Improving Software Development through Human-Centered Approaches

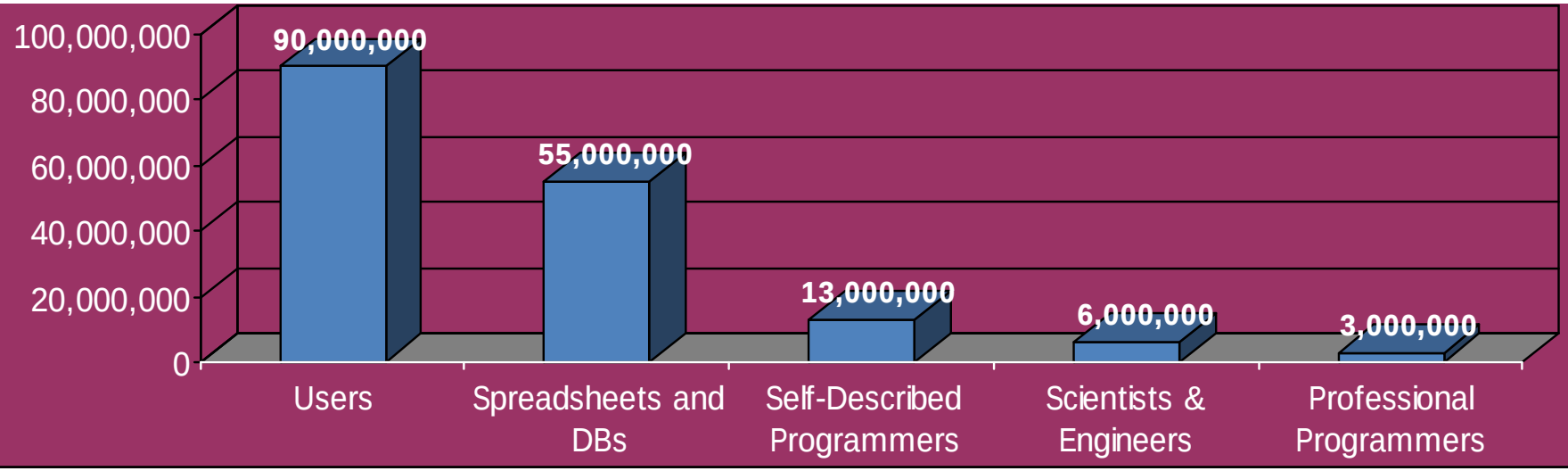
Brad A. Myers
Human-Computer Interaction Institute
School of Computer Science
Carnegie Mellon University
http://www.cs.cmu.edu/~bam
bam@cs.cmu.edu

Natural Programming Project

- Researching better tools for programmers since 1978
- Natural Programming project started in 1995
- Make programming easier and more correct by making it more *natural*
  - Closer to the way that people think about algorithms and solving their tasks
- Methodology – human-centered approach
  - Perform *studies* to inform design
    - Provide new knowledge about what people do and think, & barriers
  - Guide the designs from the data
    - Design of programming *languages* and *environments*
  - Iteratively evaluate and improve the tools
- Target novice, expert and end-user programmers

End User Programming

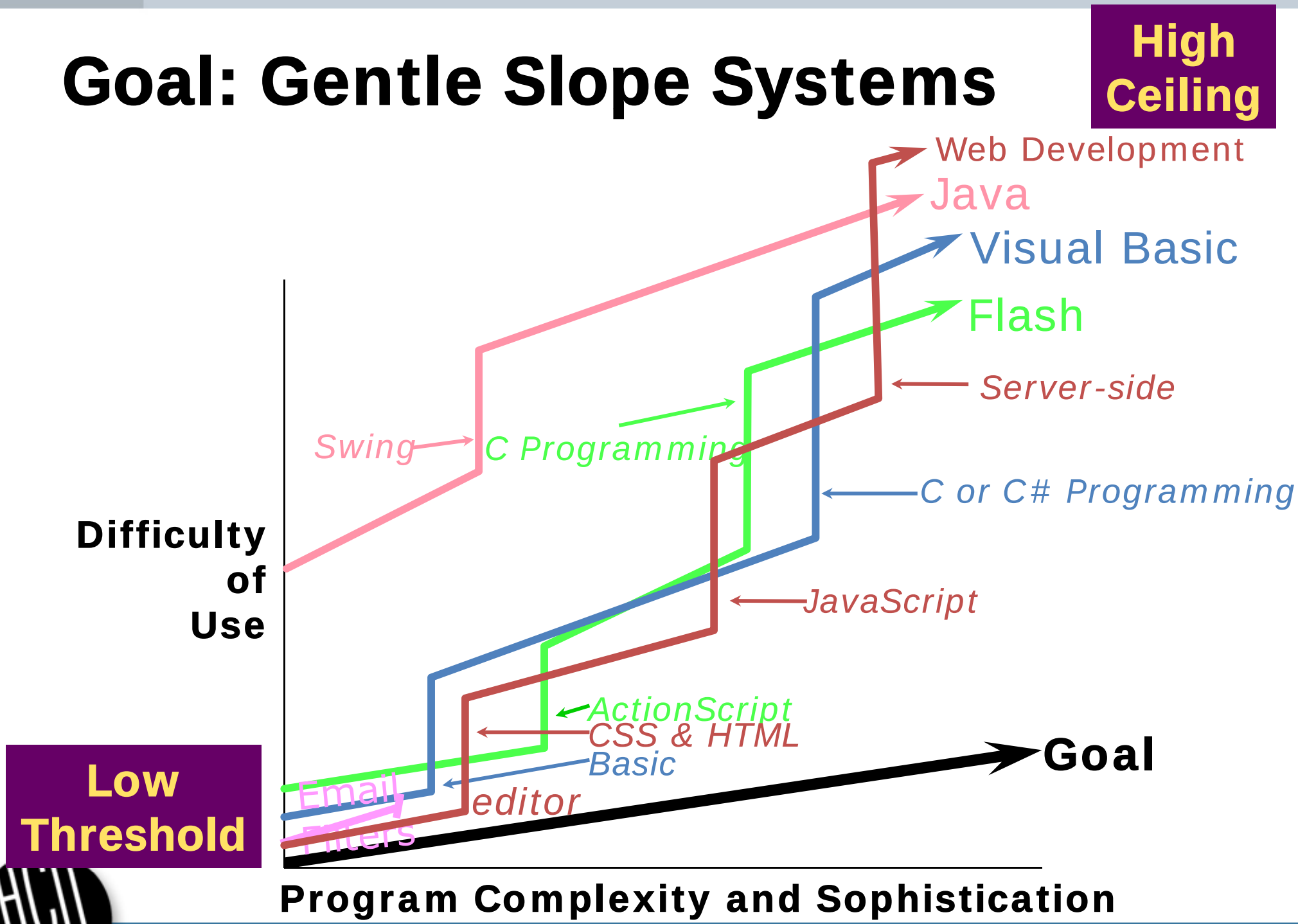
- People whose primary job is *not* programming
- In 2012, in USA at work: — *Scaffidi, Shaw and Myers 2005*
  - 3 million professional programmers
  - 6 million scientists & engineers
  - 13 million will describe themselves as programmers
  - 55 million will use spreadsheets or databases at work (and therefore may potentially program)
  - 90 million computer users at work in US
- We should make better tools for all of these people!



Debugging

- Study commissioned by NIST USA (2002) of 14 software vendors
  - Software errors cost ~$60 billion annually
  - Software engineers spend 70-80% of time testing and debugging
  - Time for 1 developer to fix 1 bug was ~17.4 hours
- Current debugging techniques *same as for last 70 years*
  - Same for end-user and professional environments

Goal: Gentle Slope Systems



Improve Developer Experience

- Use human centered approaches to:
  - Make developers *more effective*
  - *Reduce errors* in resulting code
  - Insure that developer tools are *useful*
  - Understand developers' *barriers* that cause *wasted time*
  - Direct efforts at *most important* issues
- Address: programming languages, APIs, tools, documentation & resources

Why Would Being Natural be Good?

