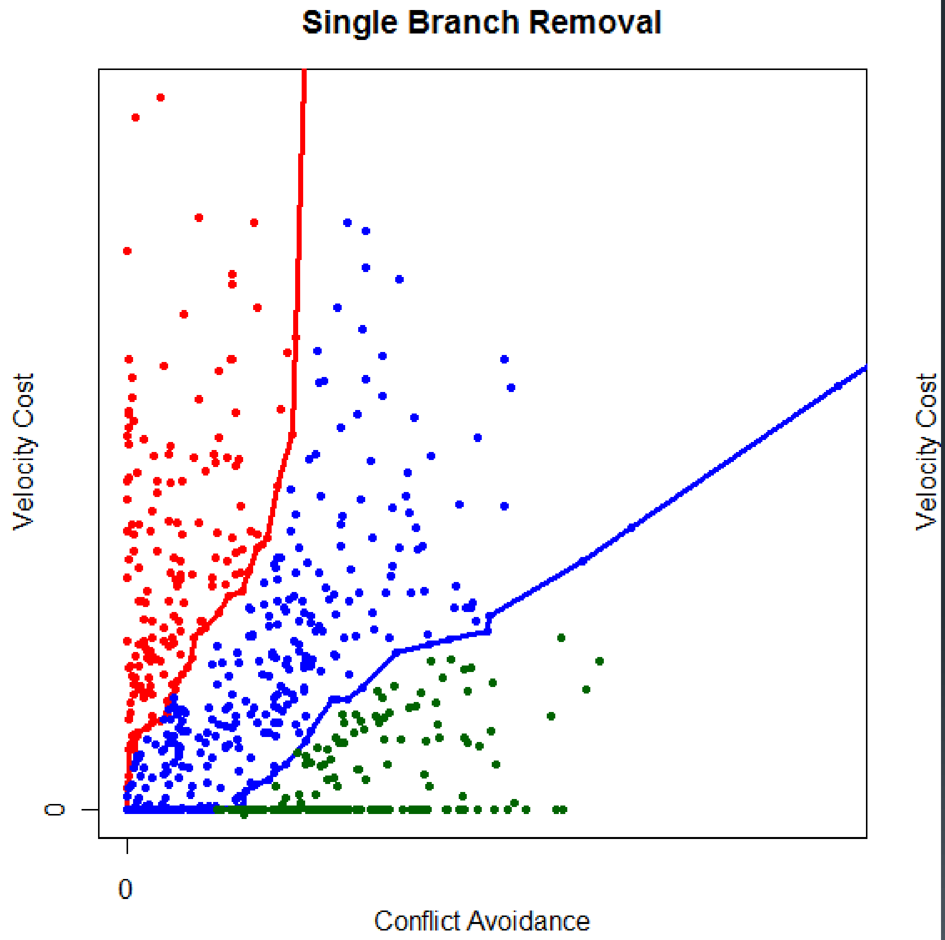
Idea: Replay Windows history

- With each feature-branch removed

Measure impact on:

- Velocity (“cost”)
- Avoided conflicts (“benefit”)

# Velocity vs. Conflict avoidance



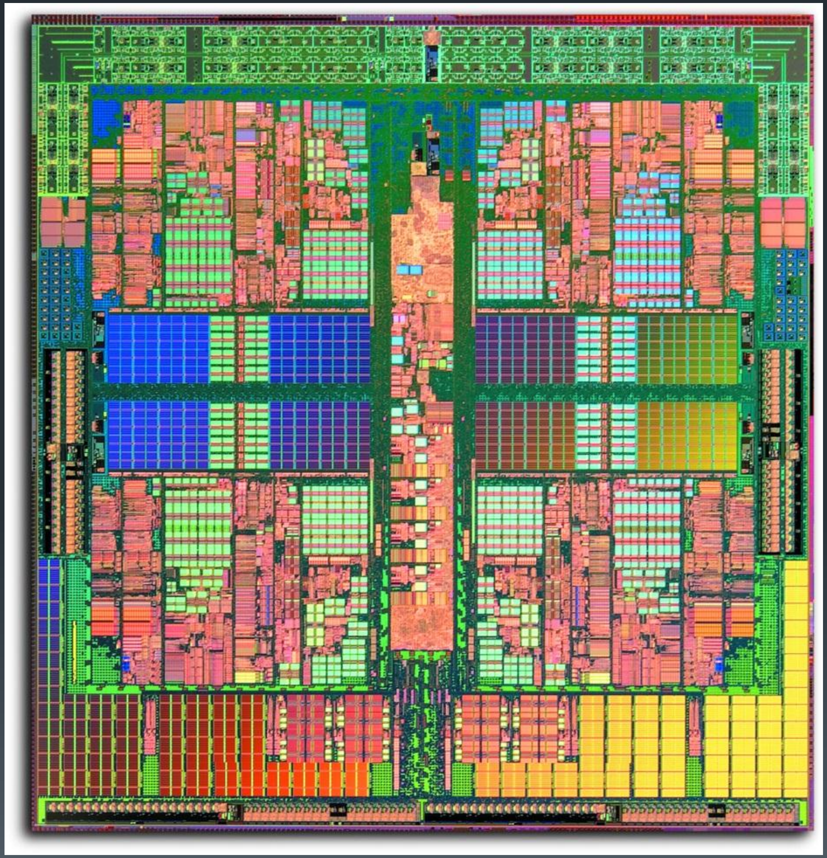
- Bad branch
- Good branch

# Summary: Branch Analytics

Software Analytics makes software development data actionable

- Branch analytics key to improve code velocity
- Better design of development structure
- Efficient scheduling
- Reliable systems with low conflicts

# Equivalence Checking (EC)



*THE BIG SUCCESS STORY OF FMS IN HARDWARE*

Formally prove that two circuit designs, like register transfer level and netlist, exhibit exactly the same behavior

# EC for Software

Formally prove that two programs (with procedures) have the same input/output behavior

- Input: State of parameters, globals and heap
- Output: State of return, globals and heap

# Example

```
void swap1(ref int x, ref int y){
    int z = x;
    x = y;
    y = z;
}
void swap2(ref int x, ref int y){
    x = x + y;
    y = x - y;
    x = x - y;
}
```

```
z0 == x0    &&
x1 == y0    &&
y1 == z0    &&
swap1.x == x1  &&  swap1.y == y1
&&
x1' == x0 + y0     &&
y1' == x1' – y0    &&
x2' == x1' –  y1'  &&
swap2.x == x2' &&  swap2.y == y1'
&&
~ (swap1.x ==  swap2.x &&
    swap1.y  ==  swap2.y)
```

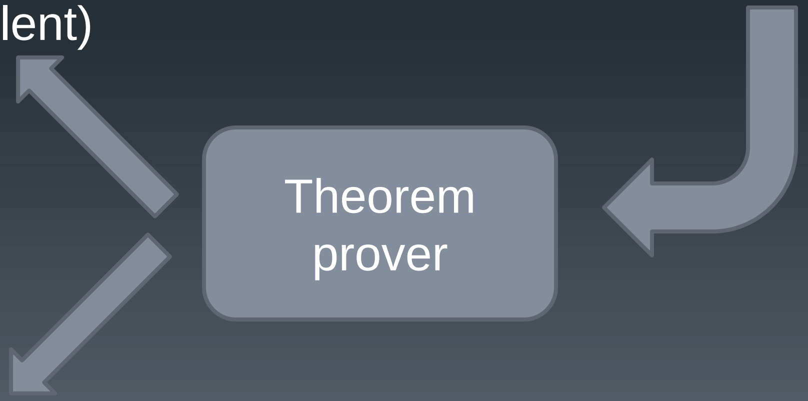
Two programs

Formula/Constraint

# Example

```
void swap1(ref int x, ref int y){
    int z = x;
    x = y;
    y = z;
}
void swap2(ref int x, ref int y){
    x = x + y;
    y = x - y;
    x = x - y;
}
```

```
z0 == x0    &&
x1 == y0    &&
y1 == z0    &&
swap1.x == x1  &&  swap1.y == y1
&&
x1' == x0 + y0     &&
y1' == x1' – y0    &&
x2' == x1' –  y1'  &&
swap2.x == x2' &&  swap2.y == y1
&&
~ (swap1.x ==  swap2.x &&
   swap1.y ==  swap2.y)
```



UNSAT (Equivalent)

Theorem prover

SAT (Counterexample)

# Interesting constructs in programs

- Branches
- Loops
- Heap and the stack
- **Procedure calls**

# Procedure calls and uninterpreted functions

```
void Foo1(ref int x, int y){
    int z = x + y;
    x = Bar(z);
}

void Foo2(ref int x, int y){
    int z = y + x;
    x = Bar(z);
}
```

```
z0 == x0 + y0        &&
x1 == F_Bar(z0)    &&
Foo1.x == x1

&&

z0' == y0 + x0          &&
x1' ==  F_Bar(z0')    &&
Foo2.x == x1'

&&
~ (Foo1.x == Foo2.x)
```

Uninterpreted function

a == b ➔ F_Bar(a) == F_Bar(b)

