

Human-Centered Approaches to Software Engineering Research

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Human-Computer Interaction Institute
School of Computer Science
Carnegie Mellon University



**Human-
Computer
Interaction
Institute**

Programmers and Work

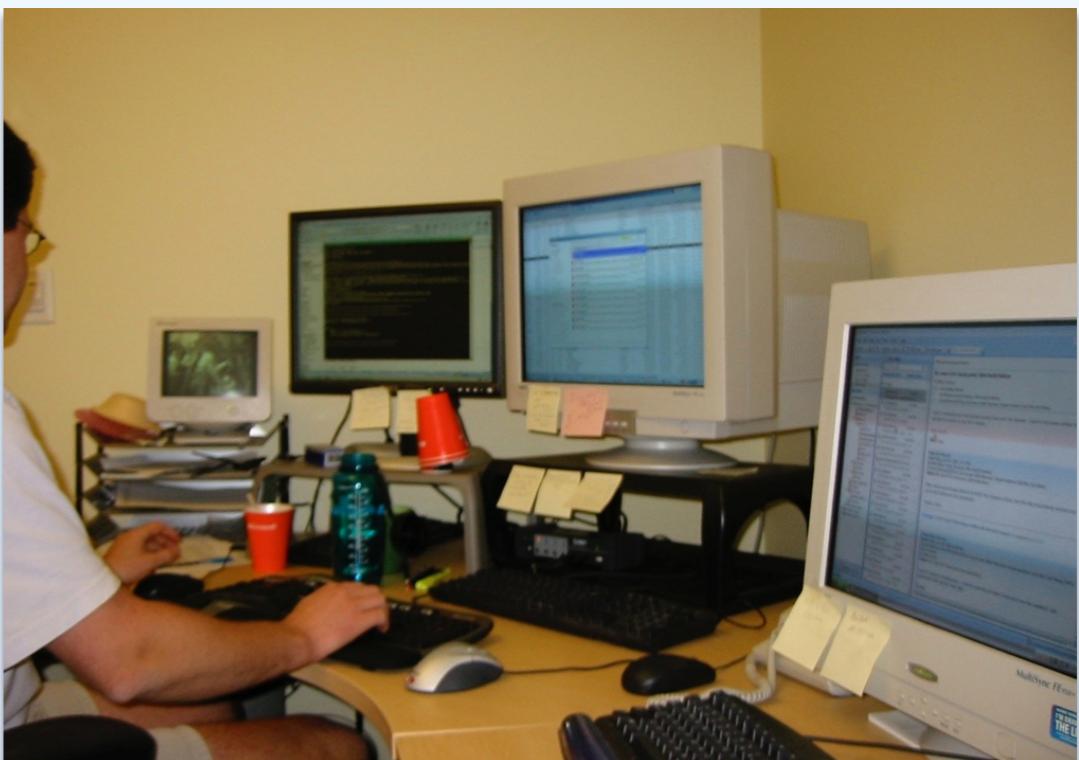
At least 55 million in the U.S. write code to get their work done (*end-user programmers*)

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!