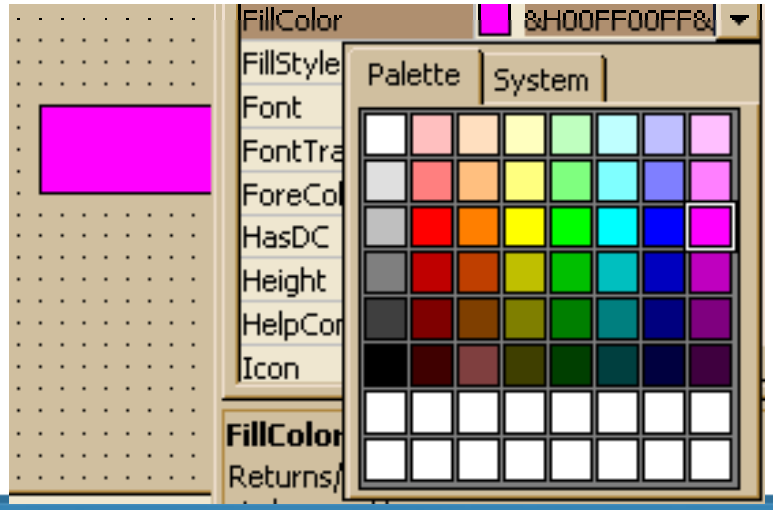
- Programmers are People Too
  - Take the human into account
- Language should be close to user's plan
  - "Programming is the process of transforming a mental plan into one that is compatible with the computer."
    — *Jean-Michel Hoc*
- *Closeness of mapping*
  - "The closer the programming world is to the problem world, the easier the problem-solving ought to be.... Conventional textual languages are a long way from that goal." — *Green and Petre*
- Depends on target population
  - Need studies

Not so Natural!

```
class HelloWorldApp {
      public static void main(String[] args) {
            System.out.println("Hello World!");
      }
}
```

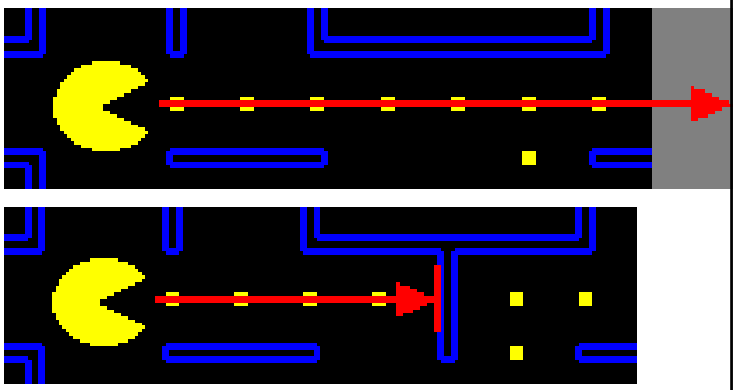
- 3 kinds of parentheses and 9 special words!
- Compared to click and type: “Hello World!”

```
Let Shape1.FillColor
  = &H00FF00FF&
```



First Natural Programming Studies

- John Pane, PhD 2002
- Studies:
  - How people *naturally* express programming concepts and algorithms
    1) Nine scenes from PacMan
    2) Transforming and calculating data in a spreadsheet



  - Specific issue of language design
    3) Selecting specific objects from a group (“and”, “or”, “not”)
  - Lots of interesting results

Examples of Results

- Rule-based style

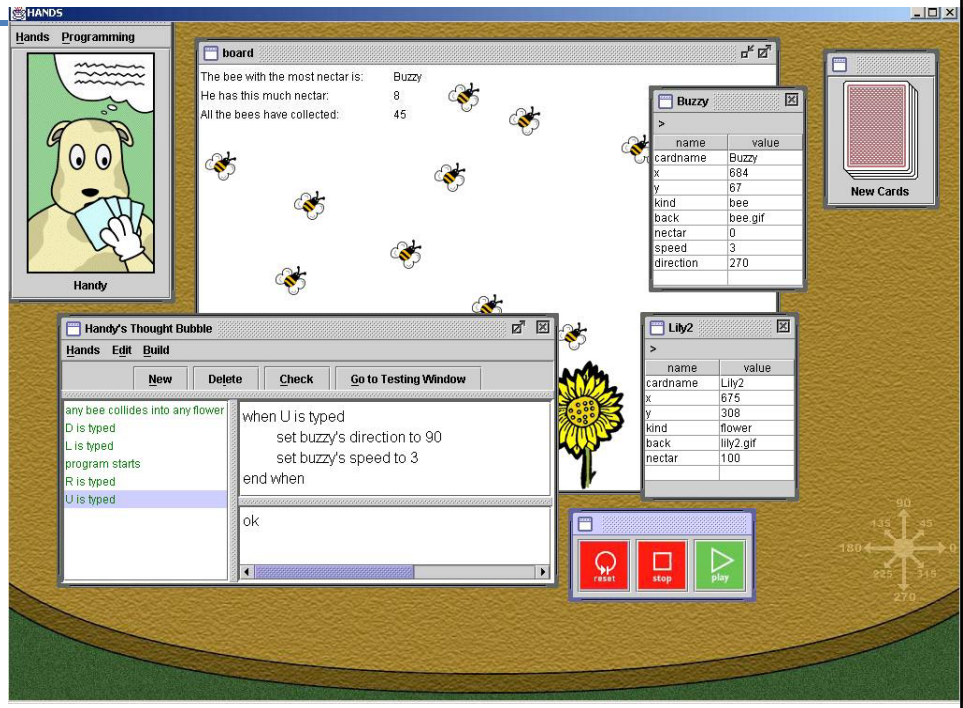
  "If PacMan loses all his lives, its game over."

- "And", "Or", "Not" don't match computer interpretation
  - ... men *and* women, ...(*not* an apple)or pear
- Operations suggest data as lists, not arrays
  - People don't make space before inserting
- Objects normally moving

  "If PacMan hits a wall, he stops."

  - so objects remember their own state

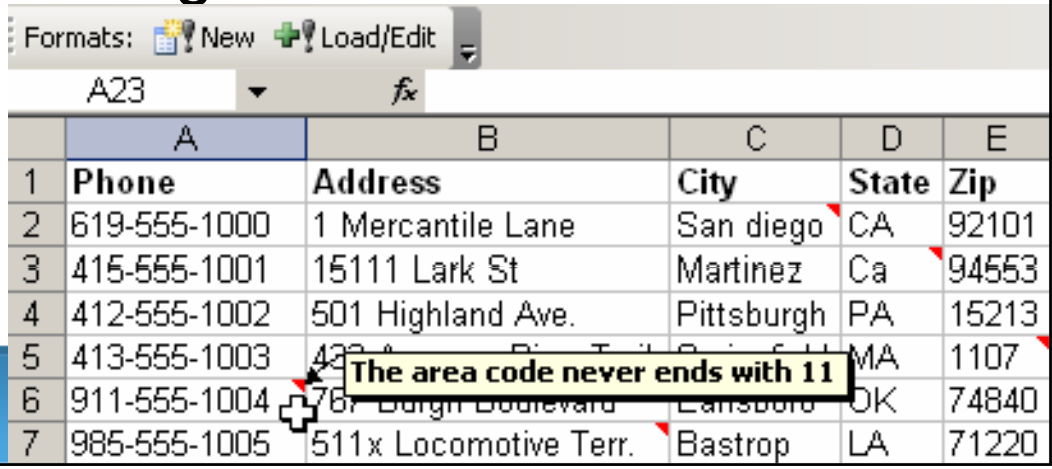
New Language and System: HANDS



- John Pane, PhD 2002
- Properties:
  - Metaphor of agent (Handy the dog) operating on cards
  - All operations can operate on single items or sets of items
  - Integrated queries with language
  - Sets can be dynamically constructed and used
    - "Set the speed of all bees to 0"
- See the video: http://web.cs.cmu.edu/~pane/HANDS/HANDS.MPG

Supporting “Natural” Data Types

- Chris Scaffidi, PhD 2009
- Ask users about types of data, say “Person name”, “age”, “date”, “Project code”, ...
- User-centered type system called “topes”
  - Structured
  - Constraints on the values and parts
    - May be “always” or “usually” true
      - “USA phone area code never ends in 11”
      - “USA Last names usually start with a capital letter”
- Library for verifying & transforming values
  - Can be used from JavaScript for web and from VB for Excel
- Editor for specifying