Two programs

Formula/Constraint

# SymDiff

A Semantic Diff tool

- Like Windiff

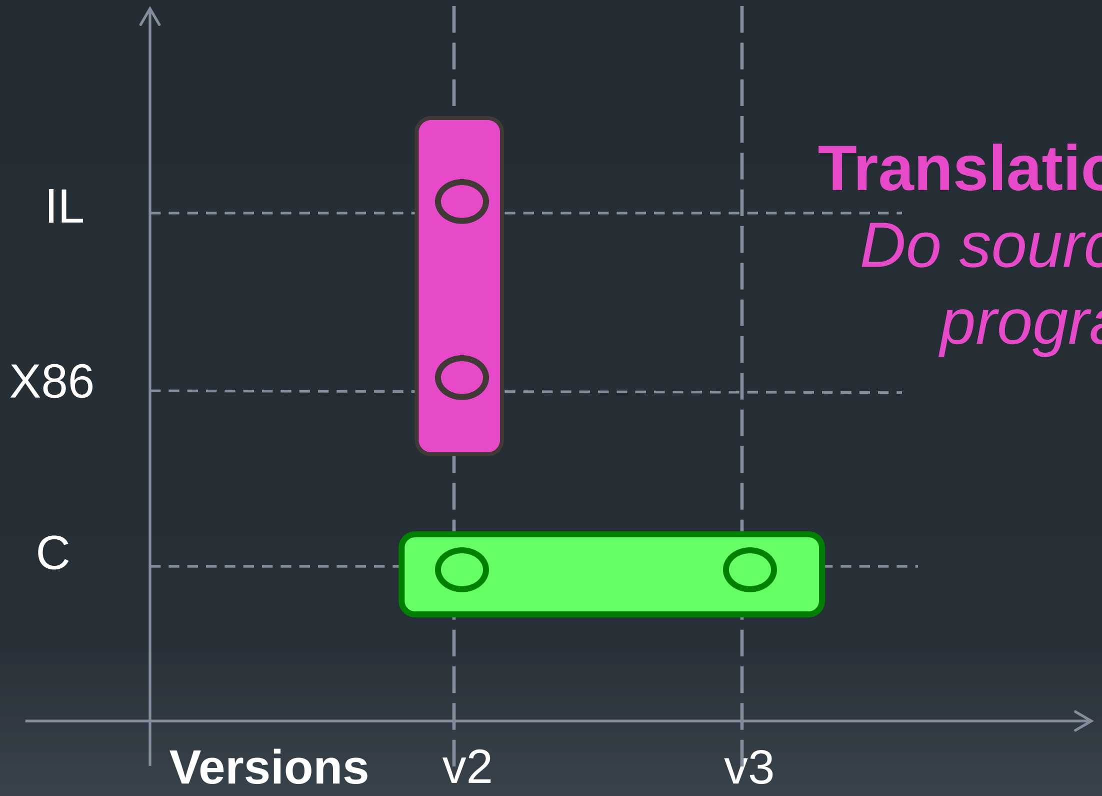
Language independent

- Builds on Boogie verifier and Z3 theorem prover

Adapt for various source languages

- C, C++, .NET, x86, ARM, ….

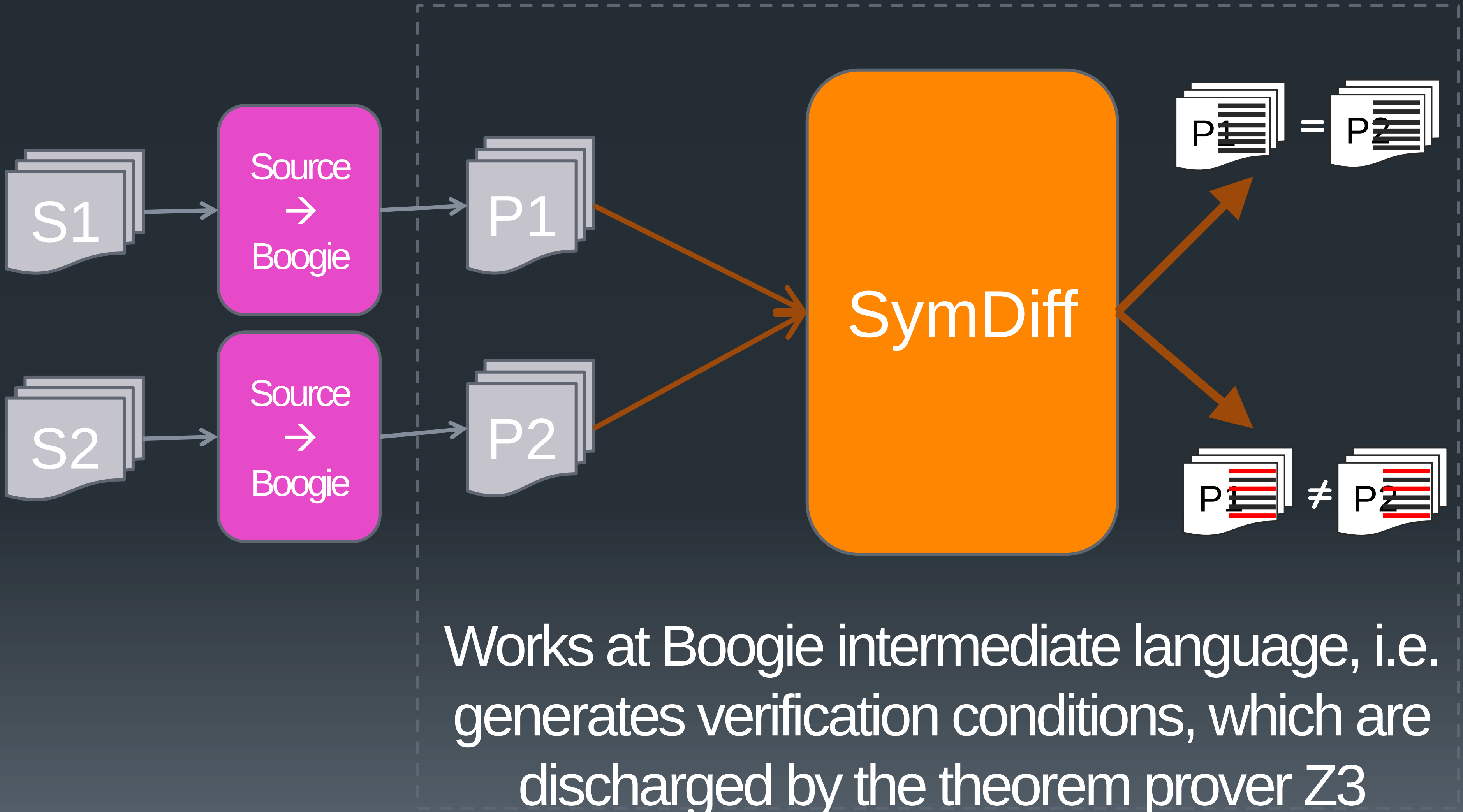
# SymDiff for Applications and Compiler



**Translation Validation:**
*Do source and target program agree?*

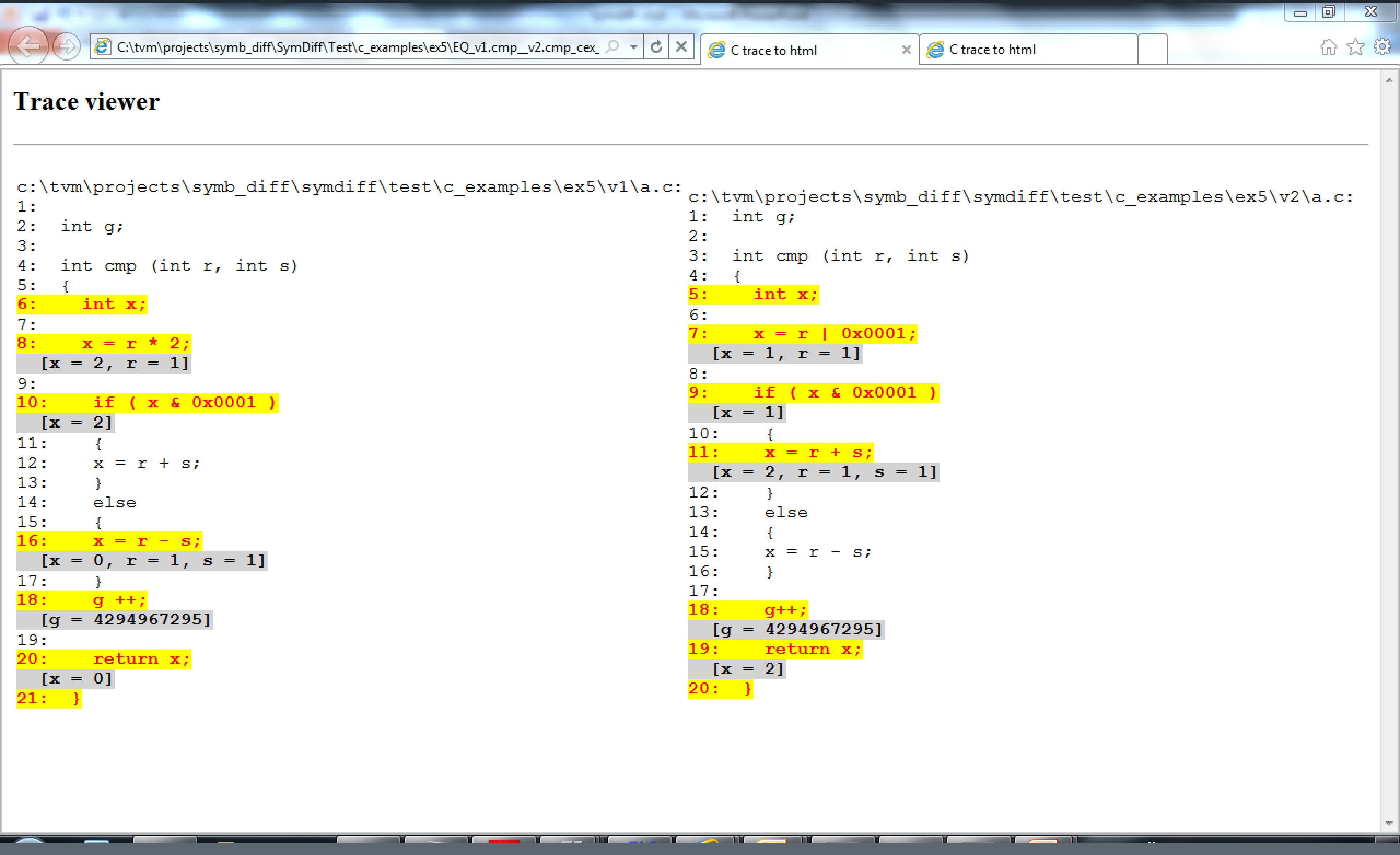
**Version/Application-compatibility:**
*Do the two versions behave the same?*
*Can be used to automatically resolve refactoring/bugfix conflicts*