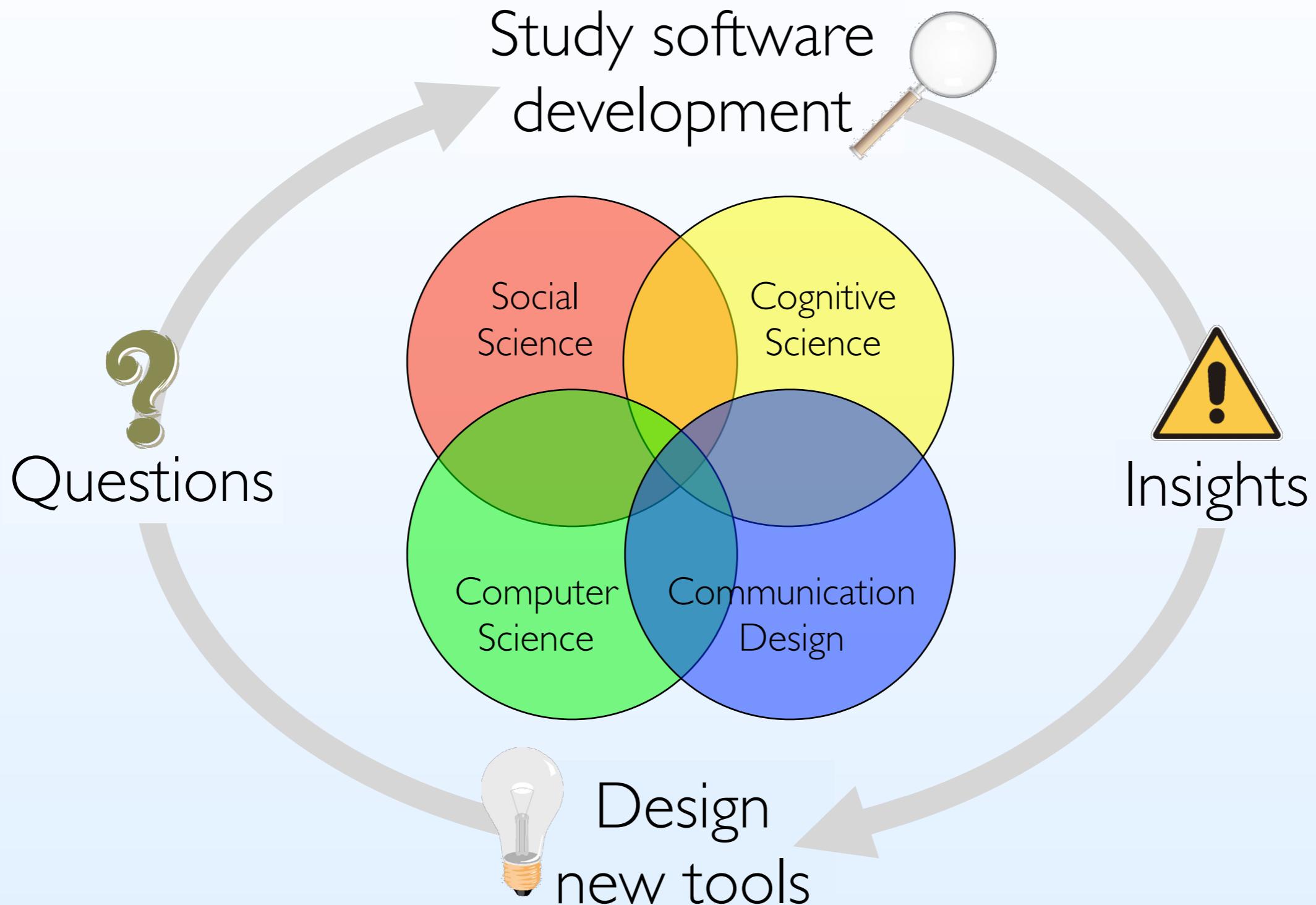
My Interests

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*?

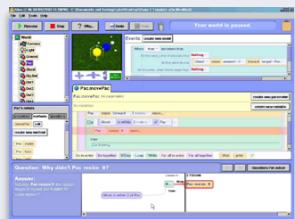
I'm interested in building interactive tools...

Process

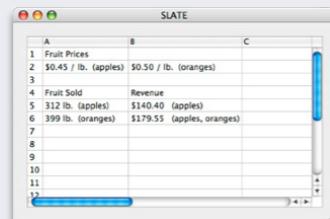


Projects

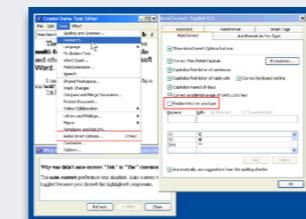
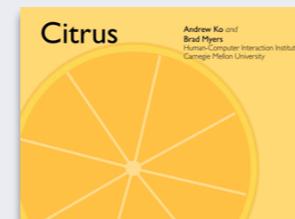
Seven tools and the studies that inspired them.



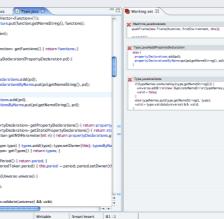
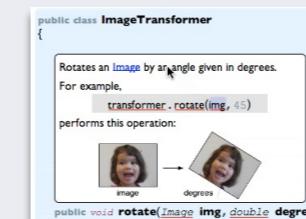
2003



2004



2005



2006



Projects

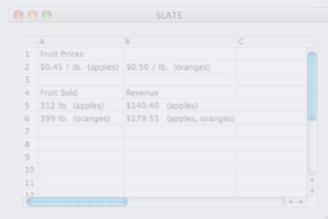


Why does bug fixing take so long?

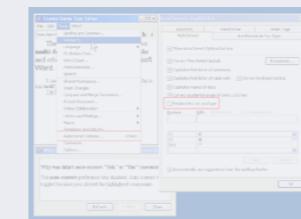
Whyline



2003

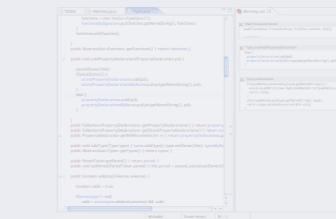


2004



2005

```
public class ImageTransformer {  
    public void rotate(Img img, double degrees)  
    {  
        // Implementation details...  
    }  
}
```



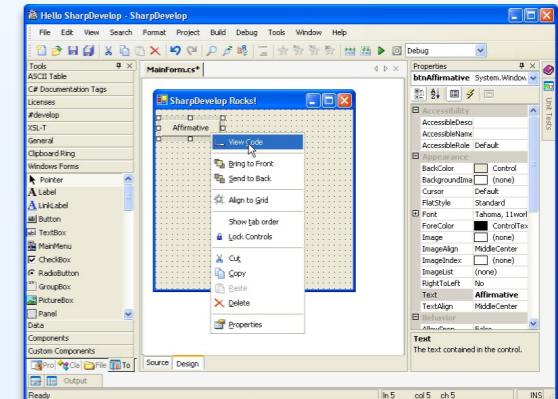
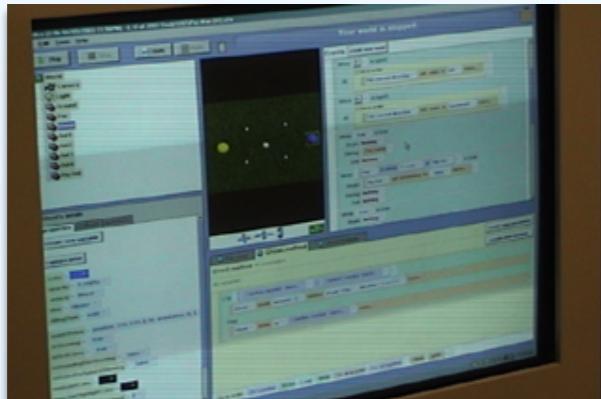
2006



