

Human-Centered Approaches to Software Engineering Research

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School of Computer Science
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**Human-
Computer
Interaction
Institute**

Programmers and Work

At least 55 million in the U.S. write code to get their work done (*end-user programmers*)

At least 3 million in the US have a career in programming (*professional programmers*)

By 2012, 30% of new jobs in the US may require programming skills

[Scaffidi 2005] [US Bureau of Labor and Statistics 2005]

Programmers are People!



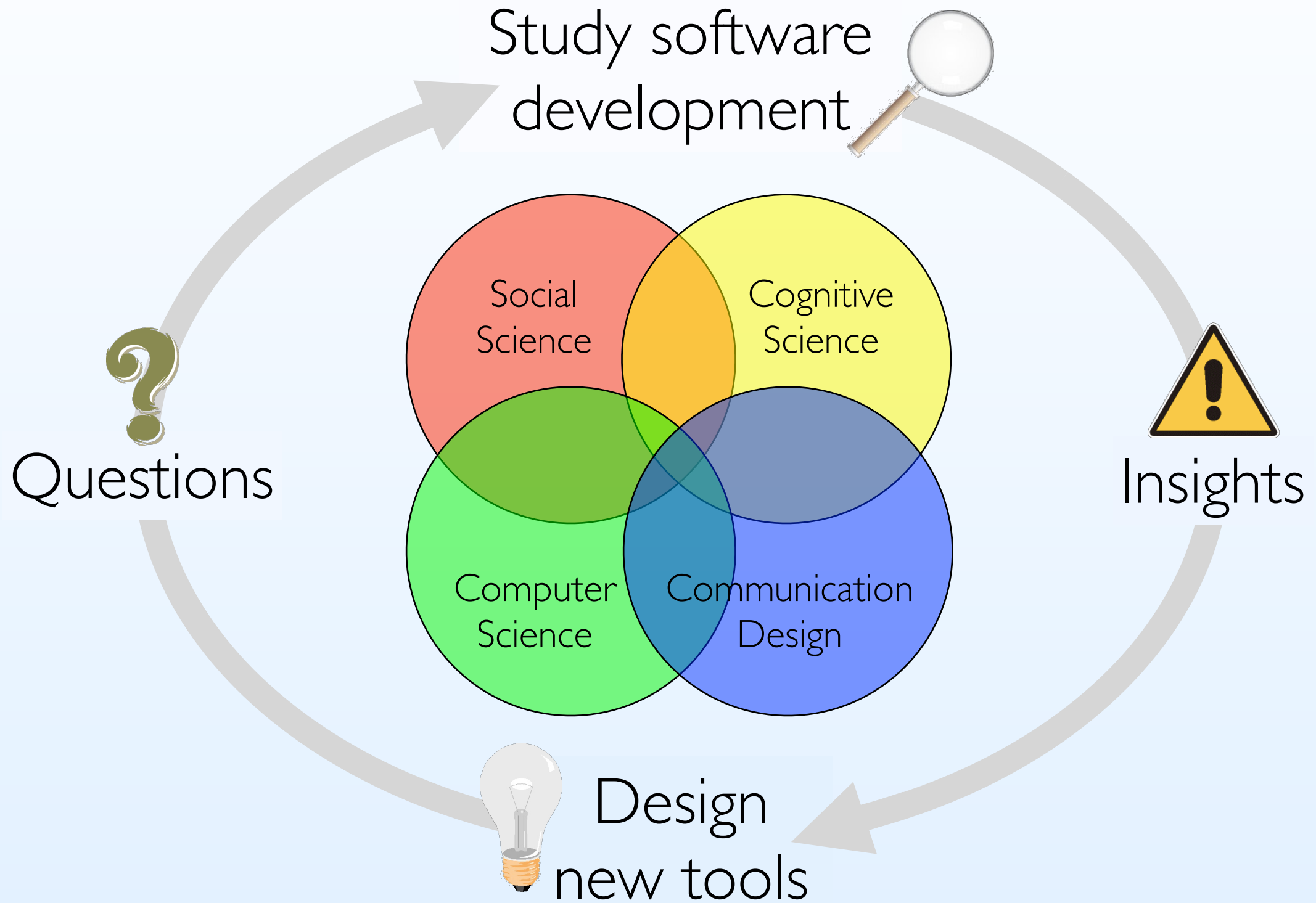
My Interests

I'm fascinated by the way that software is changing the world and changing people's work...

What can we do to help people improve *software quality* and their own *productivity*?

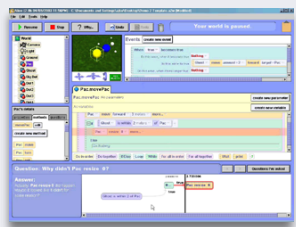
I'm interested in building interactive tools...

Process

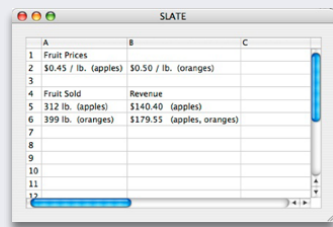


Projects

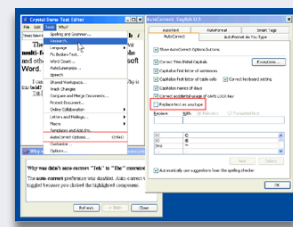
Seven tools and the studies that inspired them.



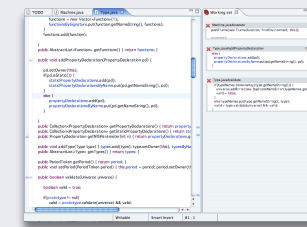
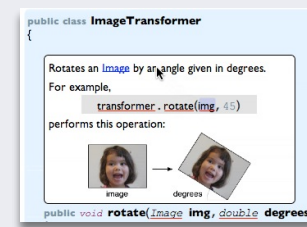
2003



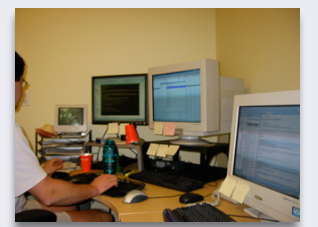
2004



2005



2006

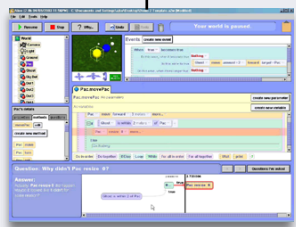


Projects

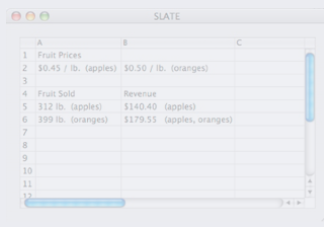


Why does bug fixing take so long?

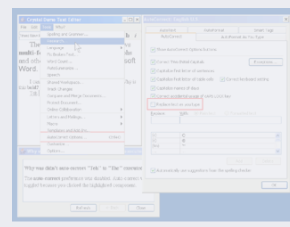
Whyline



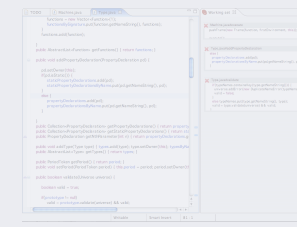
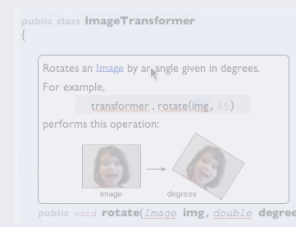
2003



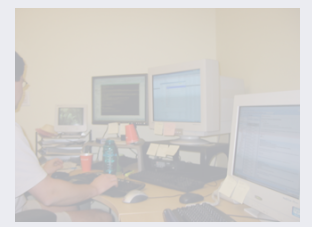
2004



2005



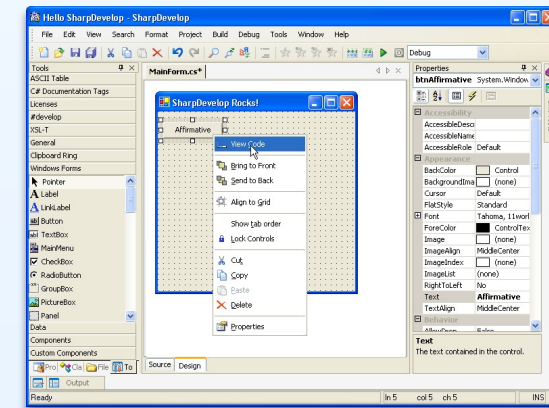
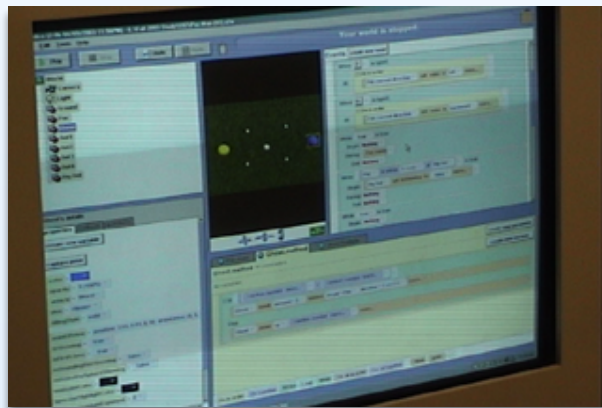
2006



Debugging Event-based Code



Observed 15 students creating games with Alice
Interviewed 7 designers creating UIs with Flash
Helped 40 students learn Visual Basic.NET



Debugging Event-based Code



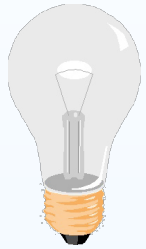
People's guesses about why a program has failed tend to be wrong, so they spend most of their time testing false hypotheses.