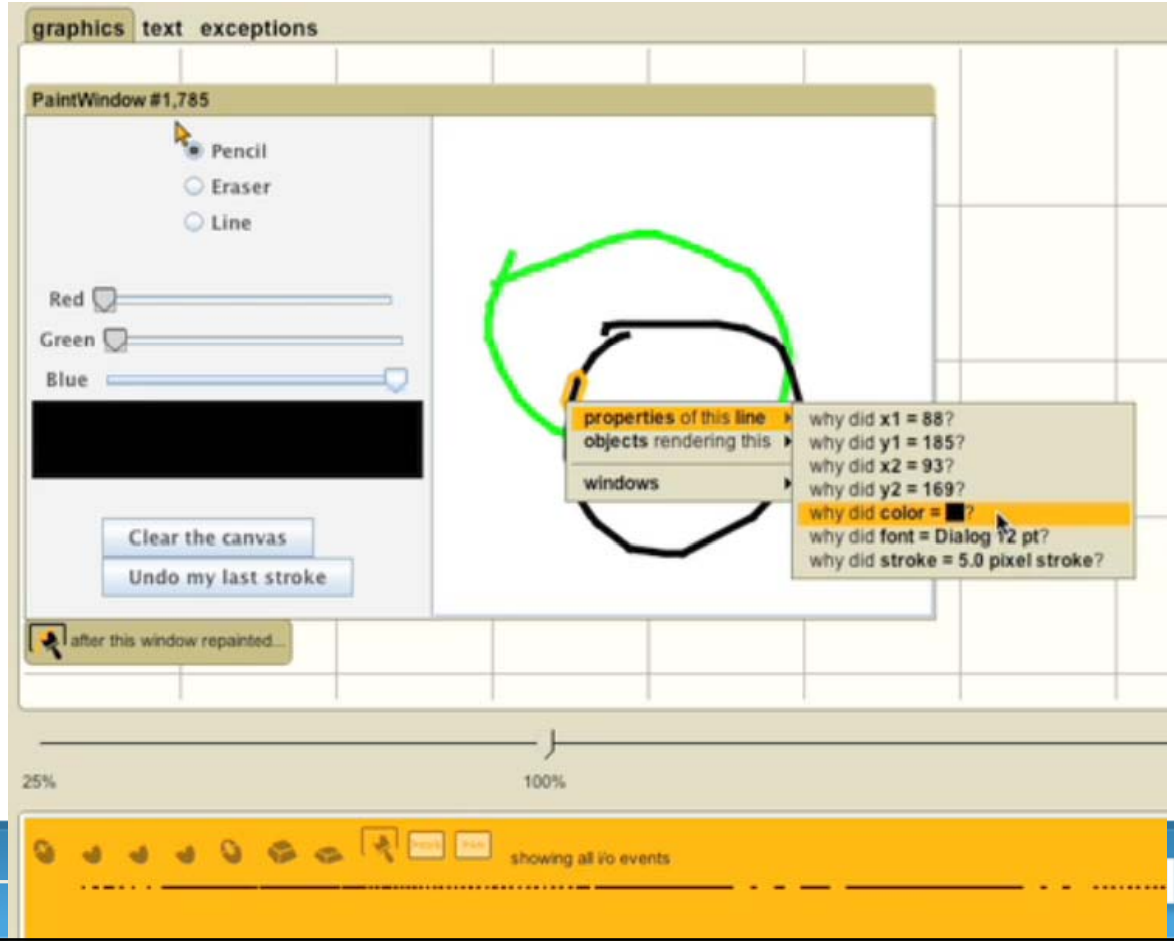
	A	B	C	D	E
1	Phone	Address	City	State	Zip
2	619-555-1000	1 Mercantile Lane	San diego	CA	92101
3	415-555-1001	15111 Lark St	Martinez	Ca	94553
4	412-555-1002	501 Highland Ave.	Pittsburgh	PA	15213
5	413-555-1003	[illegible]	[illegible]	MA	1107
6	911-555-1004	[illegible]	[illegible]	OK	74840
7	985-555-1005	511x Locomotive Terr.	Bastrop	LA	71220

Study of Errors

- Study of novice errors and debugging
  - Created a new model of barriers & kinds of errors
  - All of the observed debugging problems could be addressed by "Why" questions
    - 32% were "Why did"; 68% were "Why didn't"
- Current debugging techniques require user to *guess* where bug is or where to look
  - Most of initial guesses are *wrong*, even for experts

Whyline

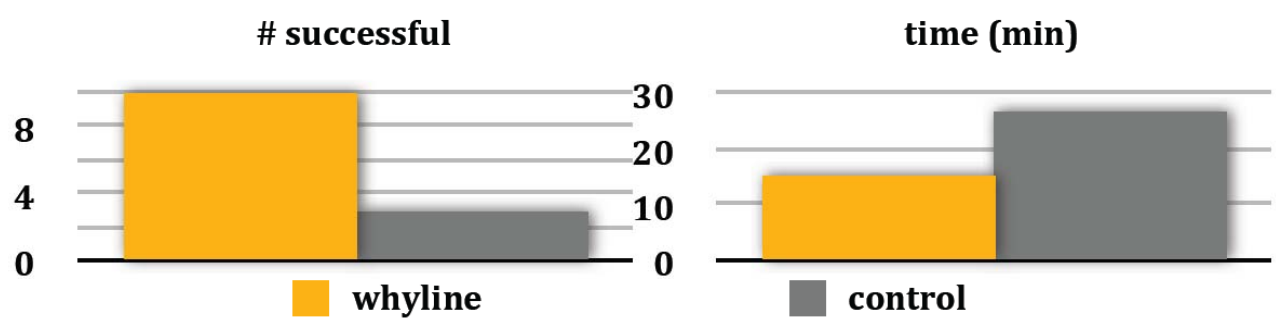
- Andy Ko, PhD 2008
- Allow users to directly ask “Why” and “Why not”



1:27

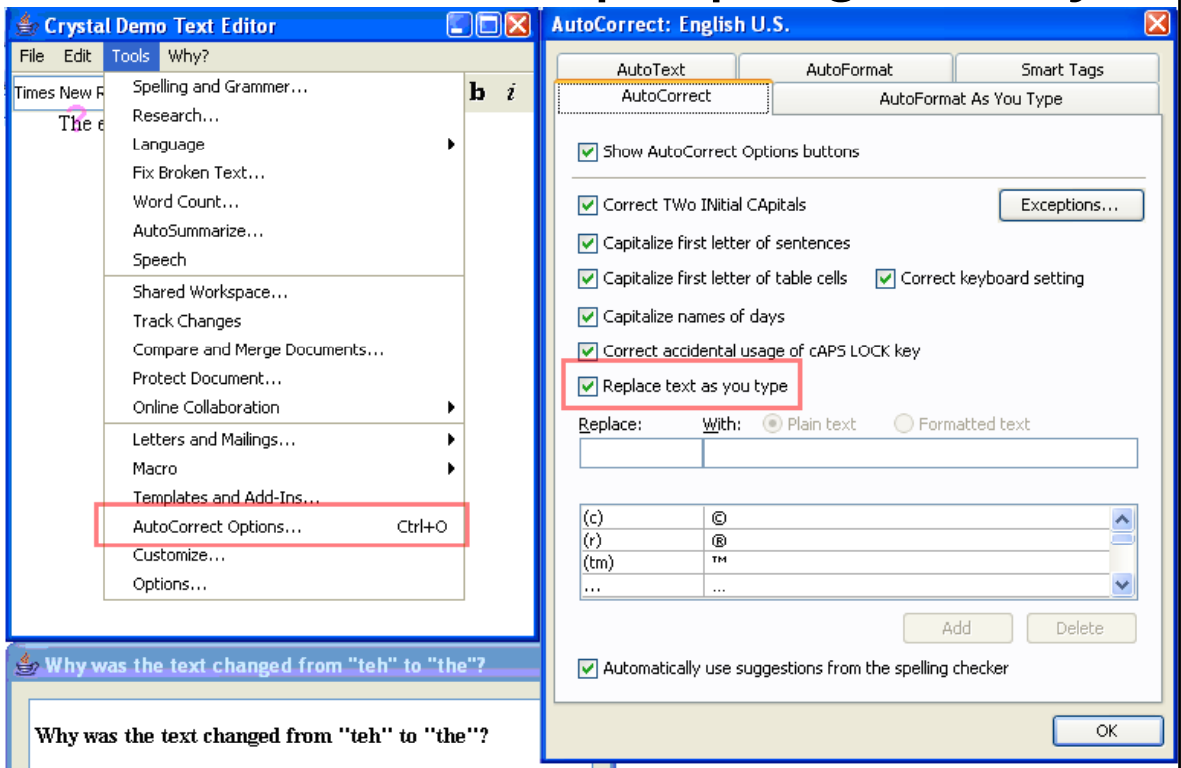
Whyline User Studies

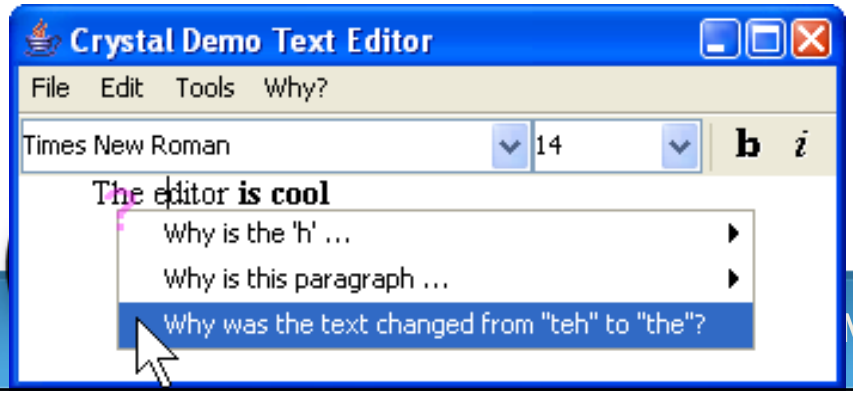
- Initial study:
  - Whyline with novices outperformed experts with Eclipse
  - Factor of 2.5 times faster
    - ($p < .05$, Wilcoxon rank sums test)
- Formal study:
  - Experts attempting 2 difficult tasks
  - Whyline over 3 times as successful, in ½ of the time