# SymDiff tool



Works at Boogie intermediate language, i.e. generates verification conditions, which are discharged by the theorem prover Z3

# SymDiff for C



C:\tvm\projects\symb_diff\SymDiff\Test\c_examples\ex5\EQ_v1.cmp__v2.cmp_cex_
C trace to html
C trace to html

## Trace viewer

```
c:\tvm\projects\symb_diff\symdiff\test\c_examples\ex5\v1\a.c:
1:
2:  int g;
3:
4:  int cmp (int r, int s)
5:  {
6:     int x;
7:
8:     x = r * 2;
   [x = 2, r = 1]
9:
10:      if ( x & 0x0001 )
   [x = 2]
11:      {
12:      x = r + s;
13:      }
14:      else
15:      {
16:      x = r - s;
   [x = 0, r = 1, s = 1]
17:      }
18:      g ++;
   [g = 4294967295]
19:
20:      return x;
   [x = 0]
21:   }
```

```
c:\tvm\projects\symb_diff\symdiff\test\c_examples\ex5\v2\a.c:
1:  int g;
2:
3:  int cmp (int r, int s)
4:  {
5:     int x;
6:
7:     x = r | 0x0001;
   [x = 1, r = 1]
8:
9:     if ( x & 0x0001 )
   [x = 1]
10:      {
11:      x = r + s;
   [x = 2, r = 1, s = 1]
12:      }
13:      else
14:      {
15:      x = r - s;
16:      }
17:
18:      g++;
   [g = 4294967295]
19:      return x;
   [x = 2]
20:   }
```

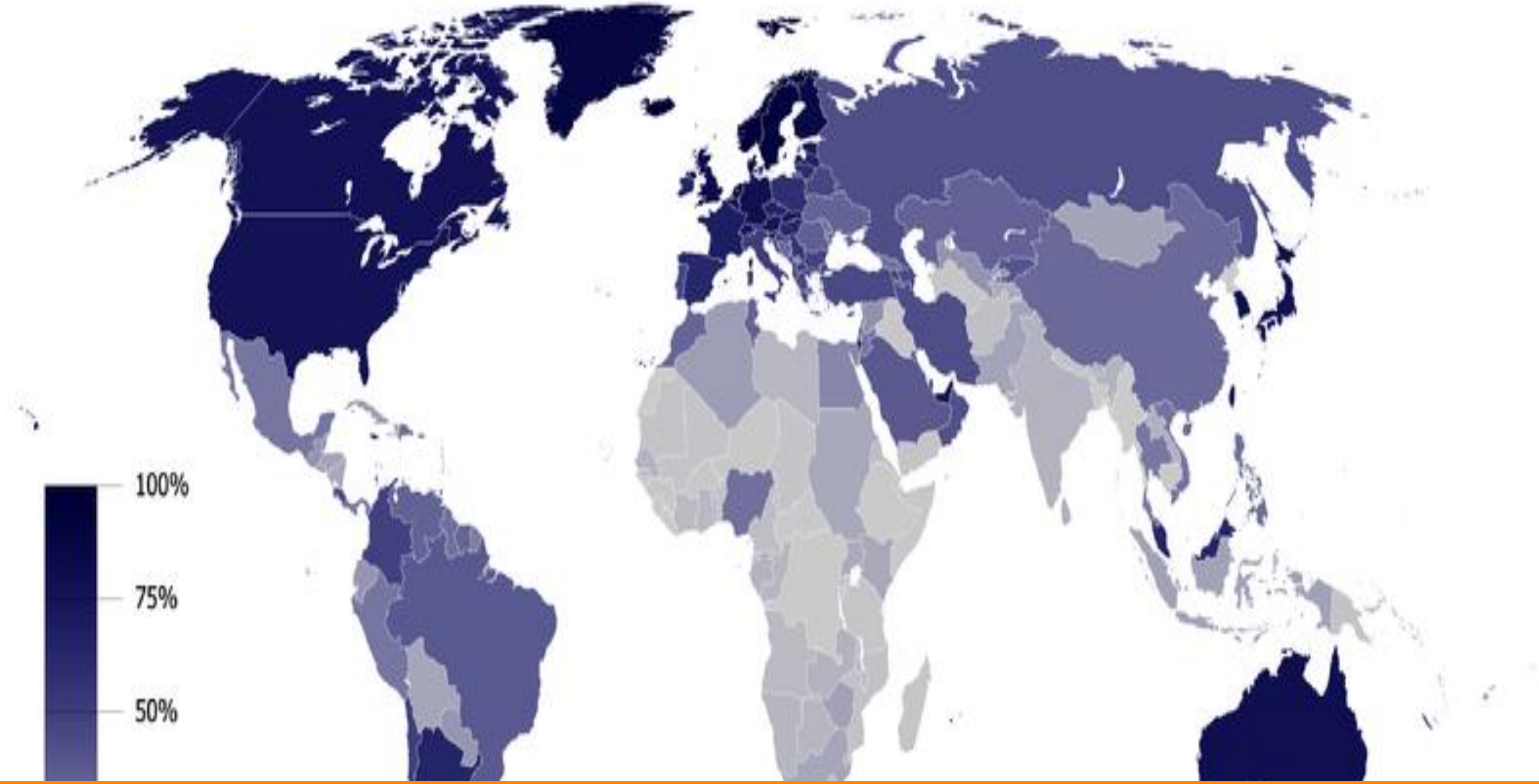
# Summary: SymDiff

Logic-based tools translate programs & constraints into formulas

SymDiff checks

- merge of refactorings
- application compatibility
- compiler translations
- “refinement”- the same except for undef behavior

Try tools out yourself: http://rise4fun.com



- Over 1.8 billion people are connected to the web
- The browser is the most widely used app
- People love to play

# Pex for Fun

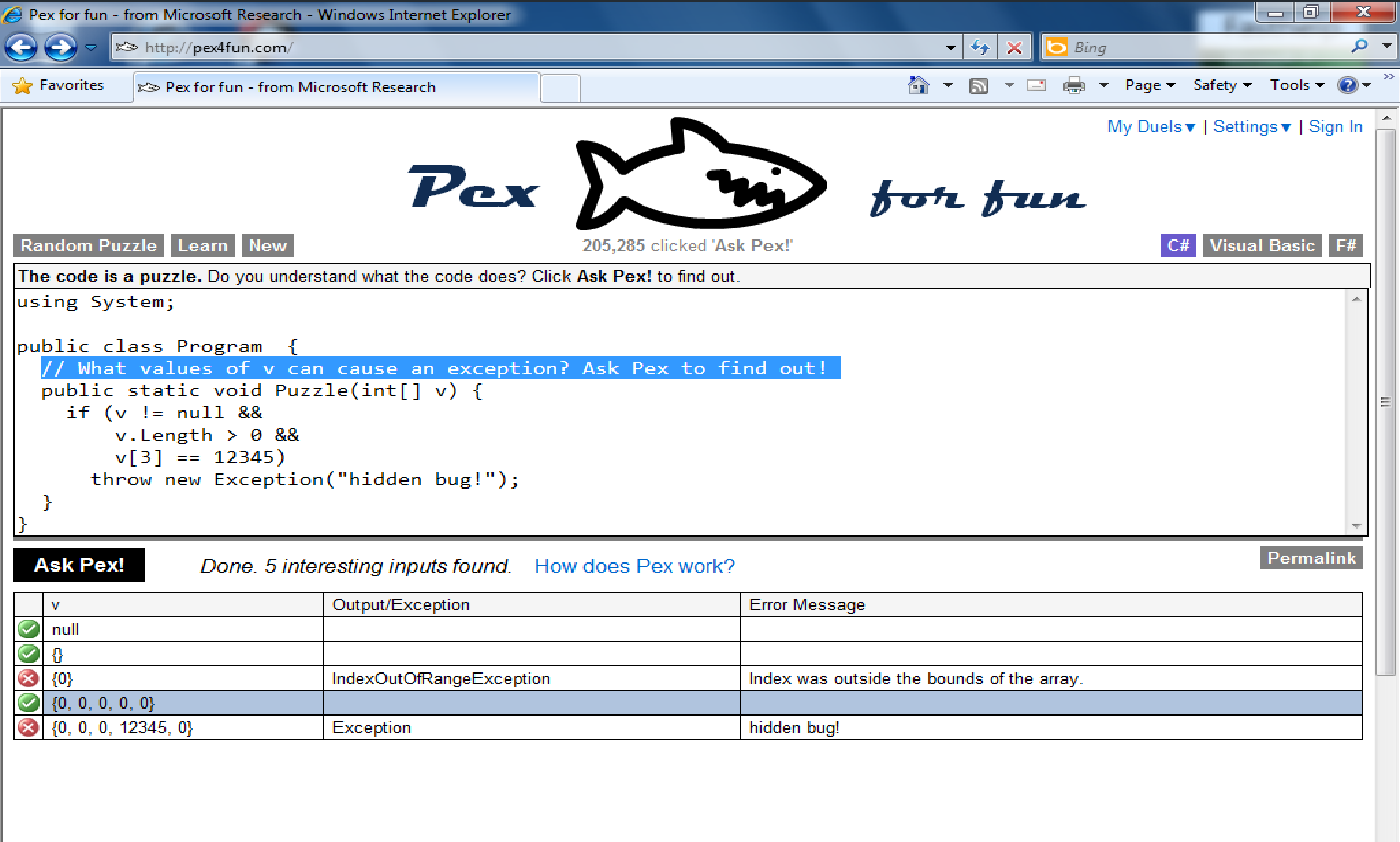
Excite people to play coding duels (puzzles), i.e.