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

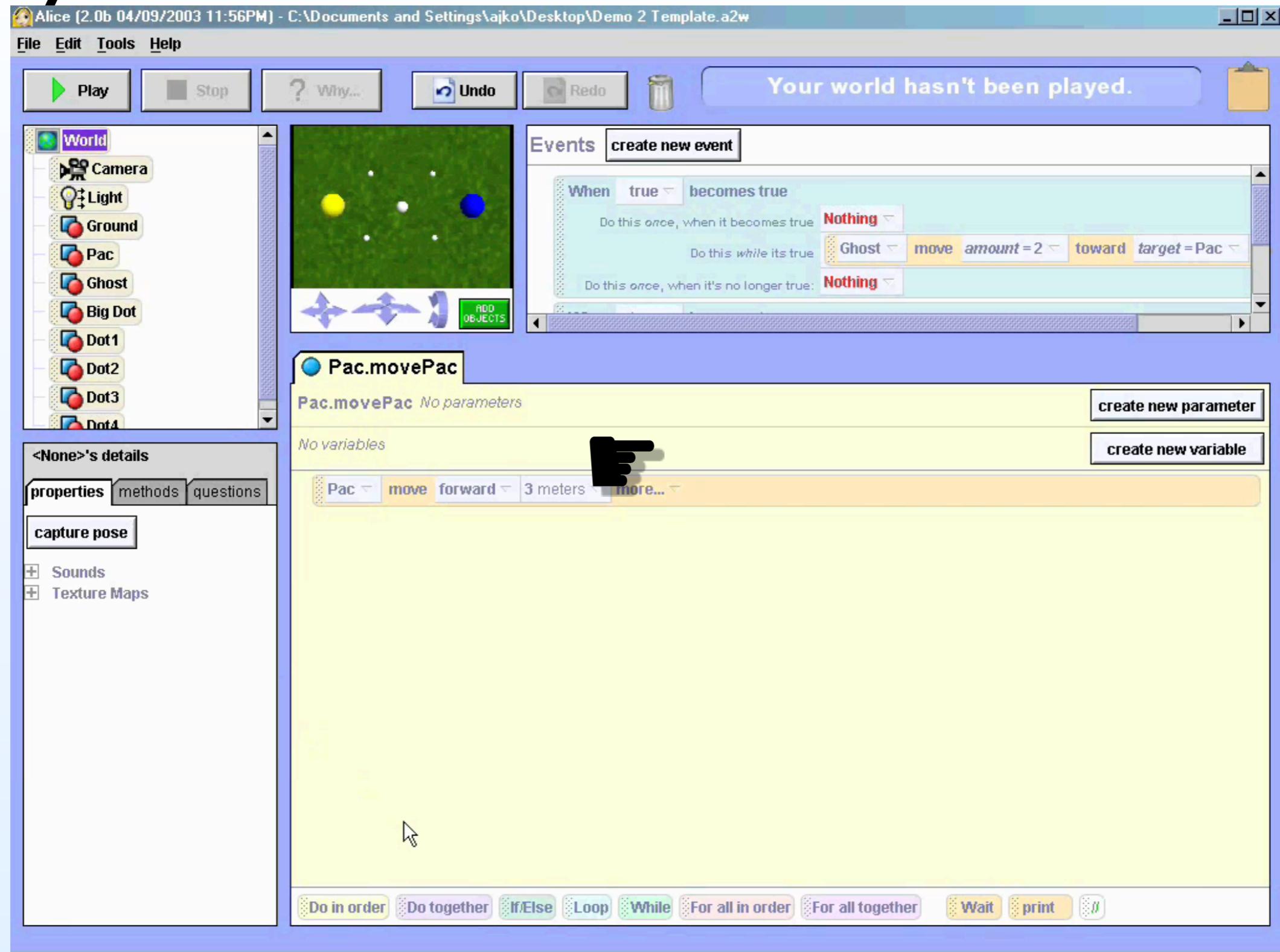


Let people ask *why did* and *why didn't* questions about their programs' *output*, which they can reason about accurately.