Crystal

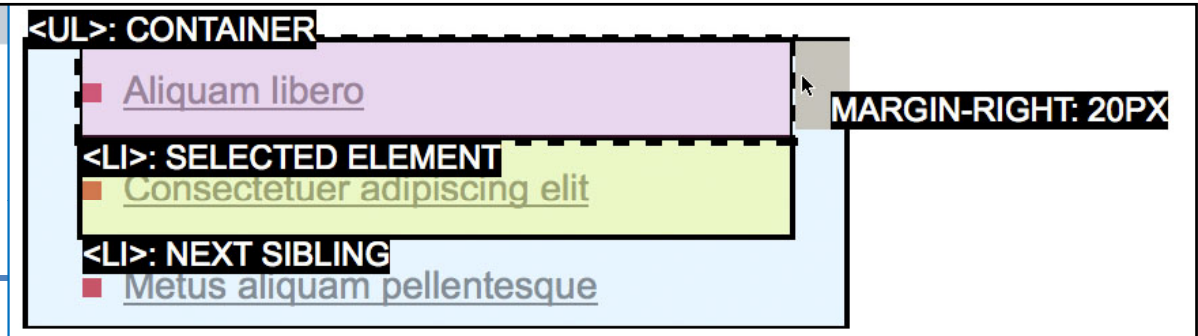
- Crystal: Clarifications Regarding Your Software using a Toolkit, Architecture and Language
- Apply WhyLine idea to regular desktop applications (Word 2003)
- Lots of complexity in powerful features that people generally like
- Ask "Why" about what recently happened
- Architecture: supports adding to application with small overhead

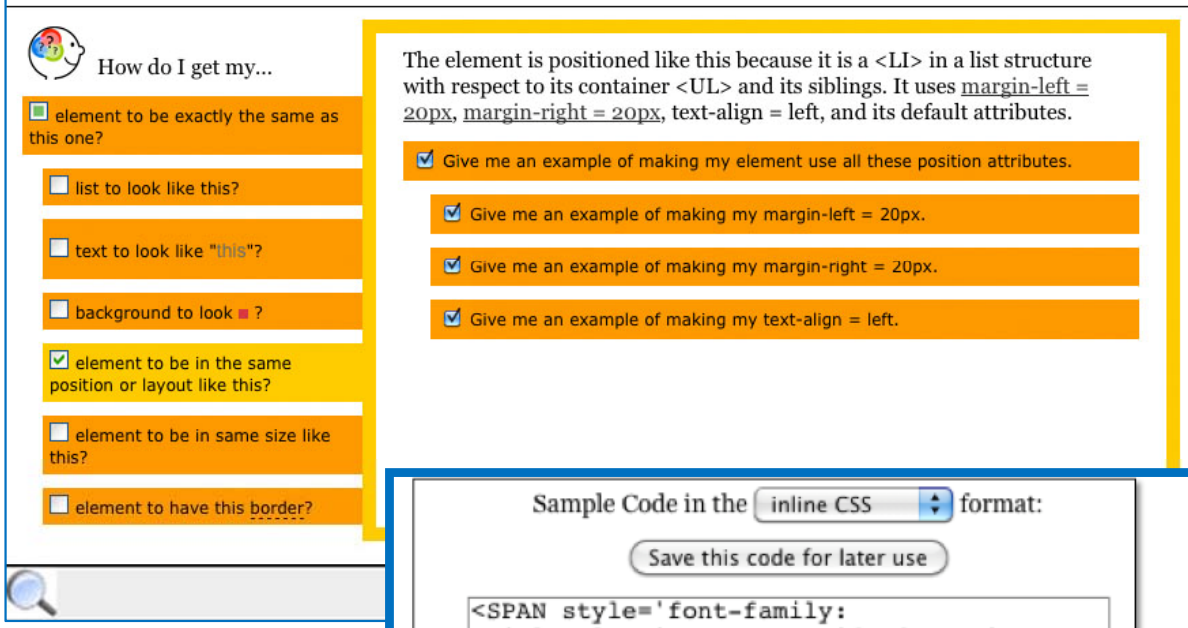


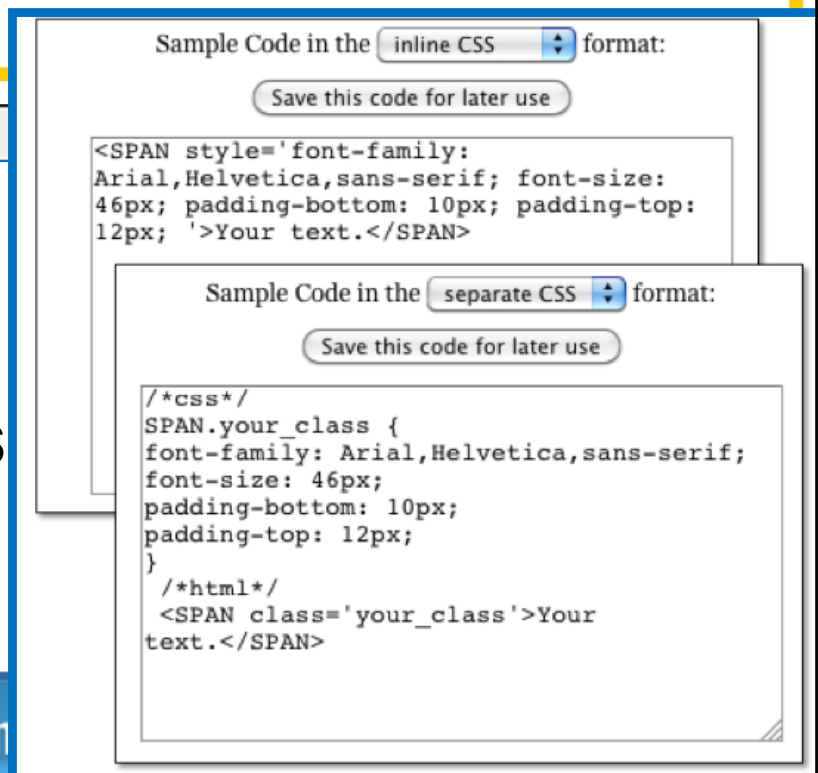


WebCrystal

- Investigate CSS and HTML responsible for example behaviors
- Navigate around HTML hierarchy
- Ask “how-do-I” questions about look, position and behavior
- Generates code in user-selected format
- Combine code for multiple elements
- *CHI’2012*







Study of Design Requirements for Maintenance-Oriented IDEs

- Studied expert use of Java Eclipse IDE in a lab setting (2004-2006)
- Focus on day-to-day maintenance tasks such as bug repairs and feature enhancements
- Lab study with detailed analysis
- Rich dataset → multiple papers

A Programmer's Working Set

- A collection of task-relevant code fragments
- In modern software development, dependencies are distributed and non-local

Times for Bottlenecks

- Each instance of an interactive bottleneck cost only a few seconds, but . . .

Interactive Bottleneck	Overall Cost
Navigating to fragment in *same* file (*via scrolling*)	~ 11 minutes
Navigating to fragment in *different* file (*via tabs and explorer*)	~ 7 minutes
Recovering working set after returning to a task	~ 1 minute
Total Costs	~19 minutes

= 35% of uninterrupted work time!

Jasper: Working Set Tool

- Jasper = Java Aid with Sets of Pertinent Elements for Recall
- Allow programmers to grab arbitrary fragments of code to represent working sets
  - Allow programmers to view in one place, one screen

*Add thickness slider

JSlider (Java 2 Platform SE v1.4.2)

value equal to the average of the min plus max.

```
JSlider(int min, int max, int value)
```

Creates a horizontal slider using the specified min, max and value.

PaintWindow.java

```
private PaintObjectConstructor objectConstructor;
```

PaintWindow.java#PaintWindow

```
colorPanel = new JPanel();
colorPanel.setOpaque(false);
colorPanel.setLayout(new BoxLayout(colorPanel, BoxLayout.Y_AXIS));
colorPanel.add(rPanel);
colorPanel.add(gPanel);
colorPanel.add(bPanel);
currentColorComponent.setPreferredSize(new Dimension(100, 50));
```

EraserPaint.java

```
public void setThickness(int thickness) {

    this.thickness = 25;
```

PaintWindow.java#PaintWindow

```
objectConstructor = new PaintObjectConstructor(this);
objectConstructor.setClass(PencilPaint.class);
objectConstructor.setColor(new Color(0, 255, 0));
objectConstructor.setThickness(5);
canvas.addMouseListener(objectConstructor);
canvas.addMouseMotionListener(objectConstructor);
```

PaintObjectConstructor.java

```
public class PaintObjectConstructor implements MouseListener, MouseMotionListener {
```

PaintWindow.java

```
private JSlider rSlider, bSlider, gSlider;
```

PaintWindow.java

```
public void paintComponent(Graphics g) {

    Color oldColor = g.getColor();
    g.setColor(objectConstructor.getColor());
    g.fillRect(0, 0, getWidth(), getHeight());
    g.setColor(oldColor);
```

PaintWindow.java#PaintWindow

```
addWindowListener(new WindowAdapter() {
    public void windowClosing(WindowEvent event) {
        System.exit(0);
    }
});
```