- Given a hidden program
- Puzzlers writes a user program

- Puzzler wins if *hidden* “=“ *user*, otherwise he gets counter examples

Enabled via Pex which uses dynamic symbolic execution, i.e. executes “all” paths of both programs

# Pex Functionality


Pex for fun - from Microsoft Research - Windows Internet Explorer
http://pex4fun.com/
Bing
Favorites
Pex for fun - from Microsoft Research
Page
Safety
Tools
My Duels | Settings | Sign In
Pex for fun
Random Puzzle
Learn
New
C#
Visual Basic
F#
Ask Pex!
Permalink

205,285 clicked 'Ask Pex!'

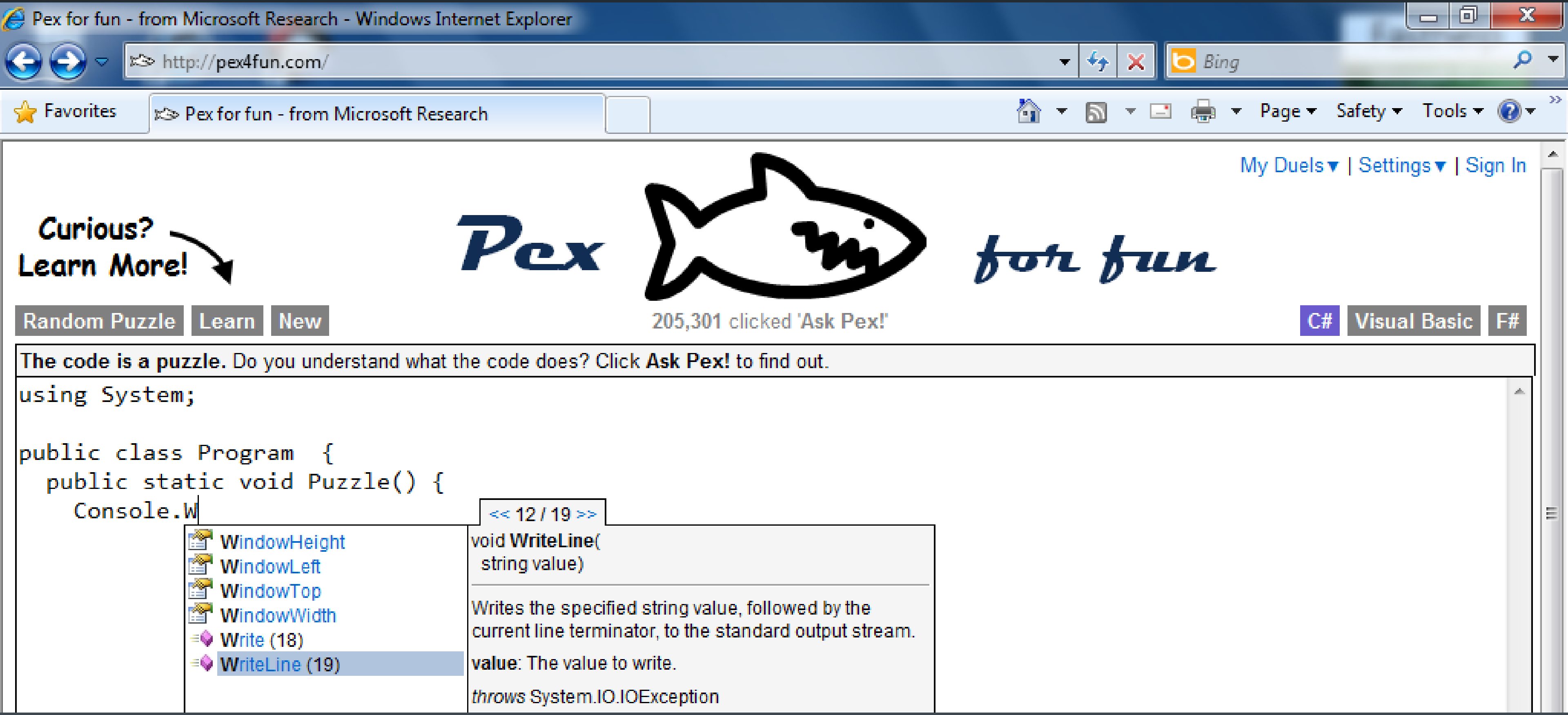
**The code is a puzzle.** Do you understand what the code does? Click **Ask Pex!** to find out.

```
using System;

public class Program  {
  // What values of v can cause an exception? Ask Pex to find out!
  public static void Puzzle(int[] v) {
    if (v != null &&
        v.Length > 0 &&
        v[3] == 12345)
      throw new Exception("hidden bug!");
  }
}
```

*Done. 5 interesting inputs found.* How does Pex work?

| | v | Output/Exception | Error Message |
|---|---|---|---|
| ✓ | null | | |
| ✓ | {} | | |
| ✗ | {0} | IndexOutOfRangeException | Index was outside the bounds of the array. |
| ✓ | {0, 0, 0, 0, 0} | | |
| ✗ | {0, 0, 0, 12345, 0} | Exception | hidden bug! |

# Intellisense



**The code is a puzzle.** Do you understand what the code does? Click **Ask Pex!** to find out.

```
using System;

public class Program  {
  public static void Puzzle() {
    Console.W
```

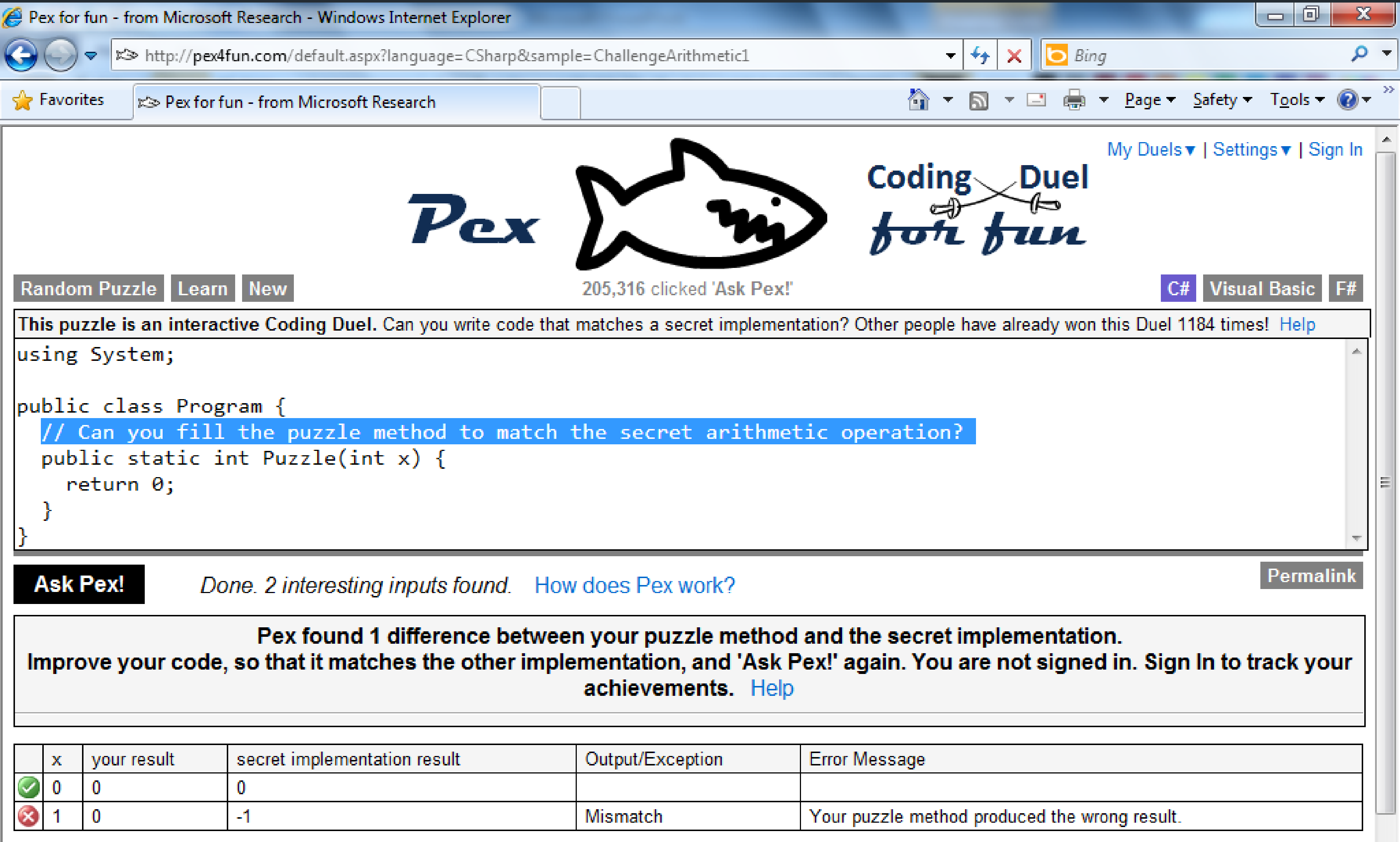
void **WriteLine**(
 string value)