People formed false hypotheses, because tools require them to form hypotheses prematurely.

```
if(tokens.peek(IsToken.class)) {  
    type.setIs(tokens.<IsToken>eat(IsToken.class));  
    type.setArticle(tokens.<ArticleToken>eat(ArticleToken.class));  
    type.setPrototype(typeExpression(tokens, unit));  
    type.setThat(tokens.<ThatToken>eat(ThatToken.class));  
}
```

Whyline

a Workspace that Helps You Link Instructions, Numbers and Events

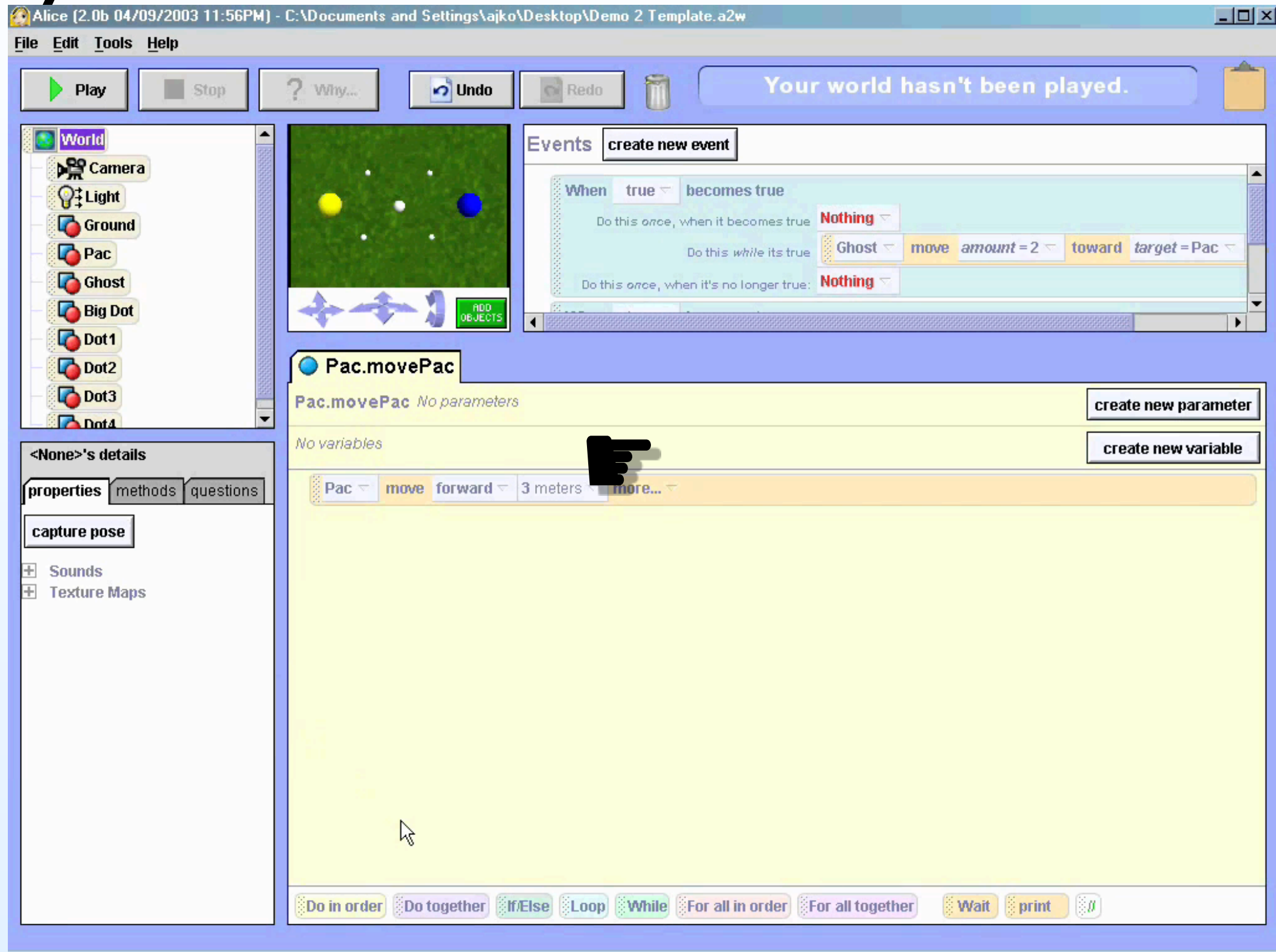


Let people ask *why did* and *why didn't* questions about their programs' *output*, which they can reason about accurately.

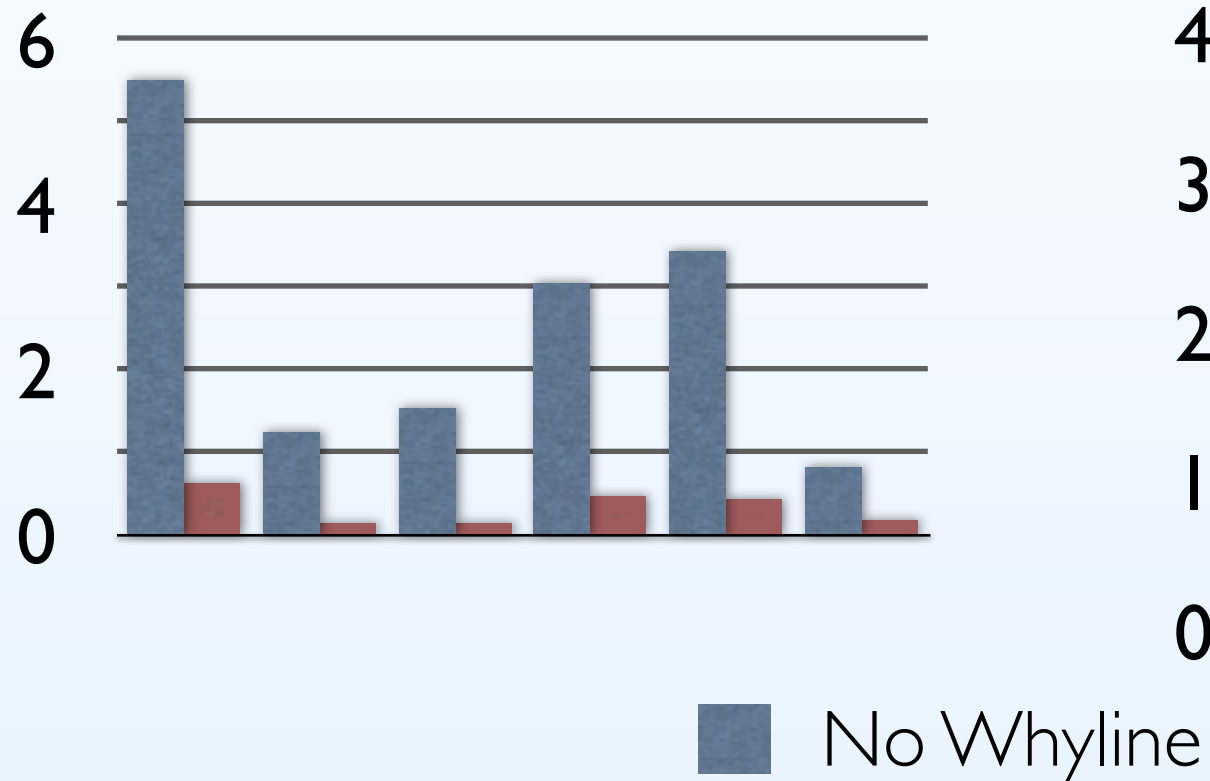
Use program slicing and other techniques to determine what code they should inspect.