Study of APIs

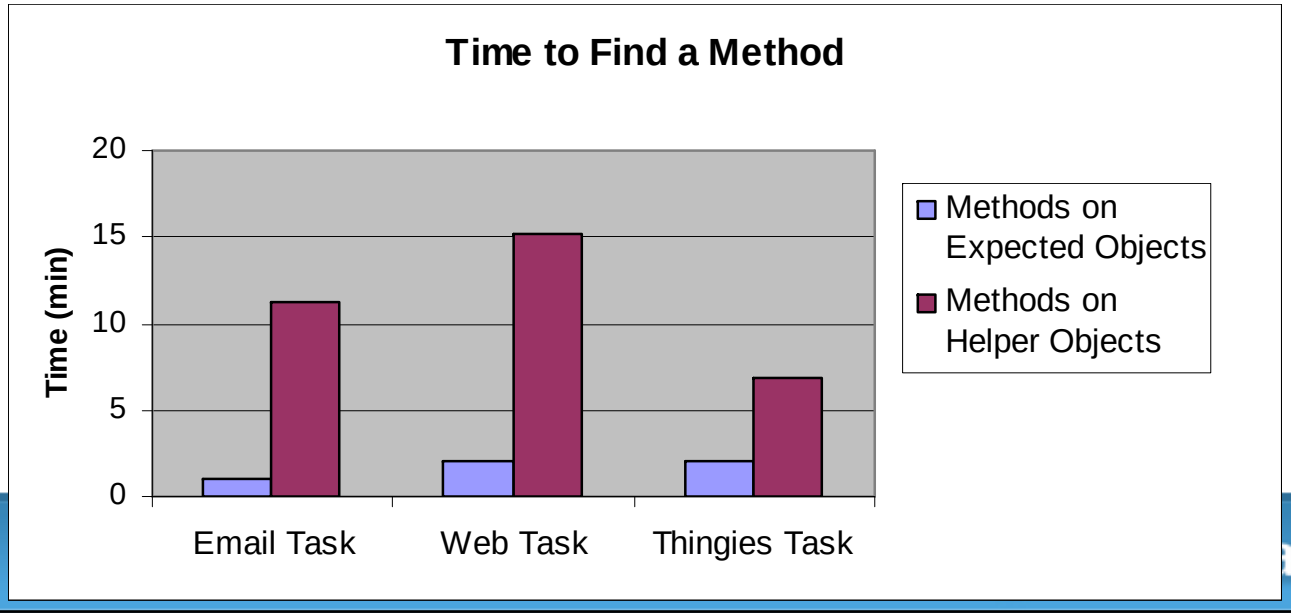
- Started as PhD work of Jeff Stylos, 2009
  - Inspired by Steven Clarke, Microsoft Visual Studio group
- Application Programming Interface
  - Libraries, frameworks, SDKs, ...
- Which programming patterns are most usable?
- Barriers to use of APIs
- Measures: learnability, errors, preferences
- Expert and novice programmers
- Studied:
  - Default parameters in constructors
  - Factory pattern
  - Object design
  - SAP's Web Services APIs

"Factory" Pattern

- Instead of "normal" creation: `Widget w = new Widget();`
- Objects must be created by *another* class:
```
AbstractFactory f =  AbstractFactory.getDefault();
Widget w = f.createWidget();
```
- Used frequently in Java (>61) and .Net (>13) and SAP
- Results:
  - When asked to design on "blank paper", no one designed a factory
  - Time to develop using factories took 2.1 to 5.3 times longer compared to regular constructors (20:05 v 9:31, 7:10 v 1:20)
  - All subjects had difficulties getting using factories in APIs

Object Method Placement

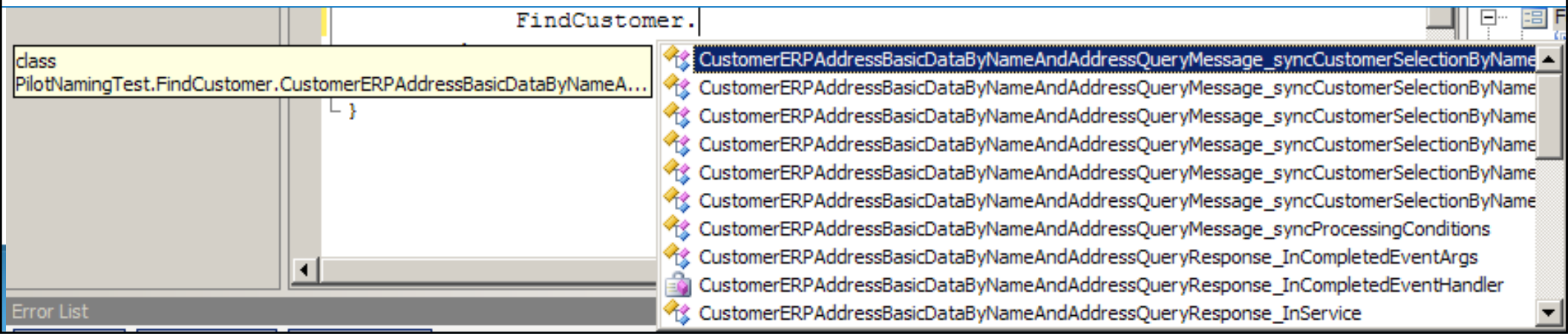
- Where to put functions when doing object-oriented design of APIs when multiple classes work together
  - `mail_Server.send( mail_Message )`
    vs.
    `mail_Message.send( mail_Server  )`
- When desired method is on the class that they start with, users were between 2.4 and 11.2 times faster *($p < 0.05$)*
- Starting class can be predicted based on user's tasks



Study of APIs for SAP

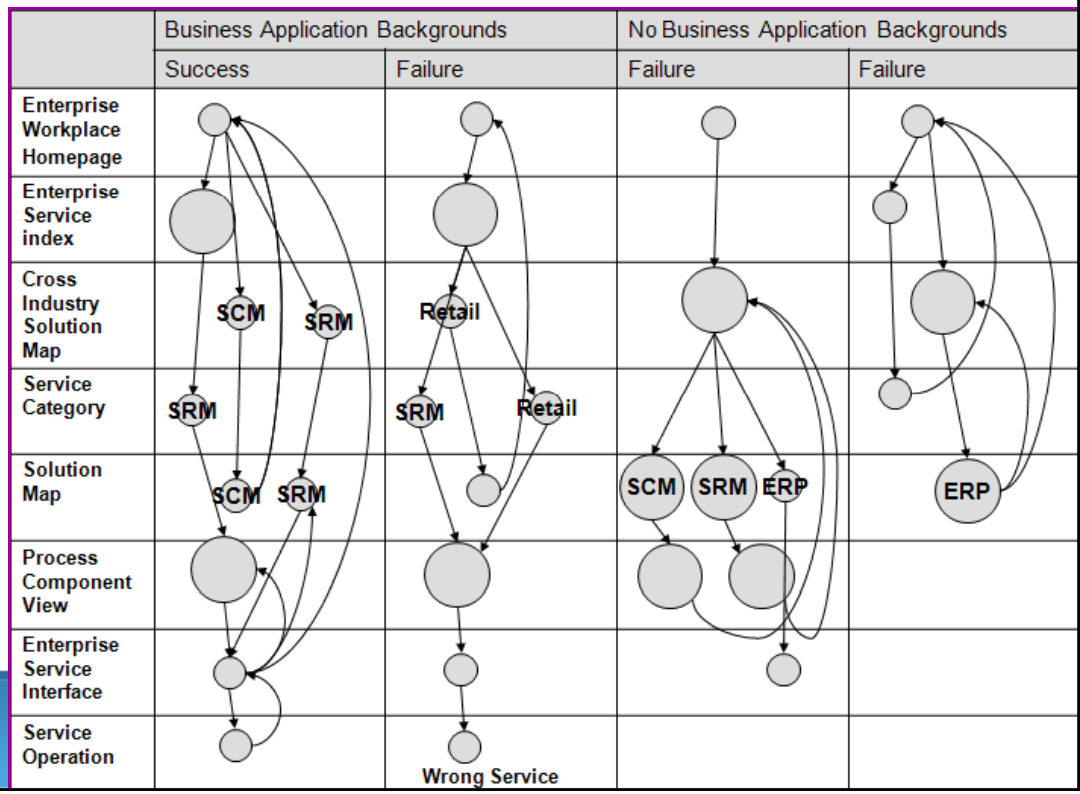
- Study APIs for Enterprise Service-Oriented Architectures (“Web Services”)
- Naming problems:
  - Too long
  - Not understandable
  - Differences in *middle* are frequently missed

CustomerAddressBasicDataByNameAndAddressRequestMessageCustomerSelectionCommonName
CustomerAddressBasicDataByNameAndAddressResponseMessageCustomerSelectionCommonName



eSOA Documentation Results

- Multiple paths: unclear which one to use
- Some paths were dead ends
- Inconsistent look and feel caused immediate abandonment of paths
- Hard to find required information
- Business background helped



SAP's NetWeaver® Gateway Developer Tools

- Plug-in to Visual Studio 2010 for developing SAP applications
- We used the HCI methods of *heuristic evaluation* and *cognitive walkthroughs* to evaluate early prototypes
- Our recommendations were quickly incorporated due to agile software development process

Our Tools to Help with APIs

- Mica 
- Jadeite 
- Calcite 
- Euklas 
- Graphite 
- Apatite 

Mica Tool to Help Find Examples

- Makes Interfaces Clear and Accessible
- Use Google to find relevant pages
- Match pages with Java keywords
- Also notes which pages contain example code or definitions

Jadeite: Improved JavaDoc

- Jadeite: Java API Documentation with Extra Information Tacked-on for Emphasis
  http://www.cs.cmu.edu/~jadeite
- Fix JavaDoc to help address problems
  - Focus attention on most popular packages and classes using font size
  - "Placeholders" for methods that users want to exist
  - Automatically extracted code examples for how to create classes

Packages
com.sun.mail.dsn
com.sun.mail.handlers
com.sun.mail.iap
com.sun.mail.imap
com.sun.mail.imap.protocol
com.sun.mail.pop3
com.sun.mail.smtp
com.sun.mail.util
javax.mail
javax.mail.event
javax.mail.internet
javax.mail.search
javax.mail.util

abstract void	saveChanges() Save any changes made to this message into the message-store when the containing folder is closed, if the message is contained in a folder.
void	send() Use the Transport.send(message) method to send Messages
protected void	setExpunged(boolean expunged) Sets the expunged flag for this Message.