Writes the specified string value, followed by the current line terminator, to the standard output stream.

**value**: The value to write.

*throws* System.IO.IOException

# Coding Duels


Pex for fun - from Microsoft Research - Windows Internet Explorer
http://pex4fun.com/default.aspx?language=CSharp&sample=ChallengeArithmetic1
Bing
Favorites
Pex for fun - from Microsoft Research
Page
Safety
Tools
My Duels | Settings | Sign In
Pex
Coding Duel for fun
Random Puzzle
Learn
New
C#
Visual Basic
F#
Ask Pex!
Permalink

205,316 clicked 'Ask Pex!'

**This puzzle is an interactive Coding Duel.** Can you write code that matches a secret implementation? Other people have already won this Duel 1184 times! Help

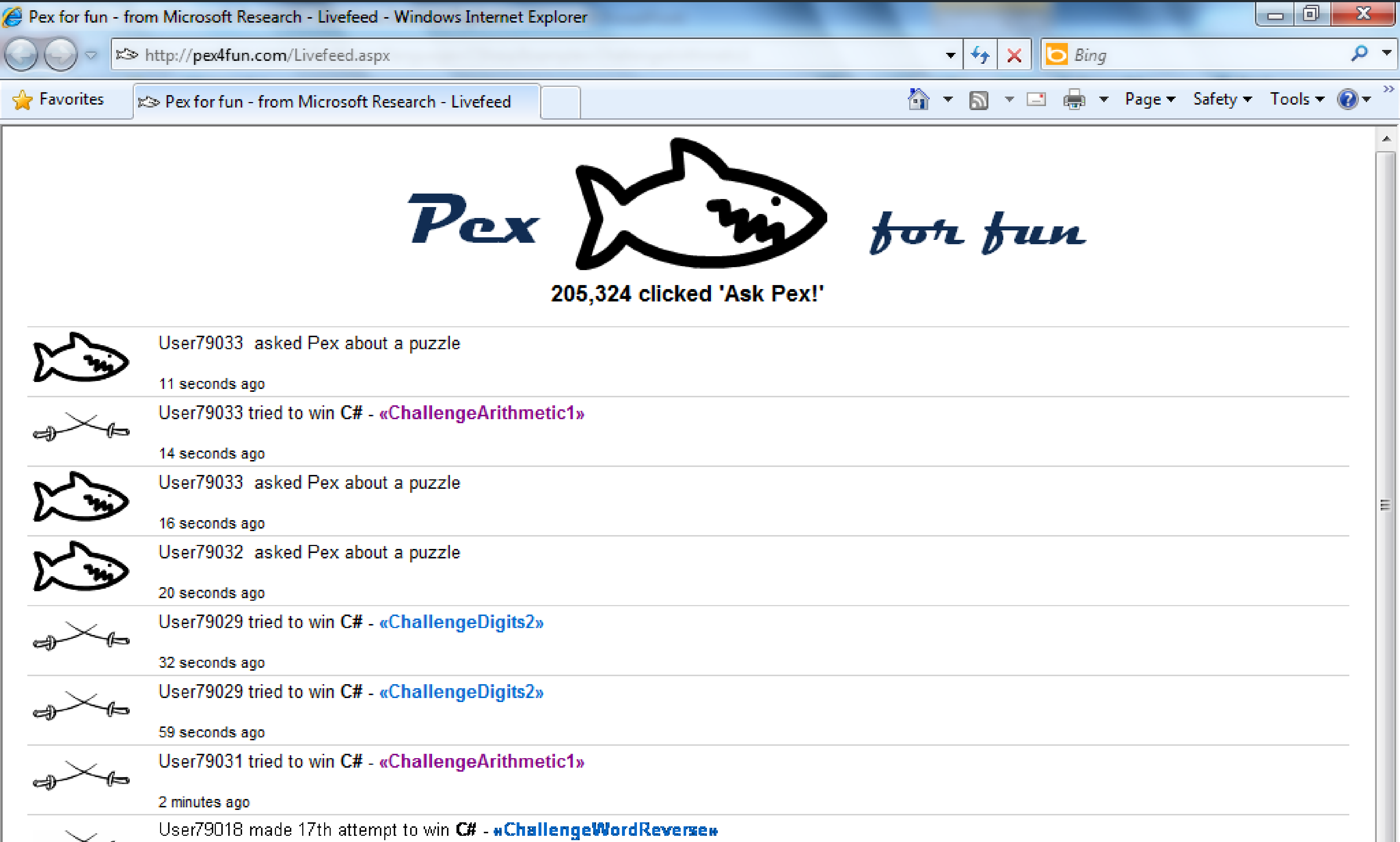
```
using System;

public class Program {
  // Can you fill the puzzle method to match the secret arithmetic operation?
  public static int Puzzle(int x) {
    return 0;
  }
}
```

*Done. 2 interesting inputs found.* How does Pex work?

**Pex found 1 difference between your puzzle method and the secret implementation.**
**Improve your code, so that it matches the other implementation, and 'Ask Pex!' again. You are not signed in. Sign In to track your achievements.** Help

|  | x | your result | secret implementation result | Output/Exception | Error Message |
|---|---|---|---|---|---|
| ✓ | 0 | 0 | 0 |  |  |
| ✗ | 1 | 0 | -1 | Mismatch | Your puzzle method produced the wrong result. |

# Social Experience



Pex for fun - from Microsoft Research - Livefeed - Windows Internet Explorer
http://pex4fun.com/Livefeed.aspx
Bing
Favorites
Pex for fun - from Microsoft Research - Livefeed
Page
Safety
Tools
Pex for fun

205,324 clicked 'Ask Pex!'