Whyline

a Workspace that Helps You Link Instructions, Numbers and Events

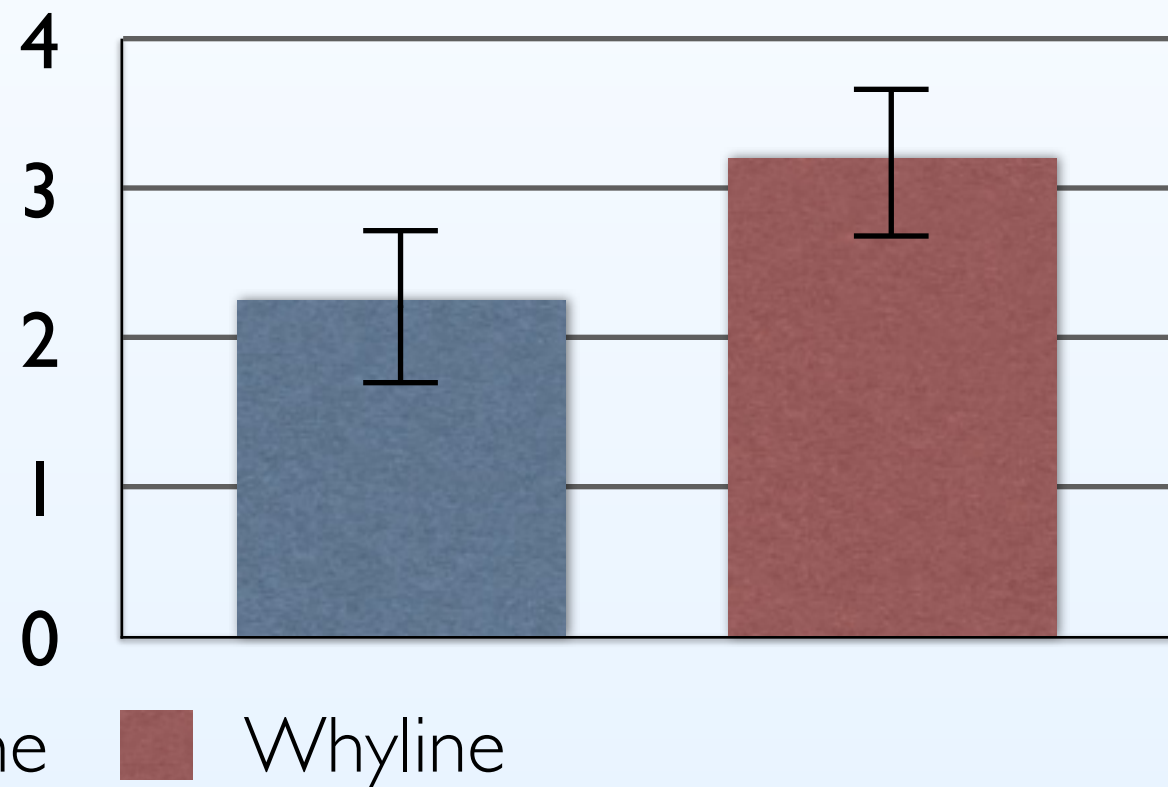


Debugging Time on 6 debugging scenarios (minutes)



Debugging time reduced by a factor of 7.8 ($p < .02$)

Average # of behaviors correctly implemented.



Correctly completed 40% more tasks ($p < .02$)

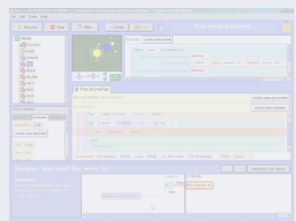
Projects



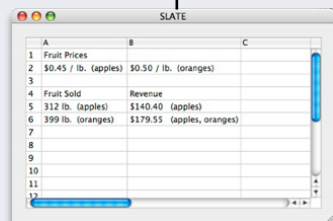
What influences a spreadsheet's correctness, but is not formally specified in the spreadsheet?

Slate

with Michael Coblenz



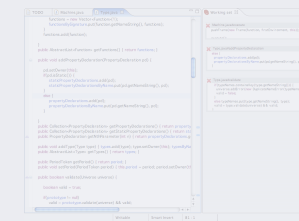
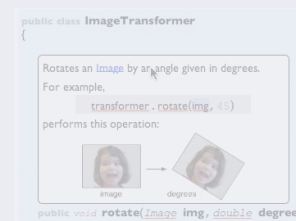
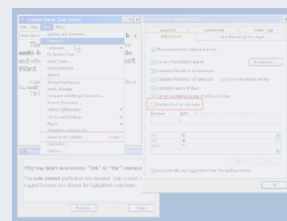
2003



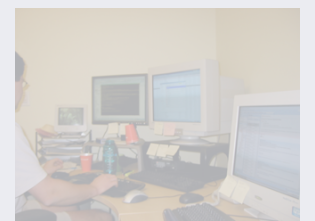
2004



2005



2006



Spreadsheet Errors



Studied data and formulas in spreadsheets from a corpus of public spreadsheets.

total weight of **fruit shipped**

average grade of **students in afternoon English**

dollars spent on **groceries in January**

Spreadsheet Errors



People encode values with both **units** and **labels**.

25.0 kg of *apples*

total weight of **fruit shipped**

Many formula errors computed valid *units*, but *invalid* labels.

25.0 kg of *apples* + 10.0 kg of *oranges* = 35.0 kg of ???



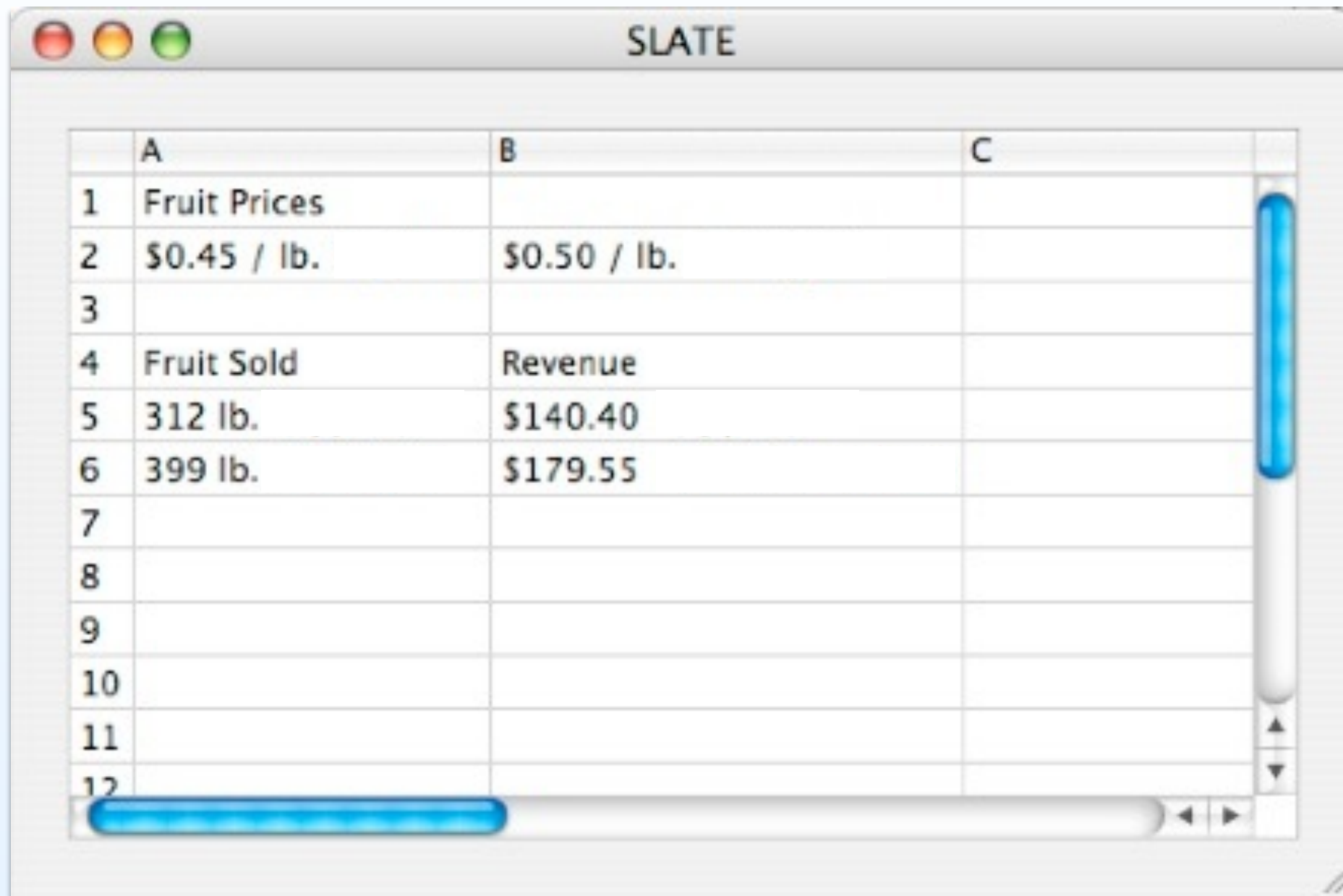
Introduce the concept of *labels*. Define a type system to allow their propagation.