See Also (auto-generated):
Transport
MimeMessage
InternetAddress

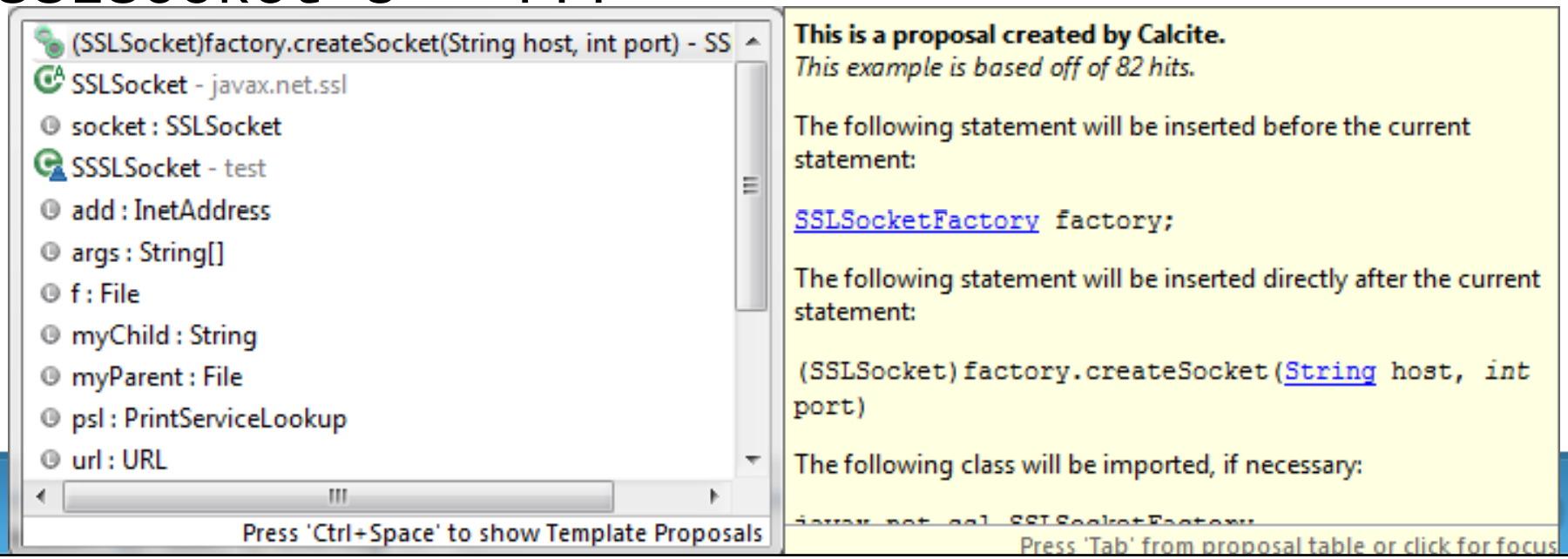
Most common way to construct:

```
SSLSocketFactory factory = …;
String host = …;
int port = …;
SSLSocket socket = (SSLSocket)factory.createSocket(host, port);
```

Based on 38 examples

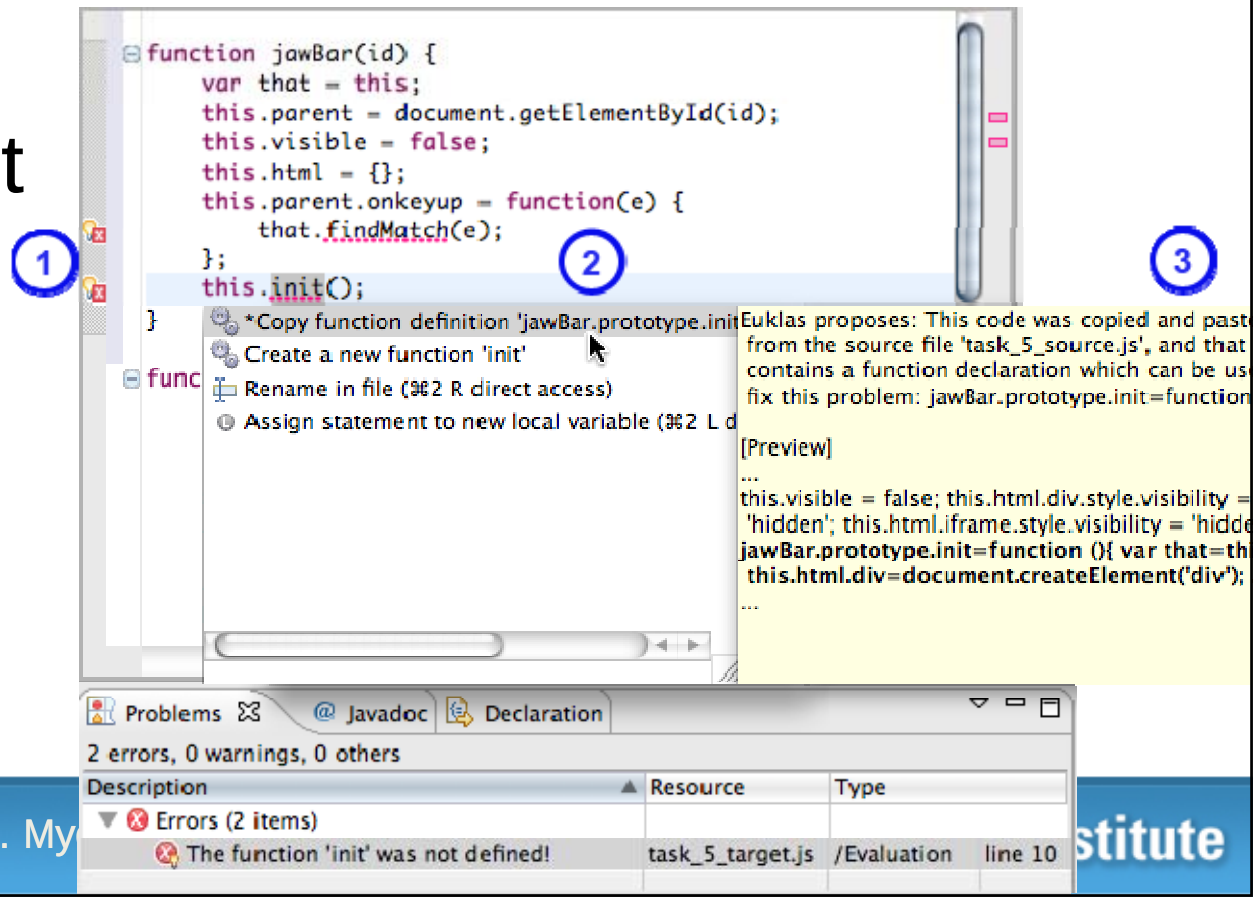
Calcite: Eclipse Plugin for Java

- Calcite: Construction And Language Completion Integrated Throughout
  http://www.cs.cmu.edu/~calcite
- Code completion in Eclipse augmented with Jadeite's information
  - How to create objects of specific classes
    `SSLSocket s = ???`