User79033 asked Pex about a puzzle
11 seconds ago

User79033 tried to win C# - «ChallengeArithmetic1»
14 seconds ago

User79033 asked Pex about a puzzle
16 seconds ago

User79032 asked Pex about a puzzle
20 seconds ago

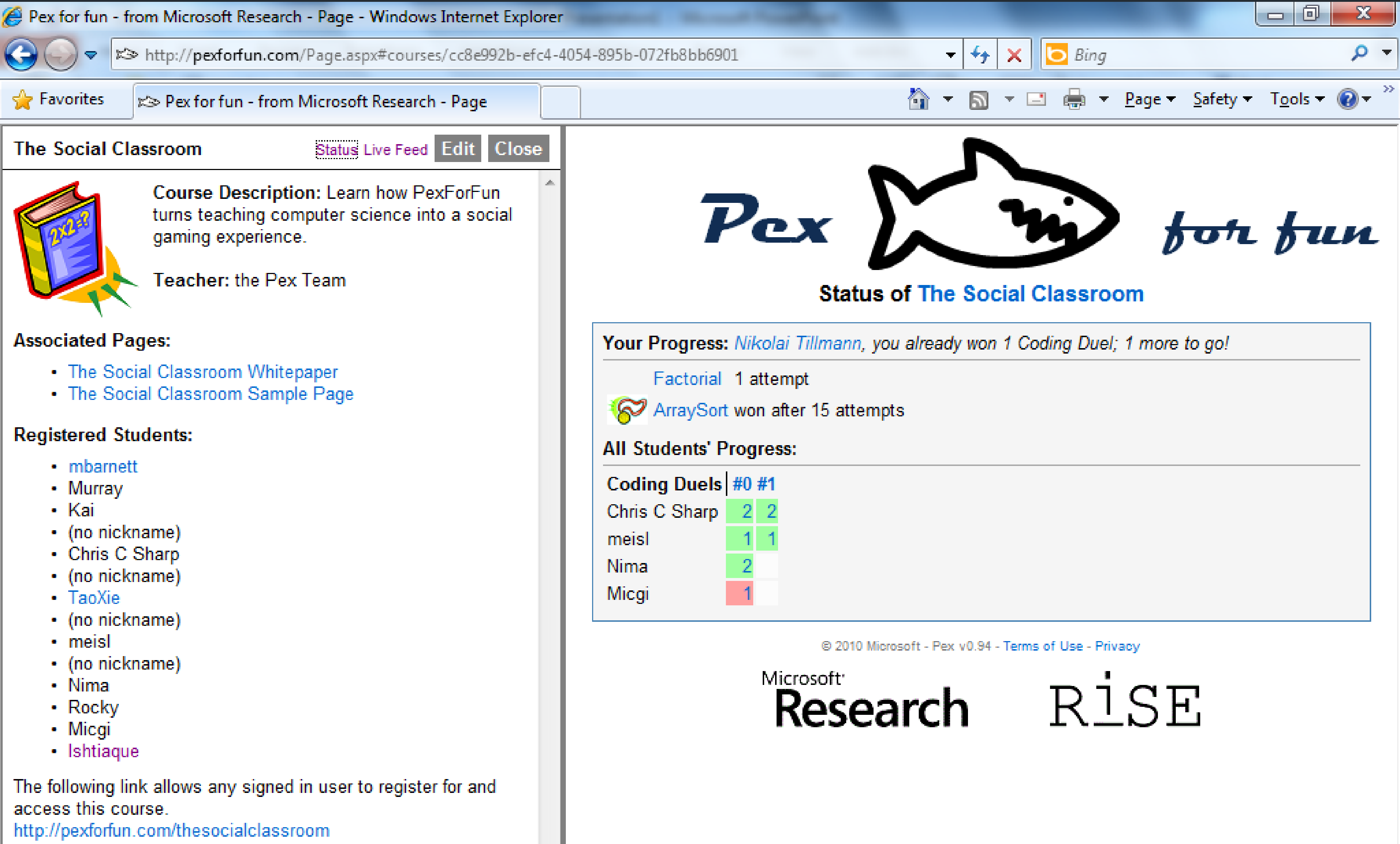
User79029 tried to win C# - «ChallengeDigits2»
32 seconds ago

User79029 tried to win C# - «ChallengeDigits2»
59 seconds ago

User79031 tried to win C# - «ChallengeArithmetic1»
2 minutes ago

User79018 made 17th attempt to win C# - «ChallengeWordReverse»

# Teaching



Pex for fun - from Microsoft Research - Page - Windows Internet Explorer
http://pexforfun.com/Page.aspx#courses/cc8e992b-efc4-4054-895b-072fb8bb6901
Bing
Favorites
Pex for fun - from Microsoft Research - Page
Page
Safety
Tools
Status
Live Feed
Edit
Close

**The Social Classroom**

**Course Description:** Learn how PexForFun turns teaching computer science into a social gaming experience.

**Teacher:** the Pex Team

**Associated Pages:**

- The Social Classroom Whitepaper
- The Social Classroom Sample Page

**Registered Students:**

- mbarnett
- Murray
- Kai
- (no nickname)
- Chris C Sharp
- (no nickname)
- TaoXie
- (no nickname)
- meisl
- (no nickname)
- Nima
- Rocky
- Micgi
- Ishtiaque

The following link allows any signed in user to register for and access this course.
http://pexforfun.com/thesocialclassroom

**Status of The Social Classroom**

**Your Progress:** *Nikolai Tillmann, you already won 1 Coding Duel; 1 more to go!*

Factorial 1 attempt

ArraySort won after 15 attempts

**All Students' Progress:**

| Coding Duels | #0 | #1 |
|---|---|---|
| Chris C Sharp | 2 | 2 |
| meisl | 1 | 1 |
| Nima | 2 | |
| Micgi | 1 | |

# Pex for Fun: Conclusion

For reach, taking programming into the browser & cloud and make it fun

Pex4Fun opens opportunities for

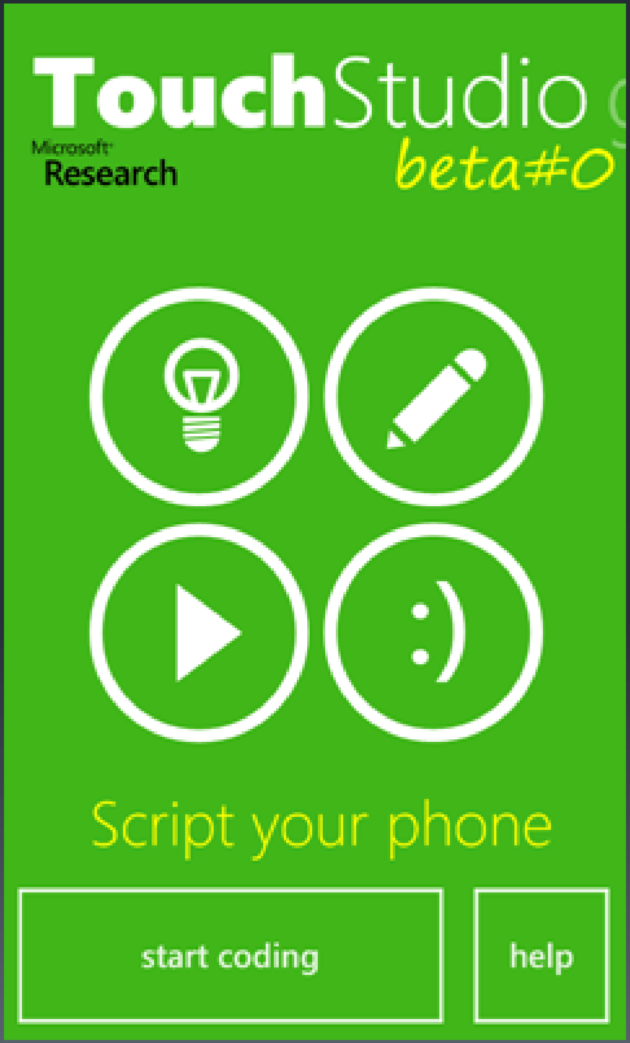
- learning using coding duels
- socialiazing using live feed, sharing duels
- teaching with automatic grading
- research: recommend fixes based on 1/2 million attempts

Try it out yourself: http://pex4fun.com

- In 2010, Smartphones outsold PCs
- Today's Smartphones more powerful than PC from 200
- But cannot be programmed …

*Shouldn't we change that?*

# Touchstudio

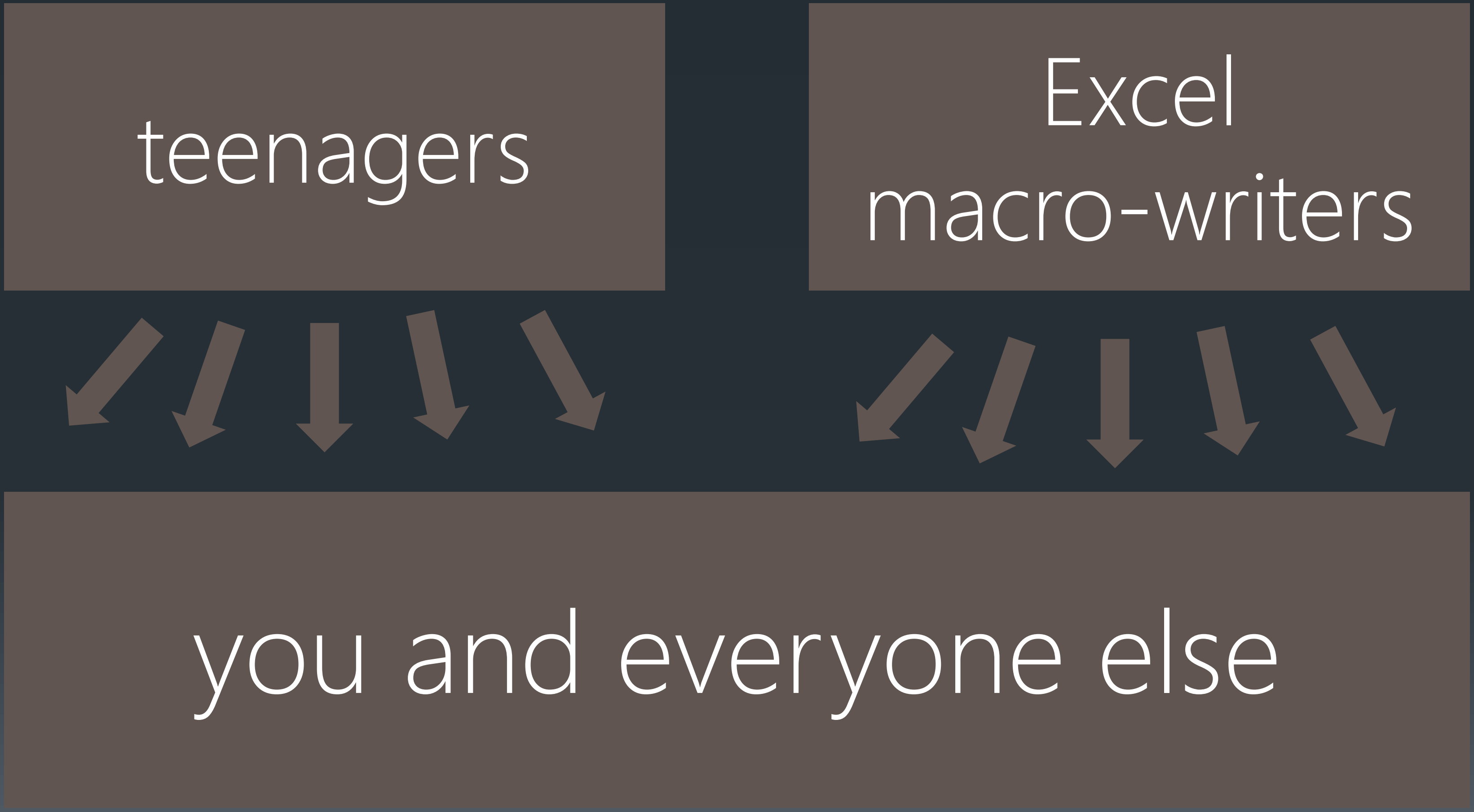


- Social experience of creating little apps
- On the phone for the phone and in the cloud