We defined semantics for adding, subtracting, multiplying, and dividing labels.

Users can compare the labels shown to the labels expected.

Slate

a Spreadsheet Language that Accentuates Type Errors



The screenshot shows a window titled "SLATE" with a spreadsheet interface. The spreadsheet has three columns labeled A, B, and C, and rows numbered 1 through 12. The data is as follows:

	A	B	C
1	Fruit Prices		
2	\$0.45 / lb.	\$0.50 / lb.	
3			
4	Fruit Sold	Revenue	
5	312 lb.	\$140.40	
6	399 lb.	\$179.55	
7			
8			
9			
10			
11			
12			

Slate

a Spreadsheet Language that Accentuates Type Errors

	A	B	C
1	Fruit Prices		
2	\$0.45 / lb. (apples)	\$0.50 / lb. (oranges)	
3			
4	Fruit Sold	Revenue	
5	312 lb. (apples)	\$140.40 (apples)	
6	399 lb. (oranges)	\$179.55 (apples, oranges)	
7			
8			
9			
10			
11			
12			

should be $A6 * B2$

$= A6 * A2$

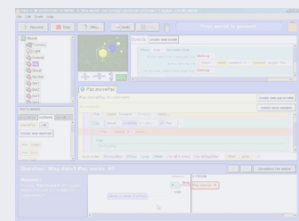
strange label calls attention to discrepancy

Projects

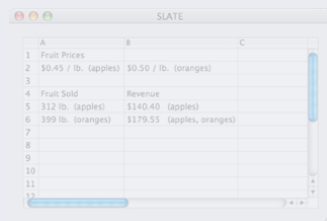


Why are programs that manipulate structured data so large and difficult to maintain?

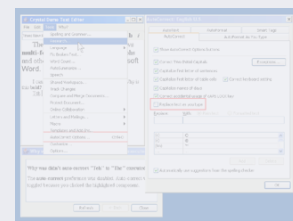
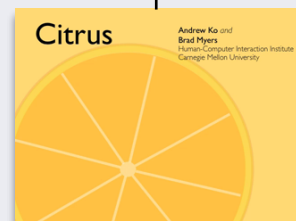
Citrus



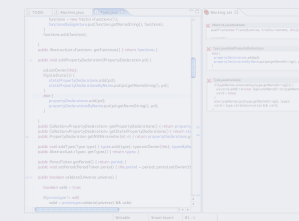
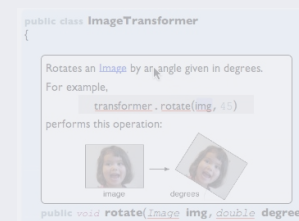
2003



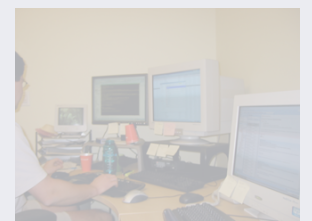
2004



2005



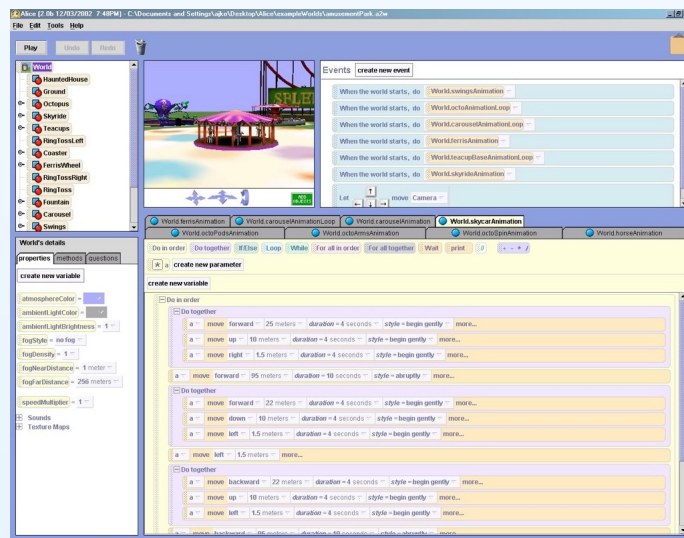
2006



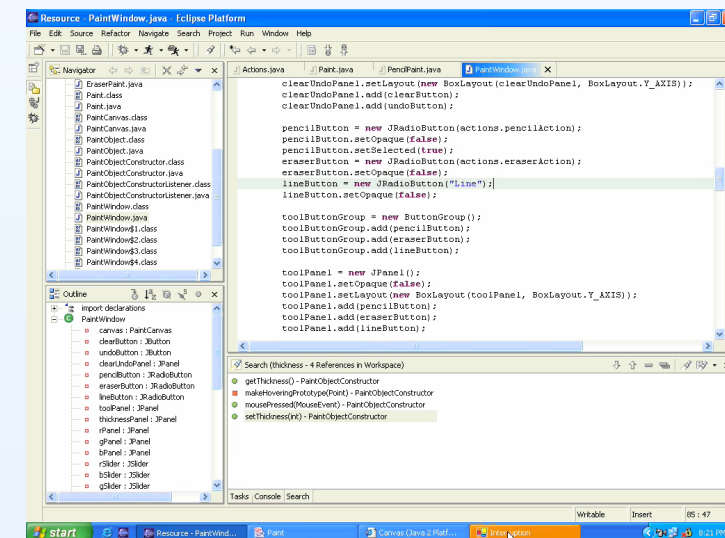
Software for Structured Data



Analyzed the source code for large interactive, incremental tools.



Alice



Eclipse

Software for Structured Data



Languages like Java necessitate large amounts of *boilerplate code* to manage *listeners*, *constraints*, and *event handlers*, *value restrictions*.

```
IWorkspace workspace = ResourcesPlugin.getWorkspace();
IResourceChangeListener listener = new IResourceChangeListener() {
    public void resourceChanged(IResourceChangeEvent event) {
        System.out.println("Something changed!");
    }
};
workspace.addResourceChangeListener(listener);

//... some time later one ...
workspace.removeResourceChangeListener(listener);
```



Create first class language features to simplify the expression of these common architectural patterns

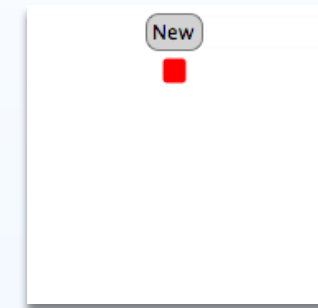
By building them into the runtime, the syntax required to express them is greatly simplified.

Citrus

a language for Creating Interactive Tools that Reshape and Utilize Structure

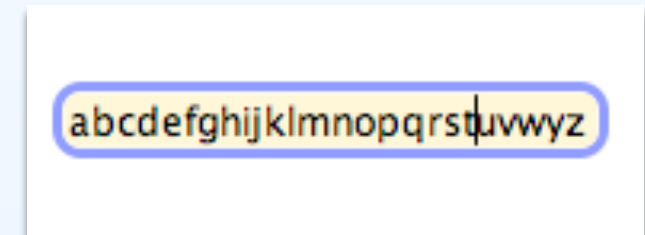
value
constraints

```
top <- ((this previousView).bottom + 5.0)
```



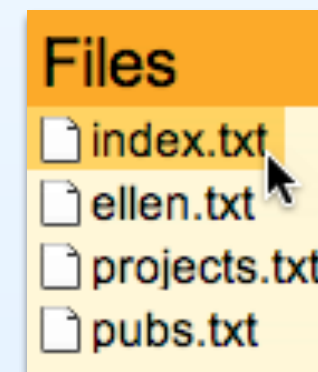
value
restrictions

```
has Int caretIndex = 0  
for which (caretIndex >= 0)  
  otherwise 0  
for which (caretIndex <= (text length))  
  otherwise (text length)
```



event
handlers

```
when event (editor FileSelected)  
(do  
  (event.old.@background set nothing)  
  (event.new.@background set Color.orange)  
)
```



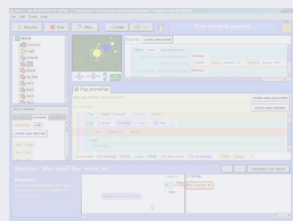
Projects



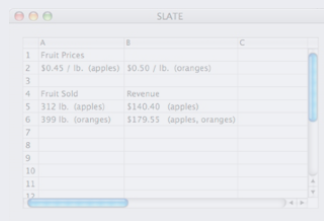
What questions do users of office applications have difficulty answering?