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

Whyline

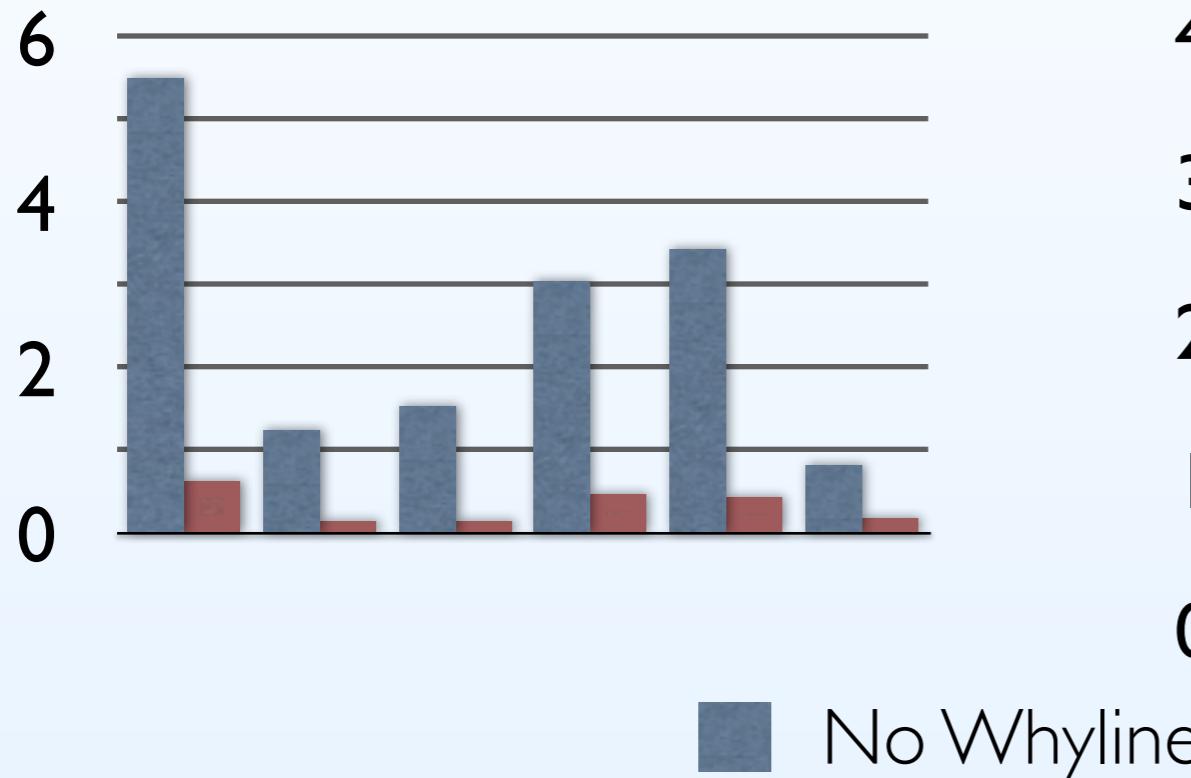
a Workspace that Helps You Link Instructions, Numbers and Events



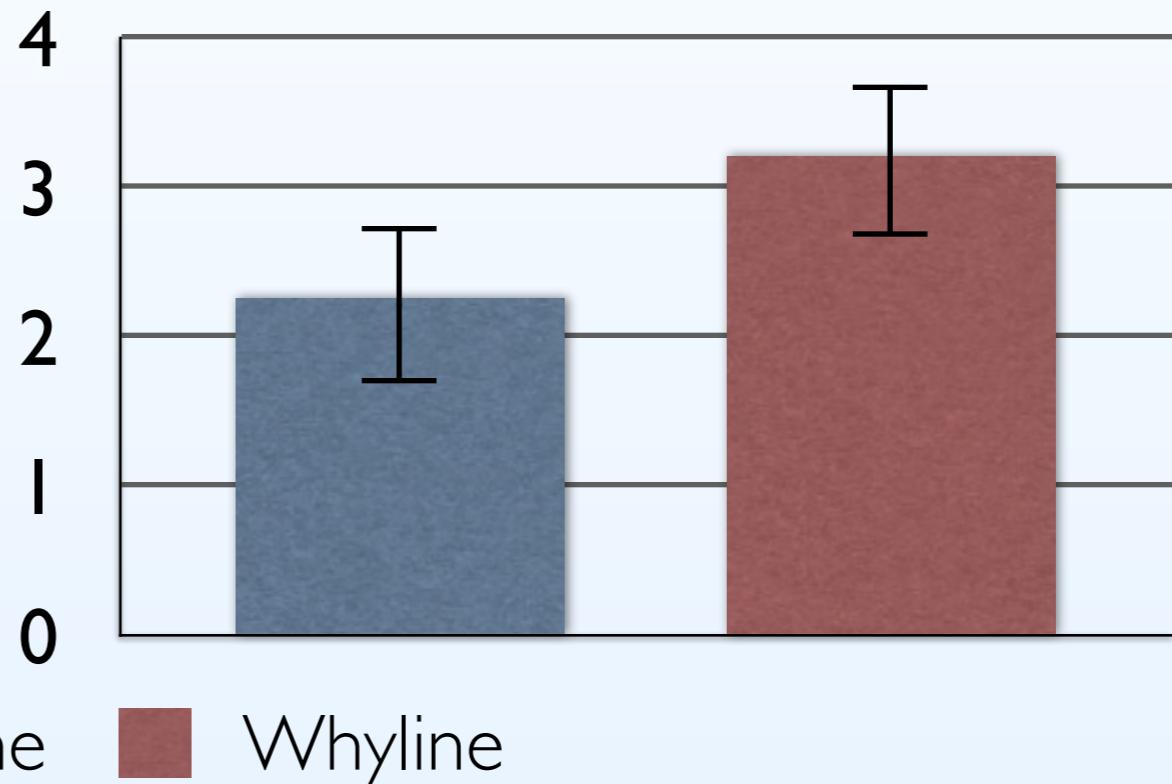
Whyline

a Workspace that Helps You Link Instructions, Numbers and Events

Debugging Time on 6 debugging scenarios (minutes)



Average # of behaviors correctly implemented.