Examples:

- print “Hello world” should go to facebook
- set ring-tone based on GPS location
- filter twitter messages
- build your own media search

# Users



teenagers

Excel macro-writers

you and everyone else

# What’s needed?

Programming on the phone

- authoring, debugging, running

Easy access to sensors/services/apps

- discoverable, minimal amount of code

Social aspects

- share programs and their data with your friends

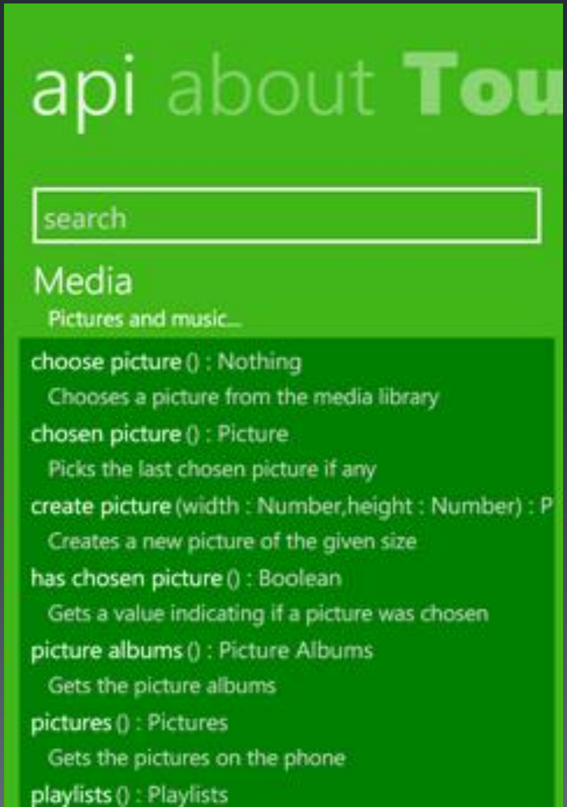
Cloud integration

- sharing state, split computation, privacy, security

# Program Model

Program is a set of event-triggered, sequentially executed actions

Async calls lead to automatic tomb-stoning and continuation


api about Tou

search

Media

Pictures and music…

choose picture () : Nothing
Chooses a picture from the media library

chosen picture () : Picture
Picks the last chosen picture if any

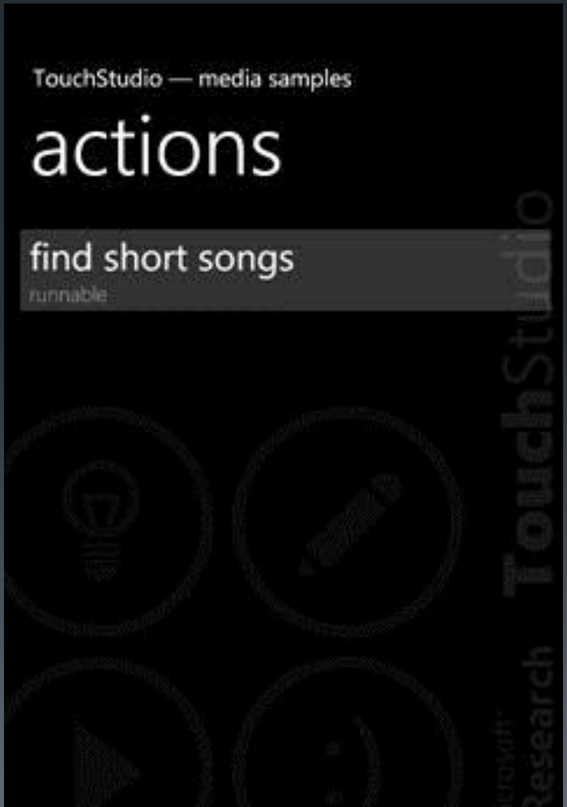
create picture (width : Number,height : Number) : P
Creates a new picture of the given size

has chosen picture () : Boolean
Gets a value indicating if a picture was chosen

picture albums () : Picture Albums
Gets the picture albums

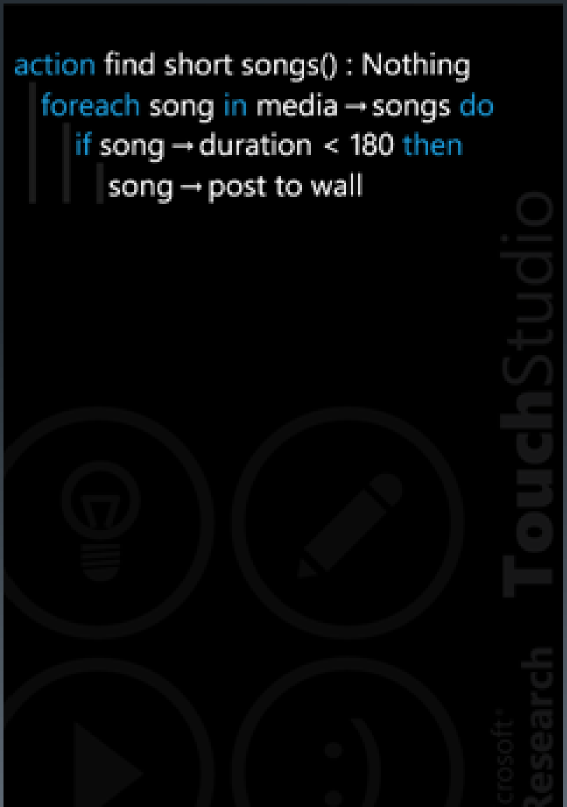
pictures () : Pictures
Gets the pictures on the phone

playlists () : Playlists


TouchStudio — media samples

actions

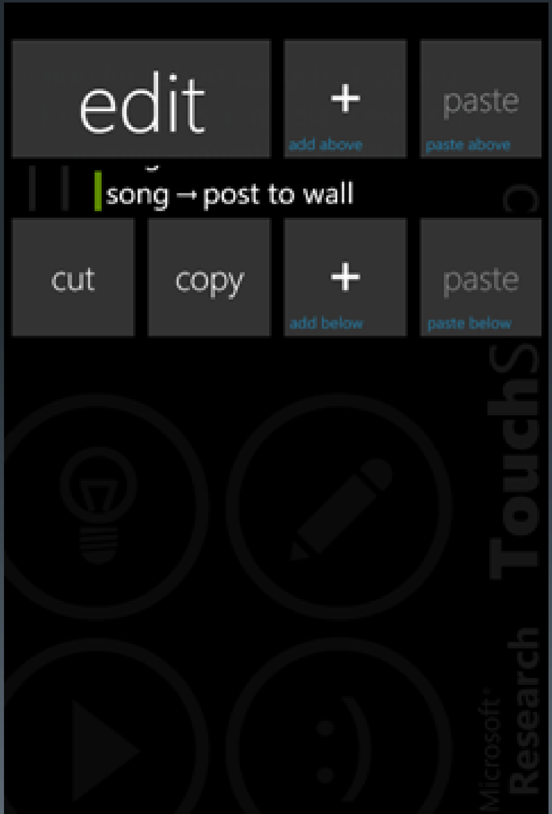
find short songs
runnable


```
action find short songs() : Nothing
  foreach song in media → songs do
    if song → duration < 180 then
      song → post to wall
```