Crystal

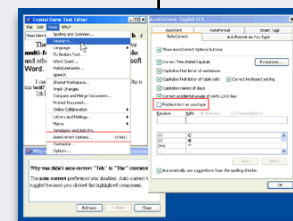
with undergrad David Weitzman



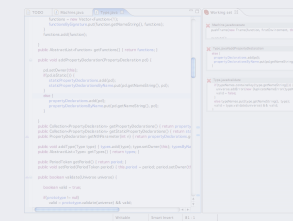
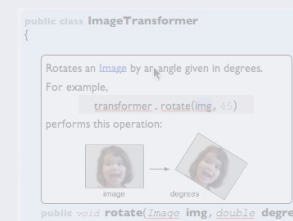
2003



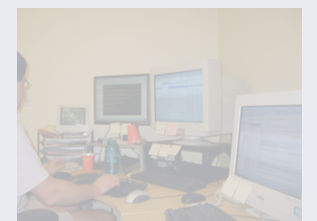
2004



2005



2006



Debugging Your Office Apps



Collected a corpus of *why* questions that office workers had about their office applications.

Teh|

Why didn't this get auto corrected?

My favorite colour ...

Why did this get marked as misspelled?

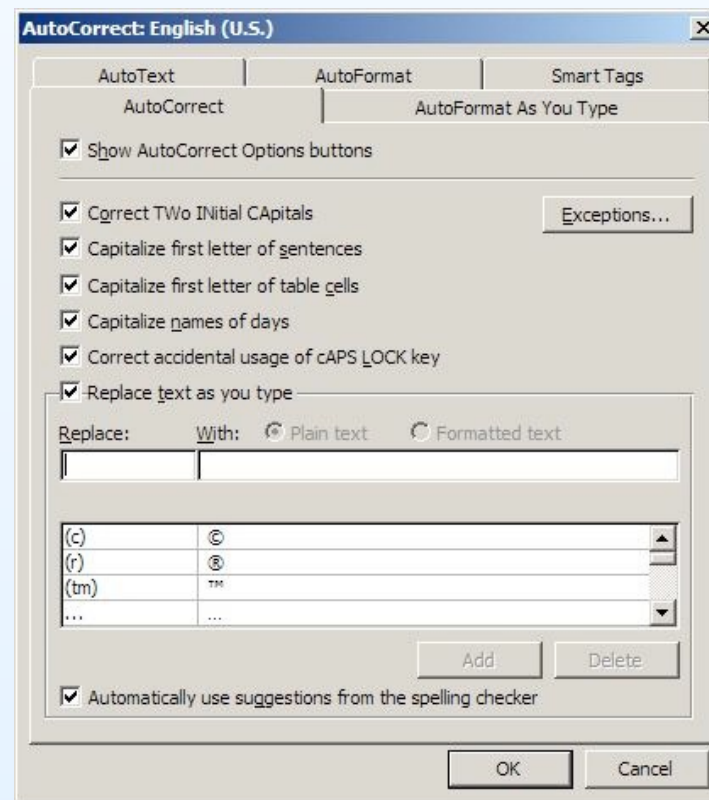
Safari can't open the page "http:/
your computer isn't connec

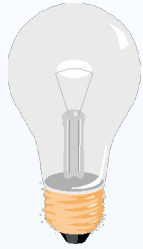
Why is this whitespace here?

Debugging Your Office App



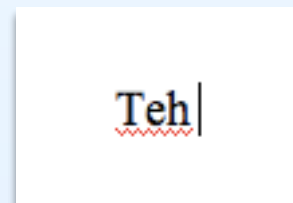
To answer these questions, users explored the user interface and online help for answers.





Allow users to click on objects in the application and select a why question about its behavior.

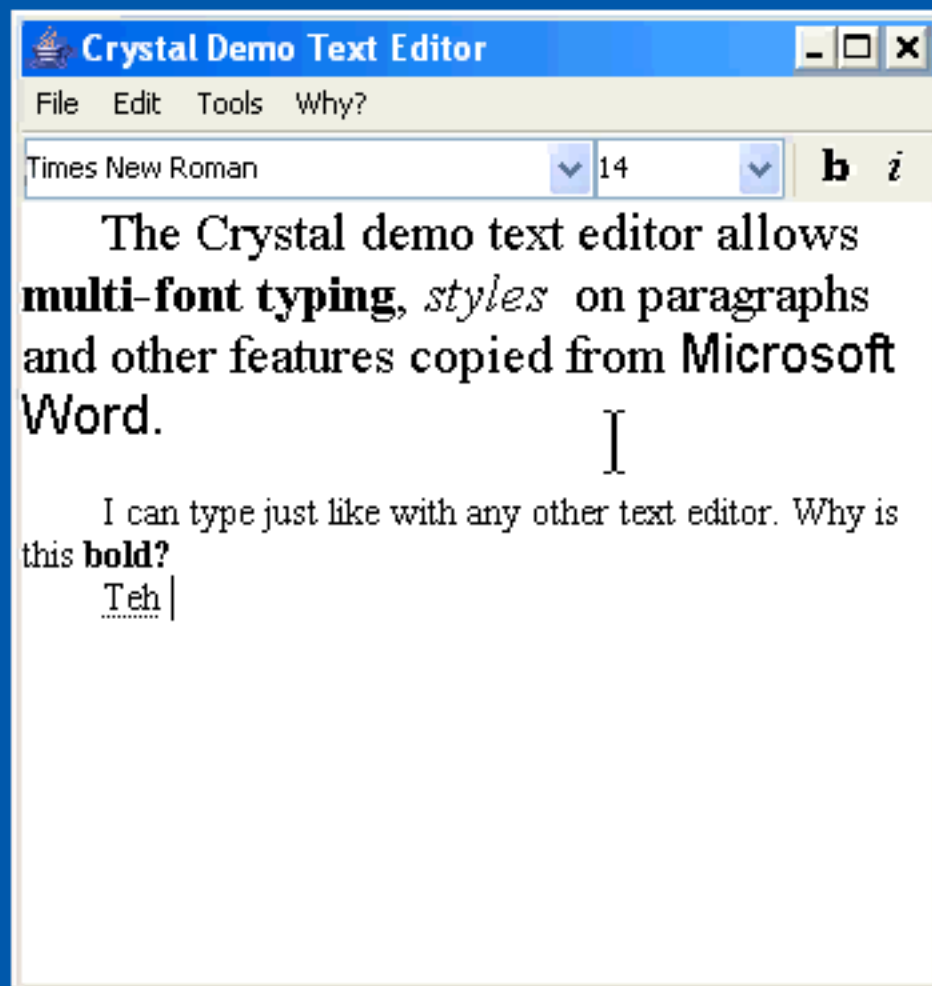
Maintain a causality graph as part of the undo history. Answers are all paths from a visible input to a visible output.



Why didn't this get auto corrected?

Crystal

Clarifications Regarding Your Software using a Toolkit, Architecture, and Language



In a user test, users with Crystal's question asking features were able to resolve all of the problems we posed.

Users without question support took significantly longer on the simpler tasks and gave up on the more complex tasks.

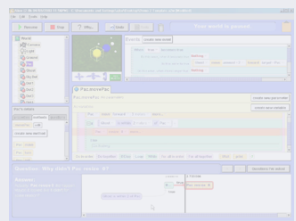
Currently speaking with Microsoft developers about the potential for this technology in future versions of Office.

Projects

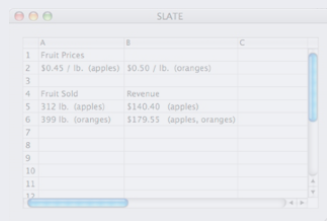


How do programmers utilize text as a medium for their work?