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

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

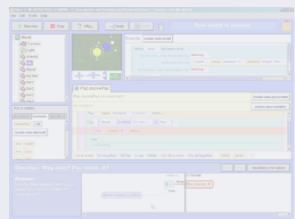
Projects



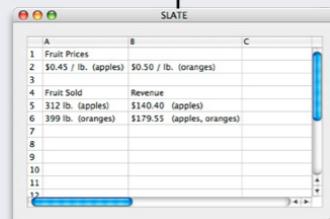
What influences a spreadsheet's correctness, but is not formally specified in the spreadsheet?

Slate

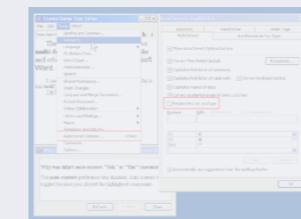
with Michael Coblenz



2003



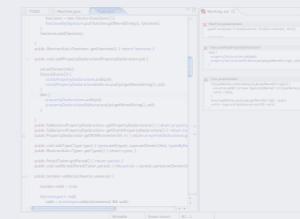
2004



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 window has three colored buttons (red, orange, green) in the top-left corner. The spreadsheet has columns labeled A, B, and C. Row 1 contains "Fruit Prices". Row 2 contains "\$0.45 / lb." in column B. Row 4 contains "Fruit Sold" in column A and "Revenue" in column B. Row 5 contains "312 lb." in column A and "\$140.40" in column B. Row 6 contains "399 lb." in column A and "\$179.55" in column B. Rows 7 through 12 are empty. A blue vertical bar is positioned to the right of column C, and a blue horizontal bar is at the bottom of the window. The status bar at the bottom right shows "HCII".

	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

The screenshot shows a spreadsheet application window titled "SLATE". The spreadsheet has three columns labeled A, B, and C. Row 1 contains "Fruit Prices". Row 2 contains "\$0.45 / lb. (apples)" in column A and "\$0.50 / lb. (oranges)" in column B. Row 4 contains "Fruit Sold" in column A and "Revenue" in column B. Row 5 contains "312 lb. (apples)" in column A and "\$140.40 (apples)" in column B. Row 6 contains "399 lb. (oranges)" in column A and "\$179.55 (apples, oranges)" in column B. A blue selection bar is visible at the bottom of the sheet. In the bottom right corner of the spreadsheet area, there is a red box containing the text "=A6 * A2" and a green box containing the text "should be A6 * B2". A vertical arrow points upwards from the red box towards the green box.

	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			

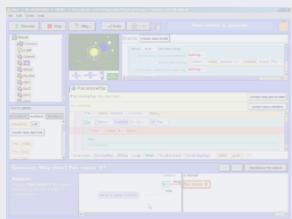
strange label calls attention to discrepancy

Projects

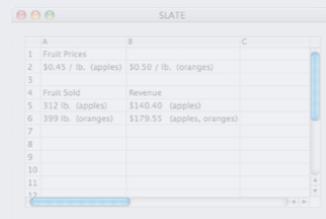


Why are programs that manipulate structured data so large and difficult to maintain?

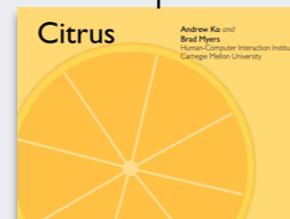
Citrus



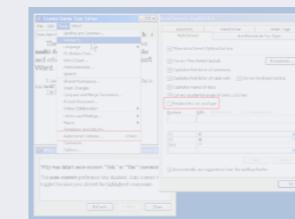
2003



2004



Citrus

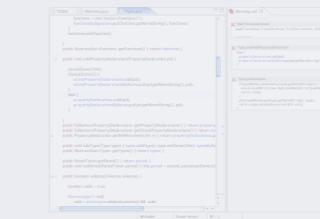


2005



public class ImageTransformer {

Rotates an `image` by an `angle` given in degrees.
For example,
`transformer.rotate(img, 45)`
performs this operation:



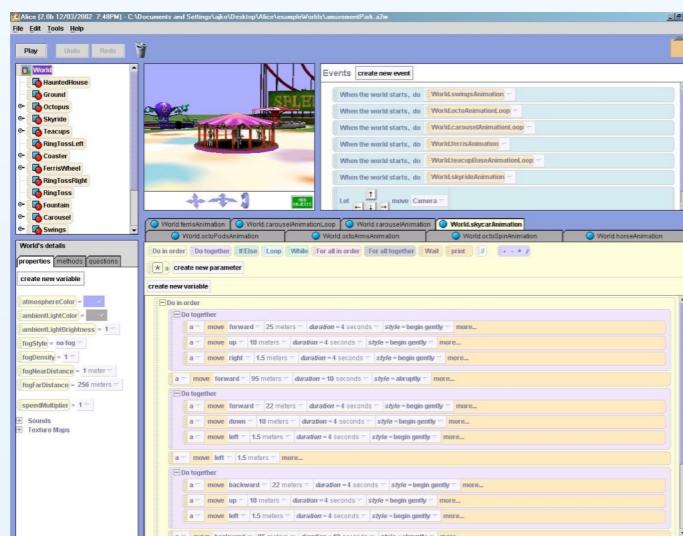
2006



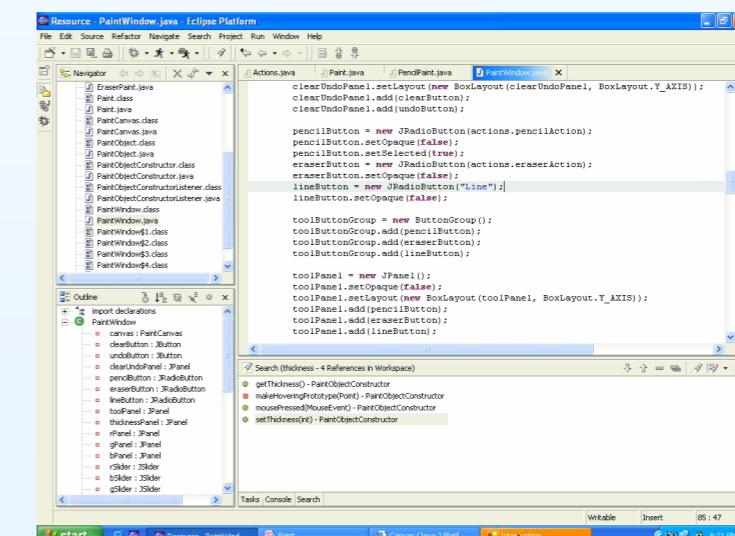
Software for Structured Data



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)
```

New



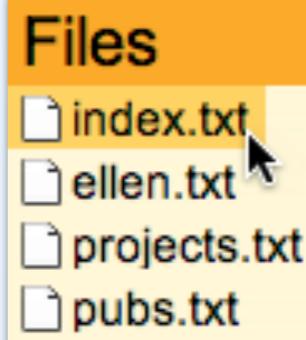
value
restrictions

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

abcdefghijklmnopqrstuvwxyz

event
handlers

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



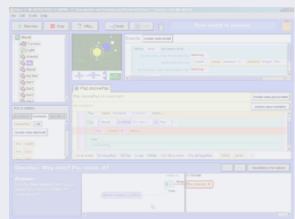
Projects



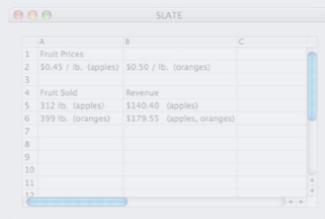
What questions do users of office applications have difficulty answering?

Crystal

with undergrad David Weitzman



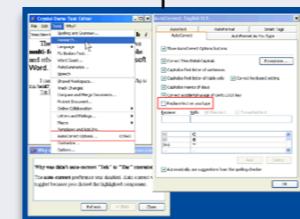
2003



2004



Andrew Ko and
Brad Myers
Human-Computer Interaction Institute
Carnegie Mellon University



2005



public class ImageTransformer

Rotates an `Image` by an angle given in degrees.

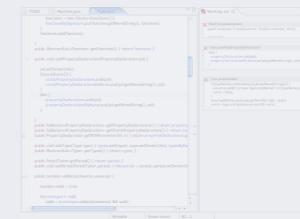
For example,