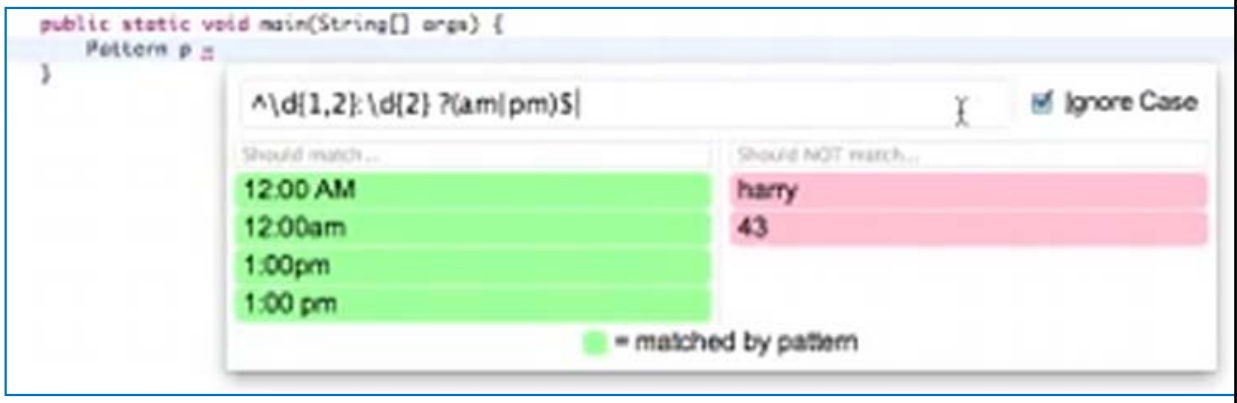
Euklas: Eclipse Plugin for JavaScript

- Euklas: Eclipse Users' Keystrokes Lessened by Attaching from Samples
  http://www.cs.cmu.edu/~euklas
- Brings Java-like analysis to JavaScript
- Auto-correct uses copy source context for errors due to copy & paste

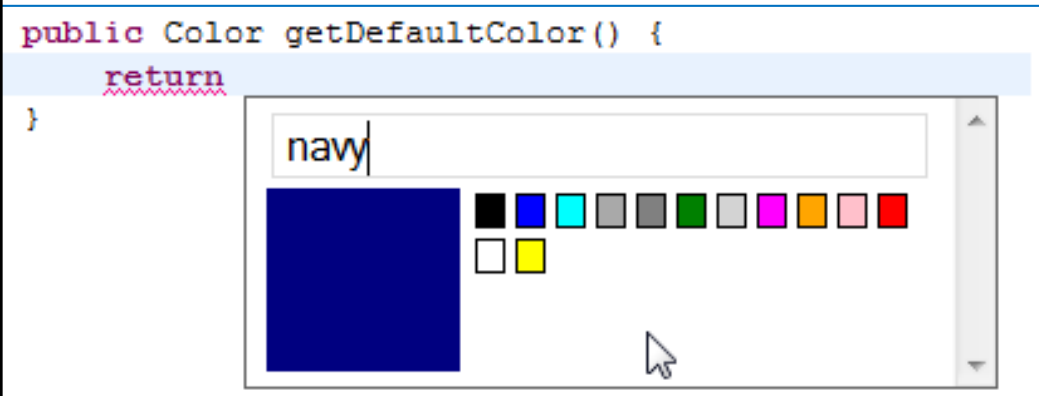


Graphite: Eclipse Plugin for Literals

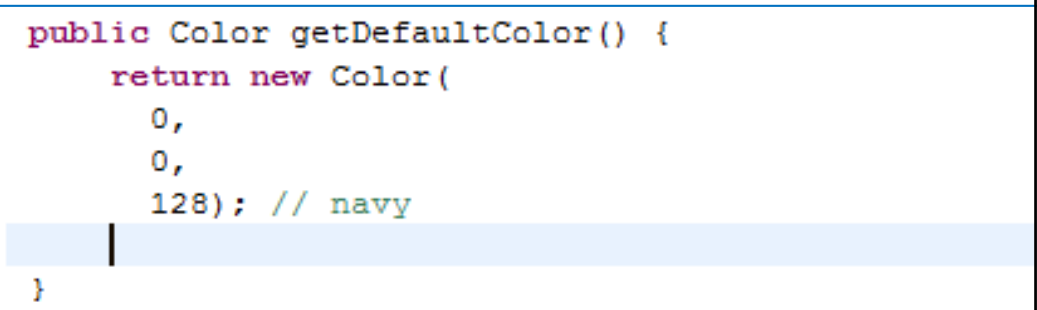
- Graphite: GRAphical Palettes Help Instantiate Types in the Editor.
- Pop up a custom palette for specialized constants (literals) in Eclipse
  - Color palettes
  - Regular expression strings
- Customizable



(ICSE'2012)



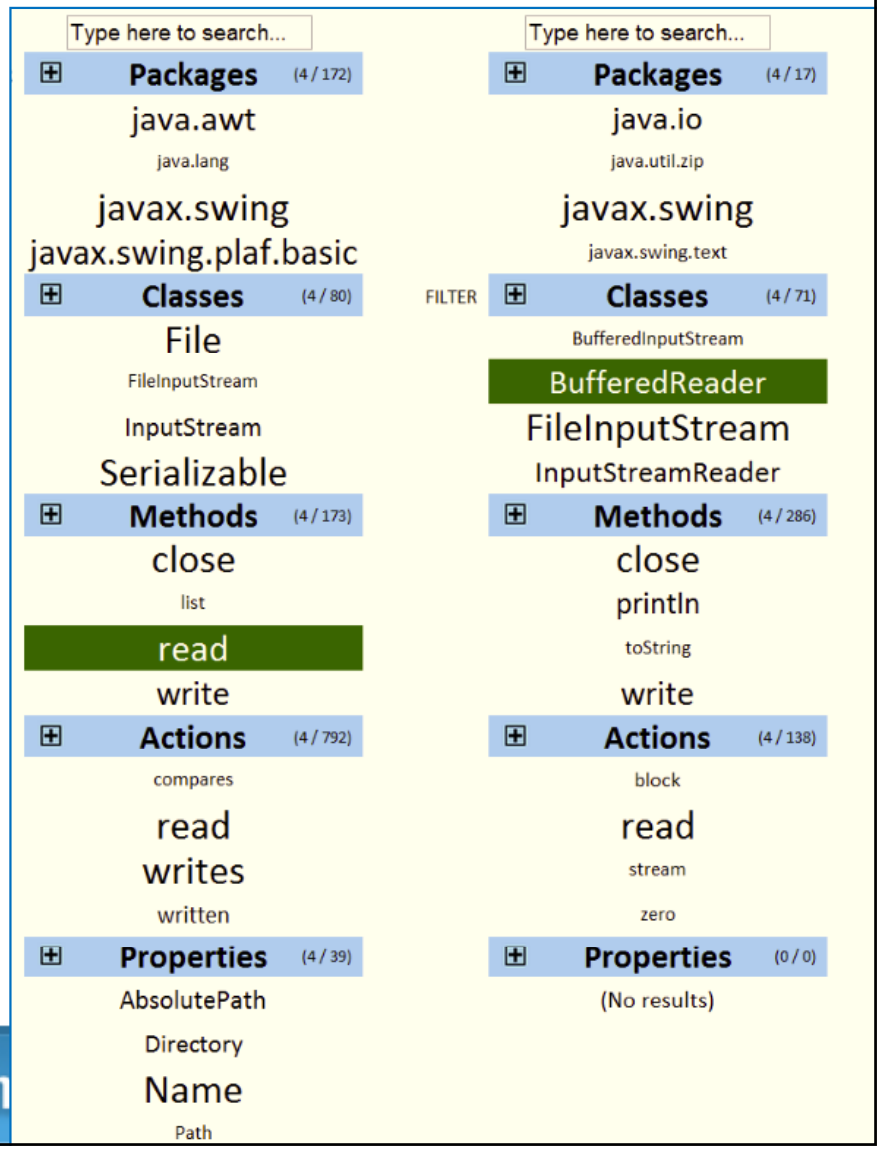
(a)



(b)

Apatite Documentation Tool

- Apatite: Associative Perusing of APIs That Identifies Targets Easily
  http://www.cs.cmu.edu/~apatite
- Start with verbs (actions) and properties and find what classes implement them
- Find associated items
  - E.g., classes that are often used together
  - Classes that implement or are used by a method