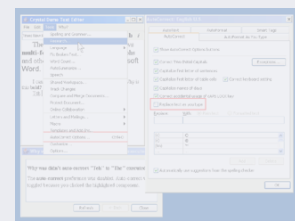
Barista



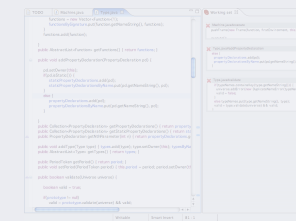
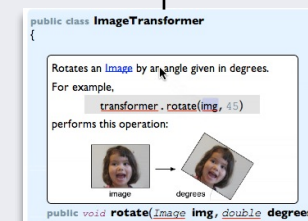
2003



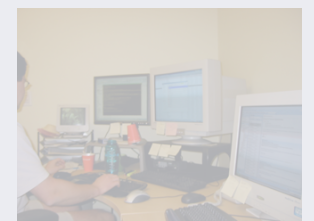
2004



2005



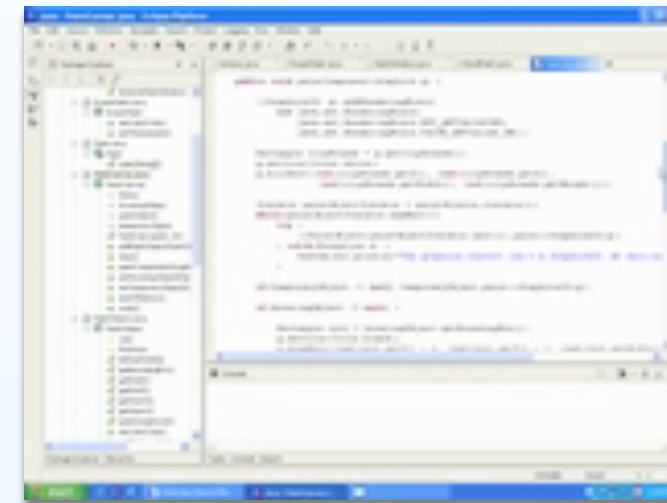
2006



Source Code Editors



Screen captured expert Java programmers doing development and maintenance tasks



Analyzed open source code comments.

```
/** creates a new instance of ExponentialChange using parameters
 * @param delay_val time until the behavior starts -ms
 * @param dur_val life span of the behavior - ms
 * @param exp_curvature exponent
 * @param amount_val offset amount
 */
public ExponentialChange(double delay_val, double dur_val, double exp, double amount_val)
{
    this();
    amount.setValue(amount_val);
    exponent.setValue(exp);
    duration.setValue(dur_val);
    addTimeFilter(new Delay(delay_val));
}

/** sets the offset amount
 * @param new_amount offset amount
 */
public void setAmount(double new_amount) {
    amount.setValue(new_amount);
}

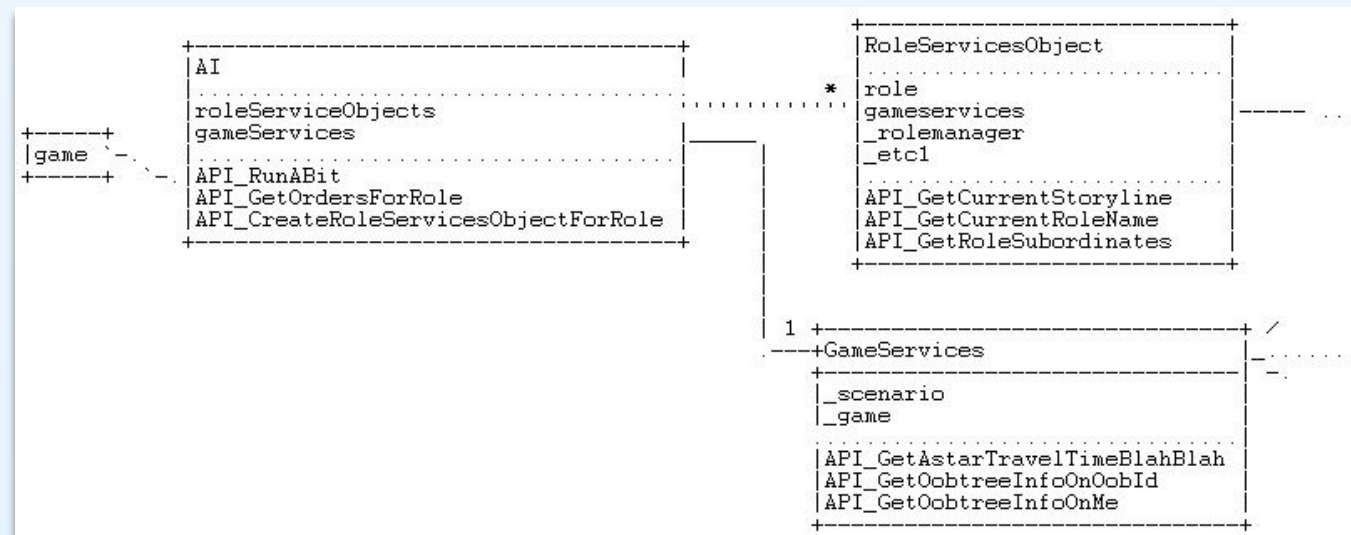
/** main routine that makes the calculation
 */
public void Process() {
    if(owner != null) {
        if(current_time <= 0) //causal function
            return;
        if(current_time < duration.endValue) {
            if(Math.abs(exponent.getEndValue()) < 0.01)
                owner.endValue += (current_time/duration.endValue)*amount.getEndValue();
            else {
                //creates an exponential curve bounded to a unit square
                owner.endValue += amount.getEndValue()*(Math.pow(Math.E,exponent.getE())
                    *(Math.pow(Math.E,exponent.getEndValue()) - 1));
            }
            isDone = false;
        }
        else {
            owner.endValue += amount.endValue;
            isDone = true;
        }
    }
}
}
```

Source Code Editors



Programmers need most of the flexibility of text for their modifications, but...

Text is an limited medium for the type of information that developers want to embed in code.