`transformer.rotate(img, 45)`

performs this operation:



`public void rotate(Image img, double degrees)`



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?

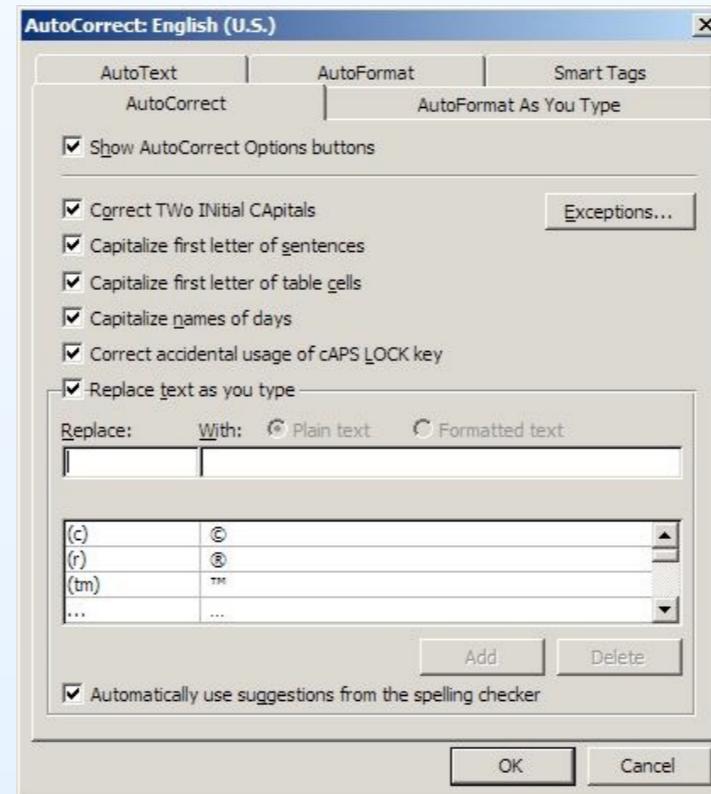
Safari can't open the page "http://
your computer isn't connec

Why is this
whitespace here?

Debugging Your Office App



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



Crystal

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



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

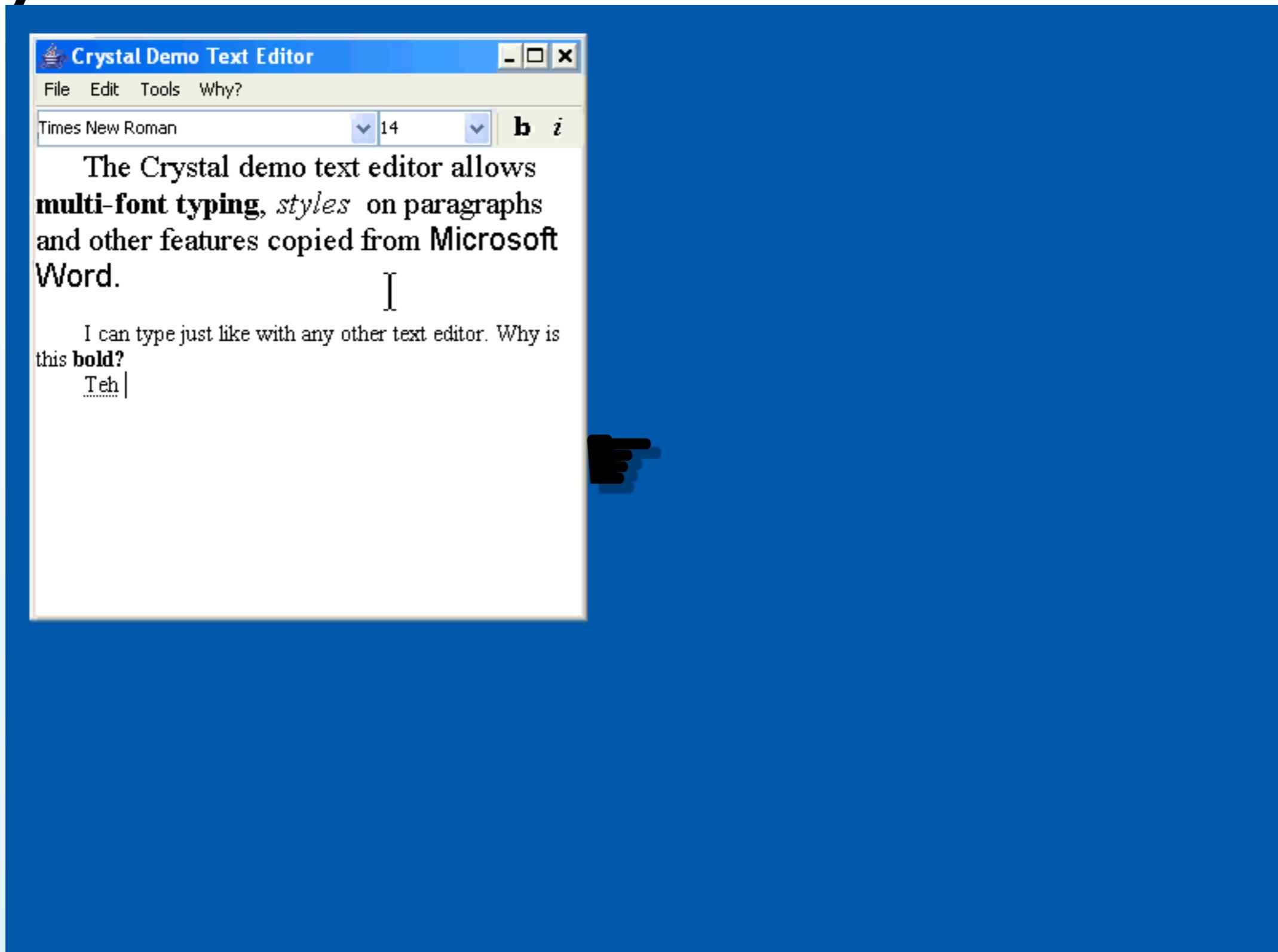
Maintain a causality graph as part of the undo history. Answers are all paths from a visible input to a visible output.

Teh|

Why didn't this get
auto corrected?

Crystal

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



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.

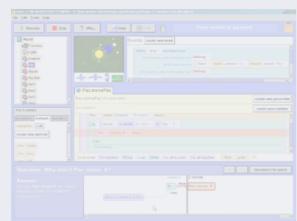
Currently speaking with Microsoft developers about the potential for this technology in future versions of Office.