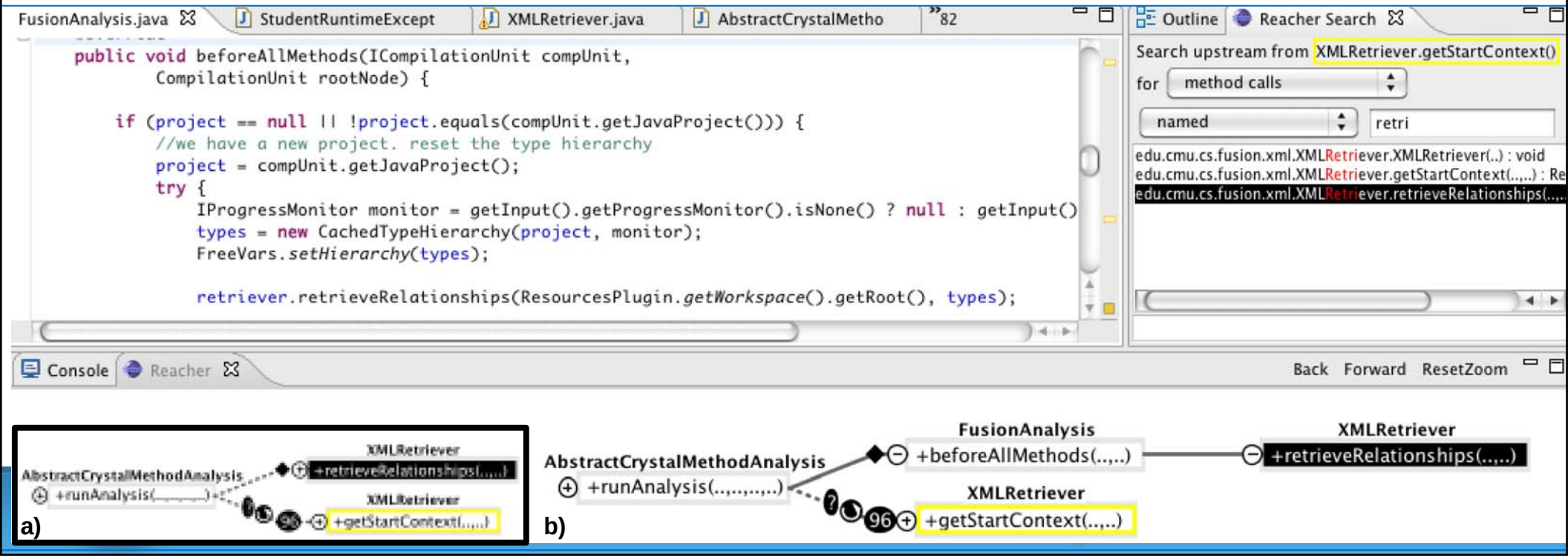
Studies of Code Understanding

- Thomas LaToza, PhD 2012
- Studies about how experts learn unfamiliar code
- Programmers investigate *reachability questions*
  - How can this code *be reached*, either upstream or downstream
  - E.g., control flow from user scrolling → update status line
- Identified over 100 hard-to-answer questions that developers asked
  - E.g., "What method implements this trigger?"
  - "Why was this designed this way?"
- Survey shows such control flow questions are difficult and important
- No easy way to discover with current tools
  - Call graphs are too general

REACHER

- Visualize exactly the paths of interest
- Search along the paths
- Focused questions and answers enable effective analysis of complex codebases
- Developers with Reacher 5.6 times more successful than those working with Eclipse only

0:53



Fluorite Logger

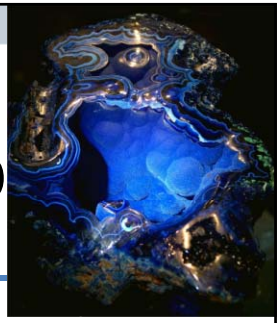
- PhD work of YoungSeok Yoon (in progress)
- Fluorite: Full of Low-level User Operations Recorded In The Editor http://www.cs.cmu.edu/~fluorite
- Logger for *all* keystrokes & events in Eclipse
- Analyzes frequencies and patterns
- Deleting is a high percent of all the keystrokes
- Also surveyed >100 developers

Commands		Keystrokes	
Type char.	17092 (31.8%)	Down arrow	5797 (13.7%)
Line down	5795 (10.8%)	Backspace	5693 (13.5%)
Delete prev.	5692 (10.6%)	Up arrow	4495 (10.6%)
Move caret	4686 (8.7%)	Right arrow	3586 (8.5%)
Line up	4491 (8.4%)	Left arrow	2751 (6.5%)
Col. next	3544 (6.6%)	Shift	1645 (3.9%)
Col. prev.	2715 (5.1%)	Enter	1641 (3.9%)
Select text	1975 (3.7%)	T	1289 (3.1%)
Sel. col. next	1035 (1.9%)	E	1250 (3.0%)
File open	907 (1.7%)	S	1021 (2.4%)
Sel. col. prev.	857 (1.6%)	N	1003 (2.4%)
Save	852 (1.6%)	I	881 (2.1%)
Delete	576 (1.1%)	Space	859 (2.0%)
Paste	459 (0.9%)	A	790 (1.9%)
Assist(auto)	456 (0.8%)	O	750 (1.8%)
Run	391 (0.7%)	L	610 (1.4%)
Copy	314 (0.6%)	Delete	576 (1.4%)
Undo	294 (0.5%)	C	557 (1.3%)
Assist(manual)	213 (0.4%)	.	546 (1.3%)
Sel. line down	212 (0.4%)	R	510 (1.2%)
Others	1113 (2.1%)	Others	5970 (14.1%)
Total	53669	Total	42220

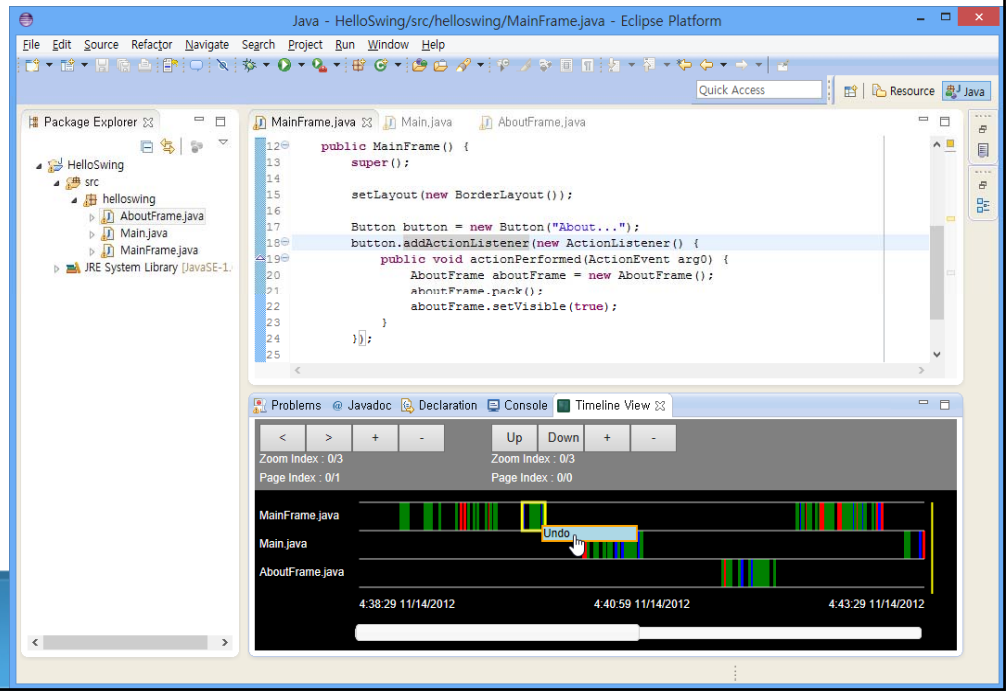
Backtracking Results

- All developers *backtrack* for many reasons
  - Explorations, investigations, iterative design
- People use comments to remove code, so they can restore it if necessary
  - But difficult to comment & uncomment correctly
  - Often non-local changes
- Undo not used for exploration, just typo fixing
- Current work: new tool to help developers backtrack

Azurite: Eclipse Plugin for Selective Undo



- PhD work of YoungSeok Yoon (in progress)
- Azurite: Adding Zest to Undoing and Restoring Improves Textual Exploration http://www.cs.cmu.edu/~azurite
- Work out semantics of selective undo for code
  - Conflicting edits of same code must be shown to user
- Time-line visualization of all past operations
- Search through history (time) to find appropriate points



Summary

- 30 studies; 18 systems in 17 years
- Doing studies first provides new insights that can inspire significantly new designs for programming languages and environments
- Need to understand software engineers' real issues
- New designs shown to be better

Thanks to:

- Funding:
  - NSF under IIS-1116724, IIS-0329090, CCF-0811610, IIS-0757511 (Creative-IT), NSF ITR CCR-0324770 as part of the EUSES Consortium
  - SAP
  - Adobe
  - IBM
  - Microsoft Research RISE

- >30 students:
  - Htet Htet Aung
  - Jack Beaton
  - Ruben Carbonell
  - John R. Chang
  - Kerry S. Chang
  - Polo Chau
  - Luis J. Cota
  - Michael Coblenz
  - Dan Eisenberg
  - Brian Ellis
  - Andrew Faulring
  - Aristiwidya B. (Ika) Hardjanto
  - Erik Harpstead
  - Sae Young (Sophie) Jeong
  - Andy Ko
  - Sebon Koo
  - Thomas LaToza
  - Joonhwan Lee
  - Leah Miller
  - Mathew Mooty
  - Gregory Mueller
  - Yoko Nakano
  - Stephen Oney
  - John Pane
  - Sunyoung Park
  - Chotirat (Ann) Ratanamahatana
  - Christopher Scaffidi
  - Jeff Stylos
  - David A. Weitzman
  - Yingyu (Clare) Xie
  - Zizhuang (Zizzy) Yang
  - YoungSeok Yoon

Thank You!

Improving Software Development through Human-Centered Approaches

Brad A. Myers

Human-Computer Interaction Institute
School of Computer Science
Carnegie Mellon University
http://www.cs.cmu.edu/~bam
bam@cs.cmu.edu