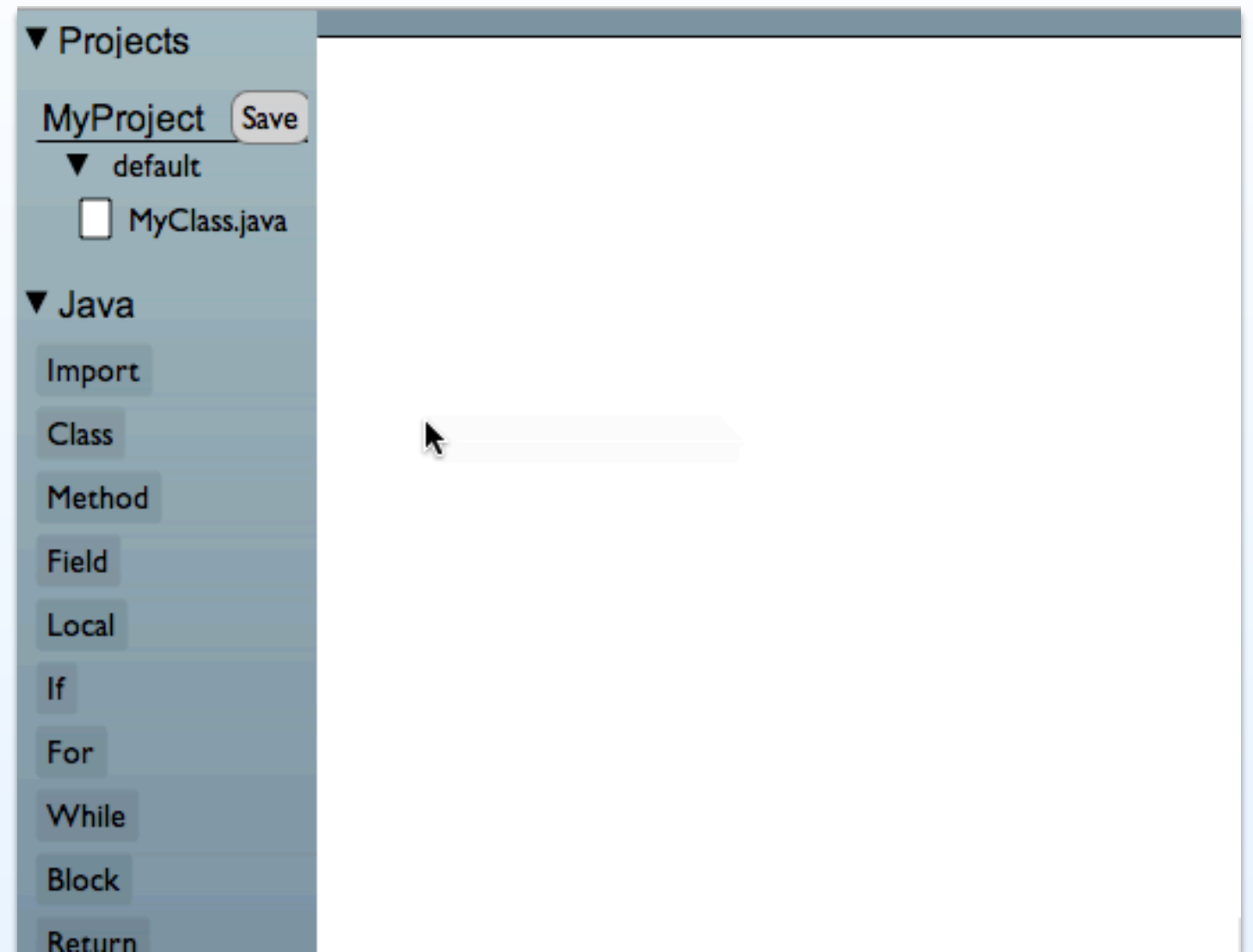
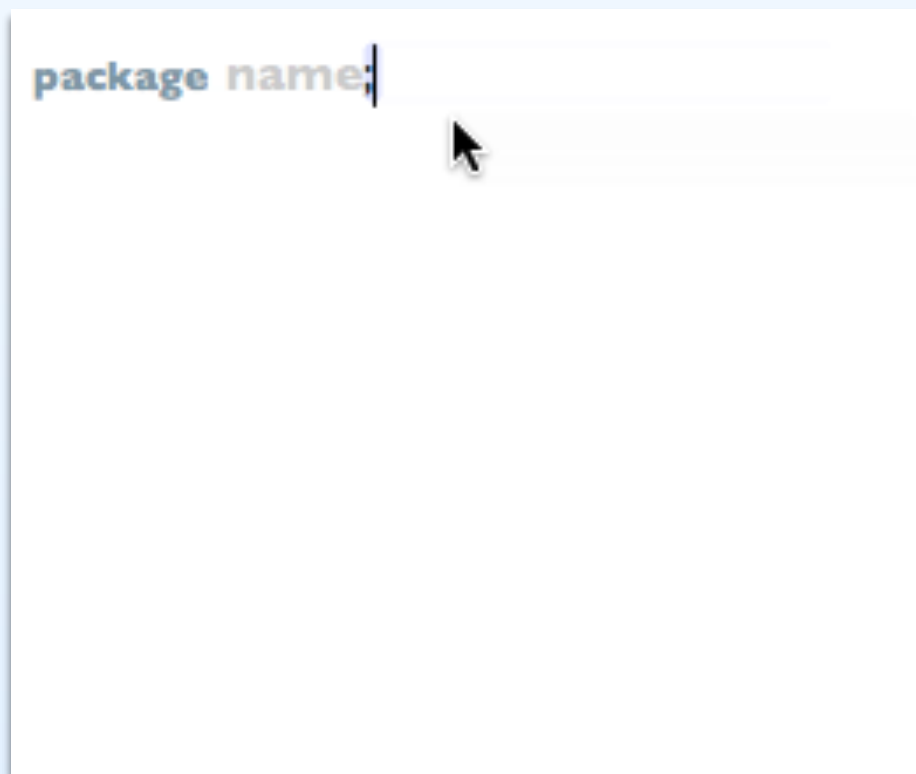
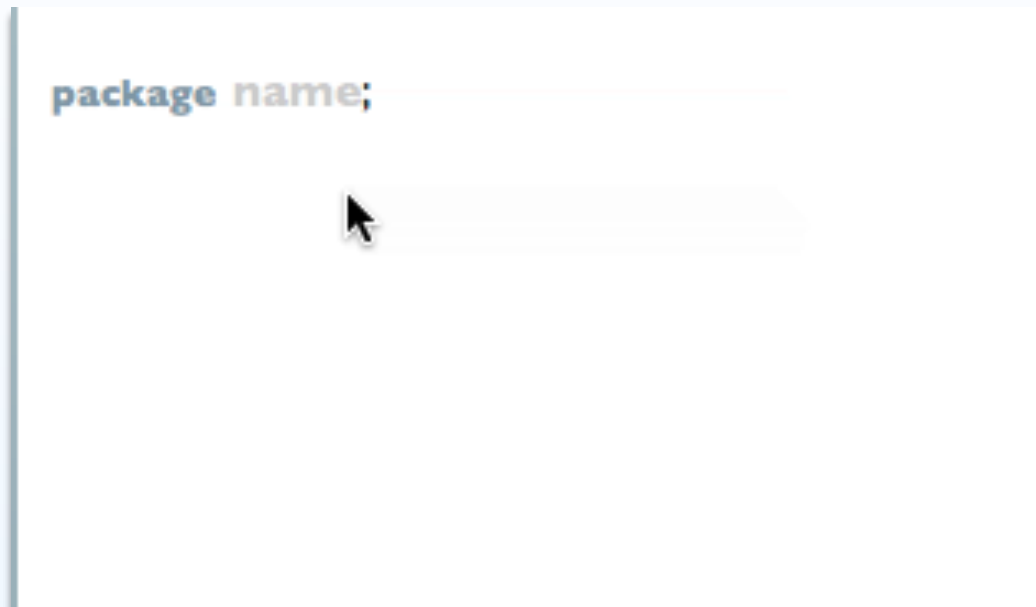


Design code editor toolkit that supports rich media, embedded tools, and alternative views, while still supporting conventional text editing.

Represents code as trees of structures and tokens, but still allows code to be edited as text.

Barista

Basic Abstractions for Rapidly Implementing Structured Text-editing Applications



Barista

Basic Abstractions for Rapidly Implementing Structured Text-editing Applications

```
× FruitPainter.java

public class FruitPainter
{
    Paints a fruit based on the shape supplied.
    public void paintFruit(Shape shape)
    {
        int left = shape.minX();
        int top = shape.minY();
        int right = shape.maxX();
        int bottom = shape.maxY();

        if (shape.round()
            shape.red() shape.green())
        {
            Image apple = load("apple.png");
            paint(apple, 40);
        }
    }
}
```

```
× Distance.java

public class Distance
{
    Computes the distance between two points.
    public static final double main(double x1, double y1, double x2, double y2)
    {
        return  $\sqrt{(x2 - x1)^2 + (y2 - y1)^2}$ ;
    }
}
```

```
× Alternatives.java

public class Alternatives
{
    Returns this view's left coordinate.
    public double getLeftPosition()
    {
        return 0.0;
    }
}
```

```
public class ImageTransformer
{
    Rotates an Image by an angle given in degrees.
    public void rotate(Image img, double degrees)
    {
    }
}
```

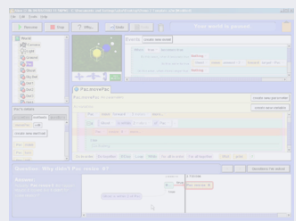
Projects



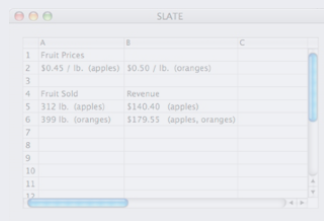
What are the major sources of effort when using an IDE to complete software maintenance tasks?

Jasper

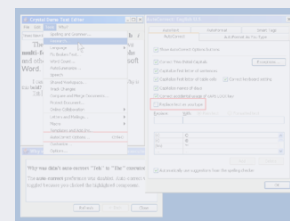
with Michael Coblenz



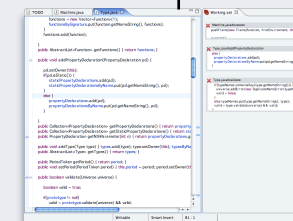
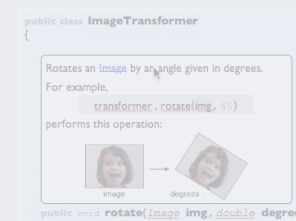
2003



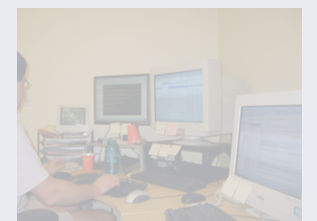
2004



2005



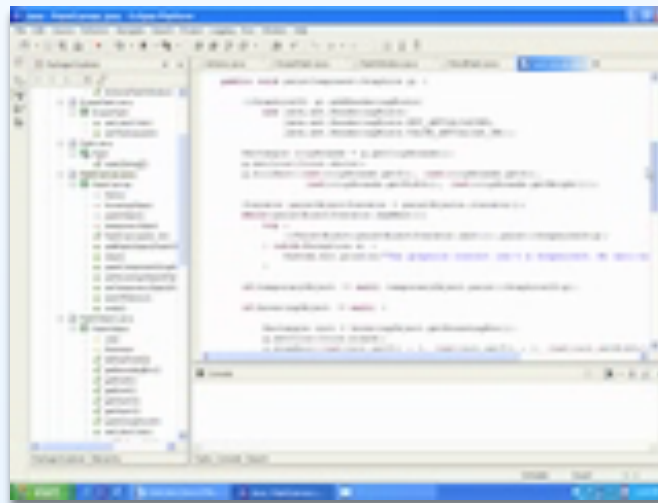
2006



Navigating Source Code



Fine-grained analysis of 10 Java programmers actions during debugging and enhancement tasks.

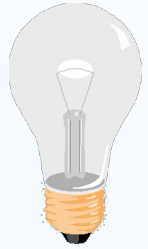


Navigating Source Code



People return to task-relevant code frequently, but to navigate to it, they have to use file tabs, scroll bars and lists.

35% of time was spent just with the mechanics of these navigations.



Design a user interface that allows all of the relevant code to be viewed in a single place.