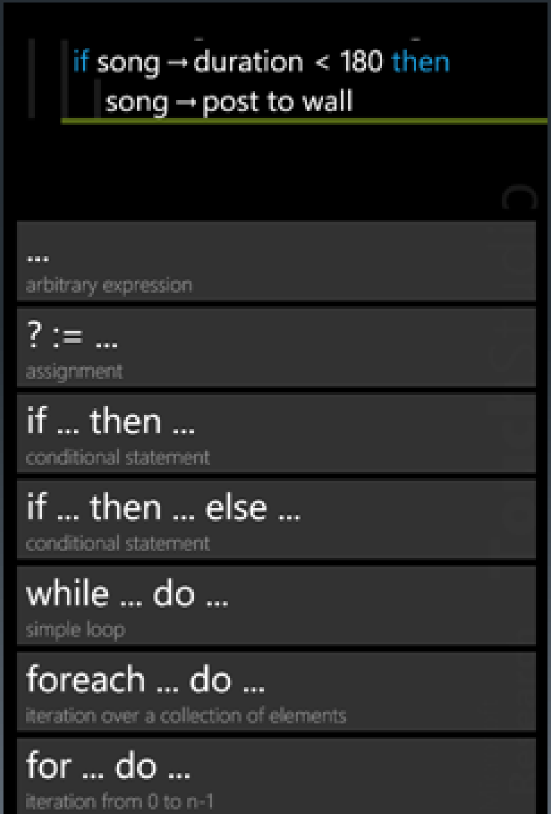
# Programming Environment

Semi-structured editing + calculator using touch

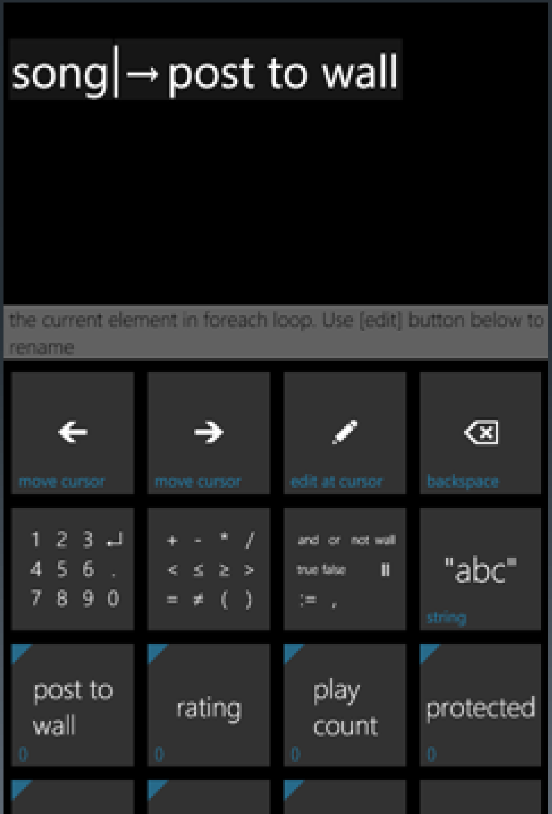
Programs on the phone; possibly shared as pictures with friends



```
song → post to wall
```



```
if song → duration < 180 then
  song → post to wall
```

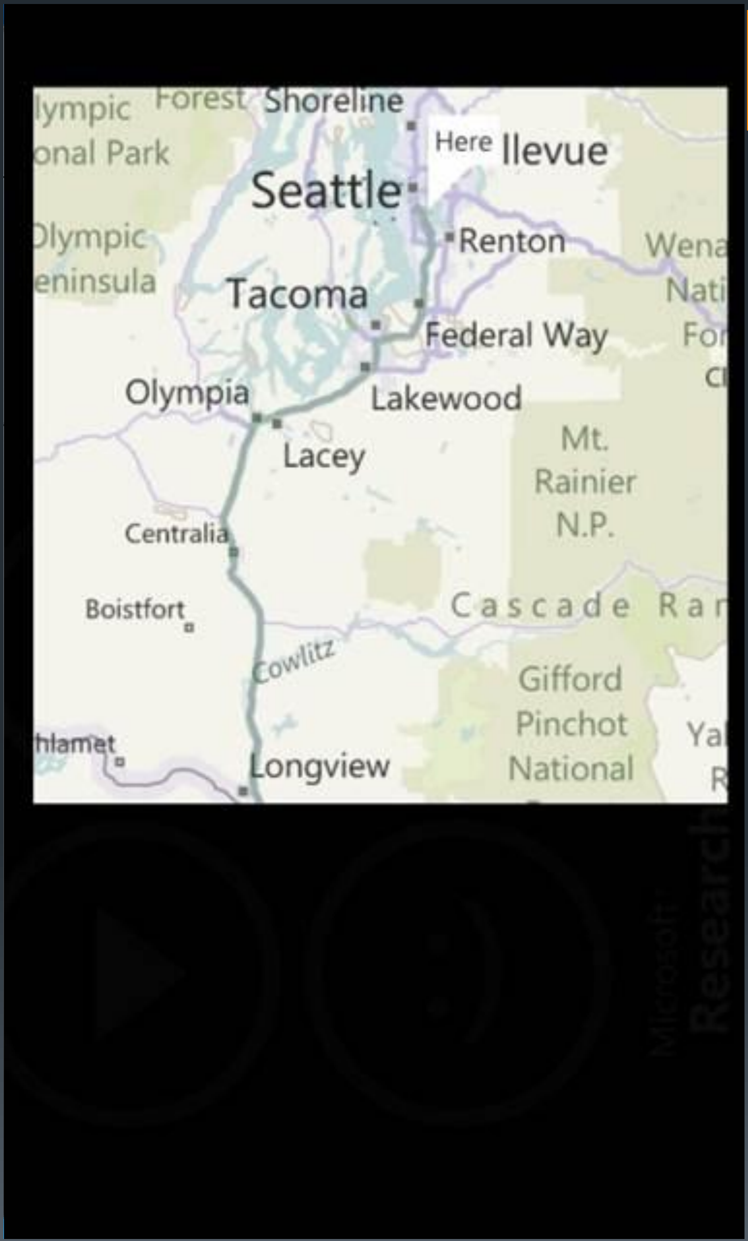


```
song|→ post to wall
```

the current element in foreach loop. Use [edit] button below to rename

# Just for fun….

- Start location feature
- Create a bing map
- Get the current location
- Add a (‘here’) pushpin
- Geocode ‘portland, usa’
- Add a (‘to’) pushpin
- Calc. a route between the 2 points
- Display it on the map (green line)
- Take a screenshot,
- Save it to the library



# Touchstudio Conclusion

Take programming on the Phone + Cloud

With TouchStudio research opportunities abound

- Dev.Environment: on the phone authoring/debugging/running
- Programming model: easy access to sensors/services/apps
- Cloud integration: sharing of programs & data, security, privacy
- Energy efficiency: on the phone/cloud, tier splitting

Try it out yourself: Windows Phone MarketStore

http://research.microsoft.com/Touchstudio

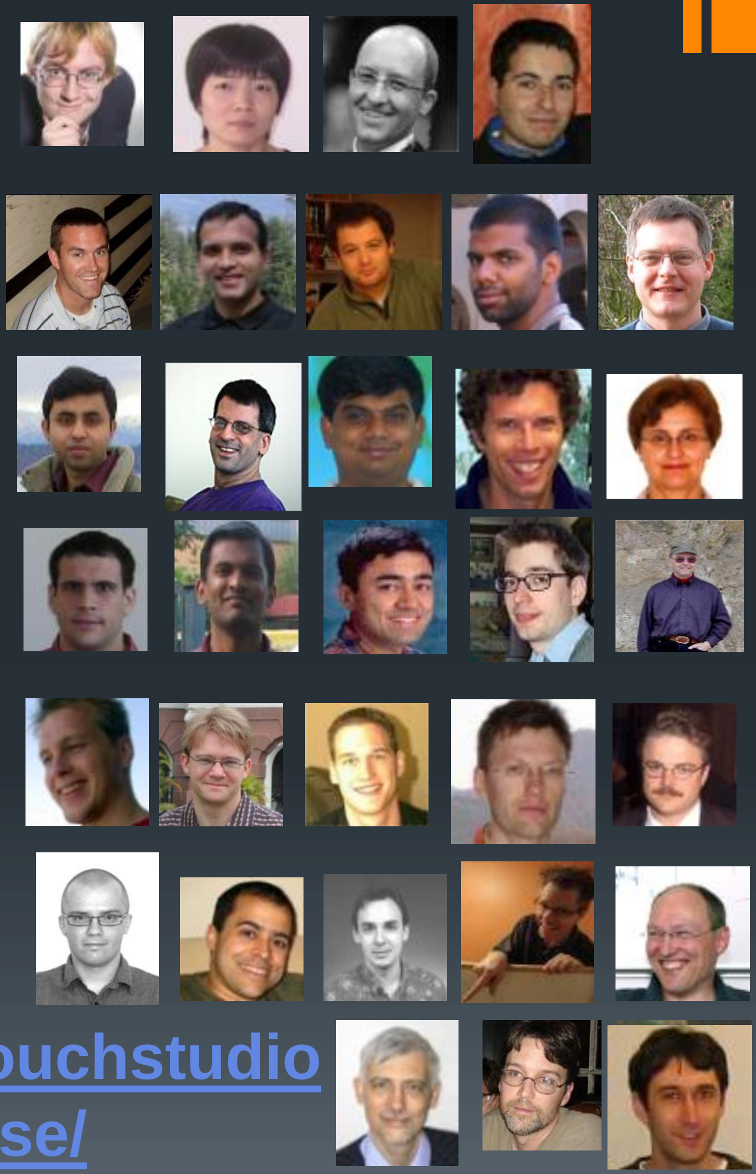
# Summary: Future of Software Engineering

Software Analytics enables data-driven decision, i.e.
which process, practice, tool to use and
deploy under which context

Logic based tools help develop better software artifacts,i.e.
help model, analyze, optimize, and
synthesize software artifacts

Future platforms excite and pose new challenges, e.g.
web, mobile devices (phone, tablet),
datacenter, games

# Q & A



schulte@microsoft.com

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http://www.pex4fun.com
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http://research.microsoft.com/rise/
http://research.microsoft.com/~schulte/