This workspace would represent a task, and could hold any kind of relevant information, in addition to code fragments.

Jasper

Java Aid with Sets of Pertinent Elements for Recall

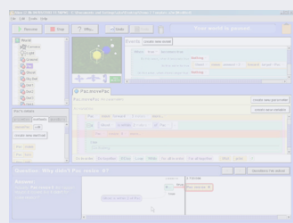
The screenshot displays the Eclipse IDE interface for the Jasper project. The Package Explorer on the left shows the project hierarchy, including the 'src' directory and sub-packages like 'edu.cmu.hcii.jasper'. The main editor window shows the code for 'EditorActionDelegate.java', which implements the 'run' method. This method uses a switch statement to handle different selection types: 'JAVA_SELECTION' (creating a 'WorkingSetJavaItem') and 'TEXT_SELECTION' (creating a 'WorkingSetTextItem'). A default case prints an error message for unknown selection types. The 'selectionChanged' method is also shown, which updates the current selection if it is a 'TextSelection'. The Problems window at the bottom indicates '0 errors, 0 warnings, 0 infos'. The Outline view on the right lists the class members, including 'run(IAction)' and 'selectionChanged(IAction, ISelection)'. A 'Reminders.txt' file is also visible in the editor, containing the note: 'URL items don't have a document - need to change hierarchy'.

Projects

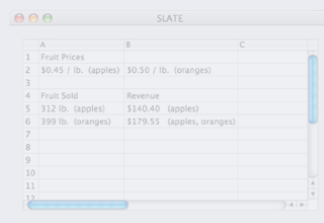


What are the information needs of bug fixing work at Microsoft?

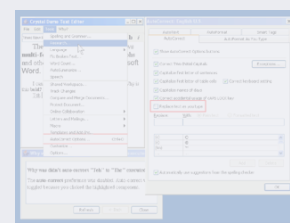
Internship
with Rob DeLine



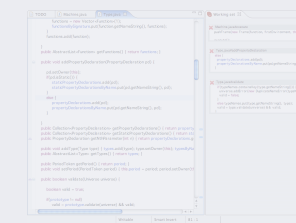
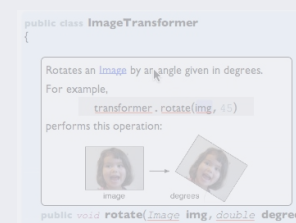
2003



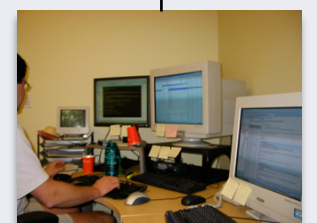
2004



2005



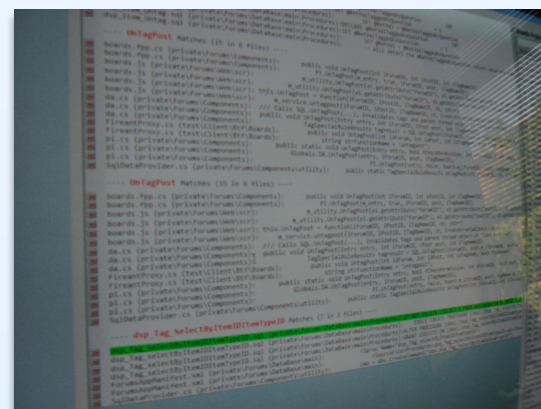
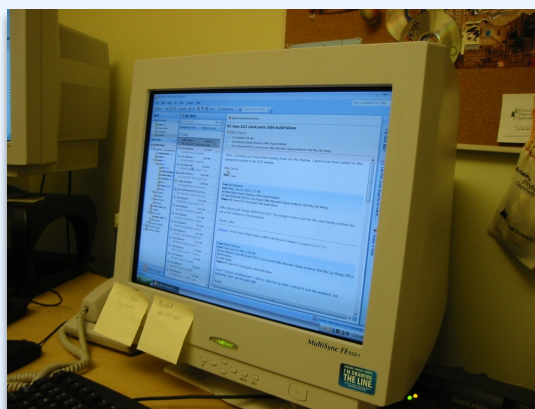
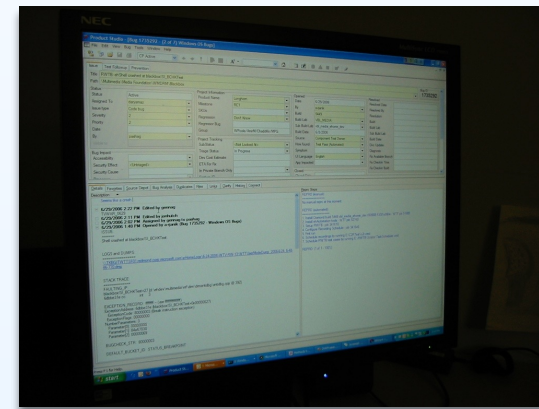
2006



Bug Fixing at Microsoft



Twenty 2-hour observations of Microsoft developers bug fixing.



Bug Fixing at Microsoft

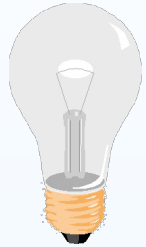


Program understanding by reading and analyzing code is rare, because of its cost and risk of failure.

Configuring a workspace for the reproduction, testing, and debugging of a bug is extremely costly.

Developers need to know the behavior of code *and* its design rationale.

Whyline for Java



JButton.java

```

.....
This paints the JButton, depending on its state.
.....
public void paintComponent(Graphics2D g) {
    g.fillRect(0, 0, 80, 20, 5, 5);
    if(enabled)
        g.setColor(Color.grey);
    else
        g.setColor(Color.black);
    g.drawString("Send", 0, 20);
}
public void setEnabled(boolean enabled) {

```

Why is this text gray?

These are the events that caused this text to be painted grey. Click on the ellipses to display more causes.

```

... --> enabled set to false --> if(enabled) was false --> setColor Color.grey
... --> JFrame created

```

```

> java BubbleSort 25 234 1 34 34 5 53 34

Sorting [25, 234, 1, 34, 34, 5, 53, 34]...

swapping 234 and 1
swapping 234 and 34
swapping 234 and 34
swapping 234 and 5
swapping 234 and 53
swapping 234 and 25

```

why was this exception thrown?

```

java.lang.ArrayIndexOutOfBoundsException: -1
    at java.util.Vector.get(Vector.java, Compiled Code)
    at Intro$3.getValueAt(Intro.java, Compiled Code)
    at javax.swing.JTable.getValueAt(JTable.java, Compiled Code)
    at javax.swing.JTable.prepareRenderer(JTable.java, Compiled Code)
    at javax.swing.plaf.basic.BasicTableUI.paintCell(BasicTableUI.java, Compiled Code)
    at javax.swing.plaf.basic.BasicTableUI.paintCells(BasicTableUI.java, Compiled Code)
    at javax.swing.plaf.basic.BasicTableUI.paint(BasicTableUI.java, Compiled Code)

```

line
pencil
fill

at x1=10?
at y1=20?
at x2=288?
at y2=233?
2.0 thick?
black?

line
rectangle
window

why is this
why isn't this

after this drag...
why did this
why didn't this

color change?
size change?
position change?

red
green
blue

rectangle
panel
window

Logged into your FTP...

why did this
why didn't this

change
display

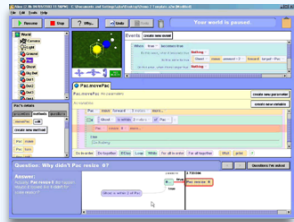
directory_contents?
error_message?

Conclusions

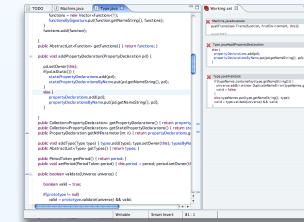
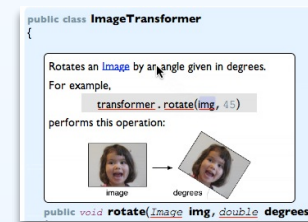
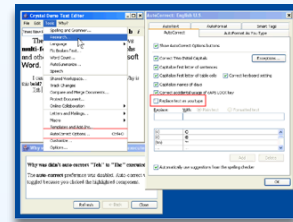
Software development is complex and social work.

Understanding this work and designing tools to support it is an interdisciplinary problem.

Questions?



A	B	C
1	Fruit Prices	
2	\$0.45 / lb. (apples)	\$0.50 / lb. (oranges)
3		
4	Fruit Sold	Revenue
5	312 lb. (apples)	\$140.40 (apples)
6	399 lb. (oranges)	\$179.55 (apples, oranges)
7		
8		
9		
10		
11		
12		



<http://www.cs.cmu.edu/~marmalade>



Human-
Computer
Interaction
Institute