Projects

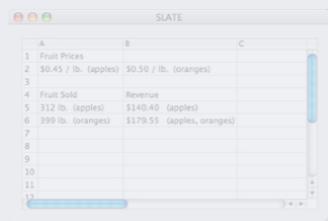


How do programmers utilize text as a medium for their work?

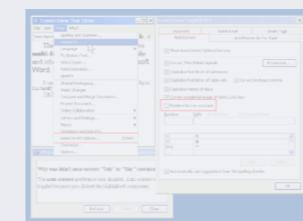
Barista



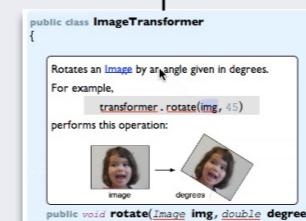
2003



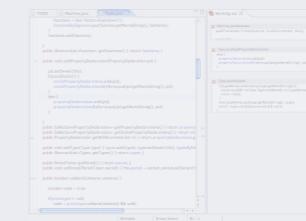
2004



2005



2005



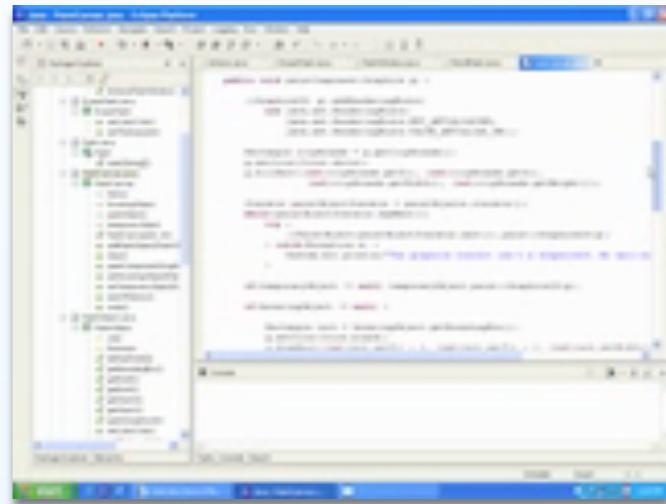
2006



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);
    }

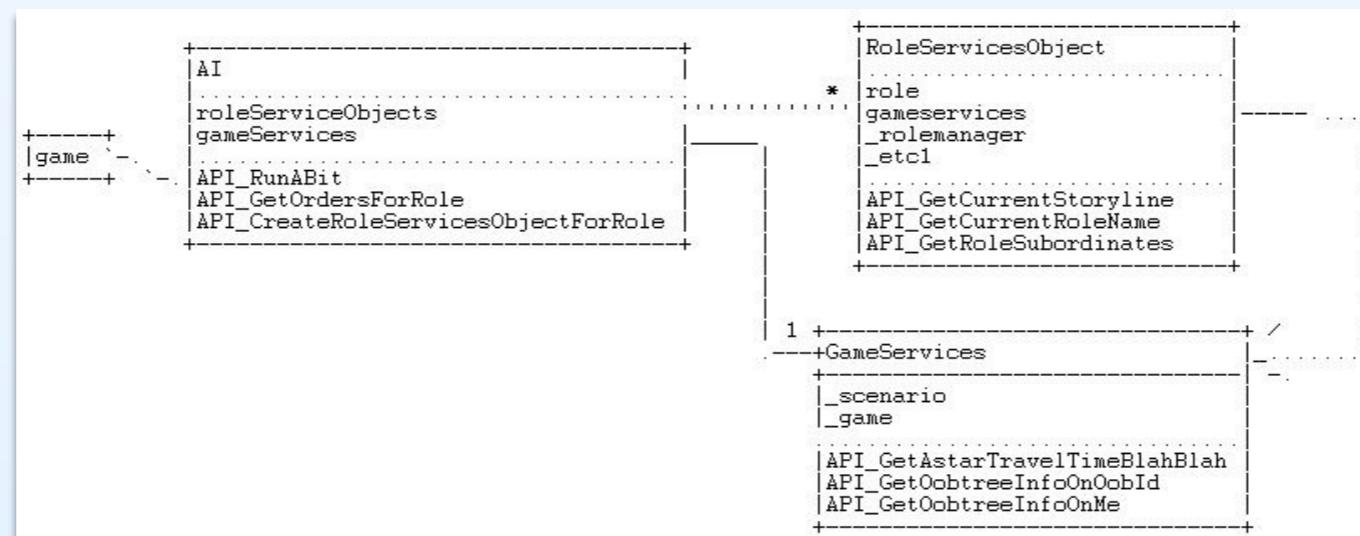
    /**
     * main routine that makes the calculation
     */
    public void Process() {
        if(owner != null) {
            if(current_time <= 0) //causal function
                return;
            if(current_time < duration.endValue) {
                if(Math.abs(exponent.getEndValue()) < 0.01)
                    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.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.



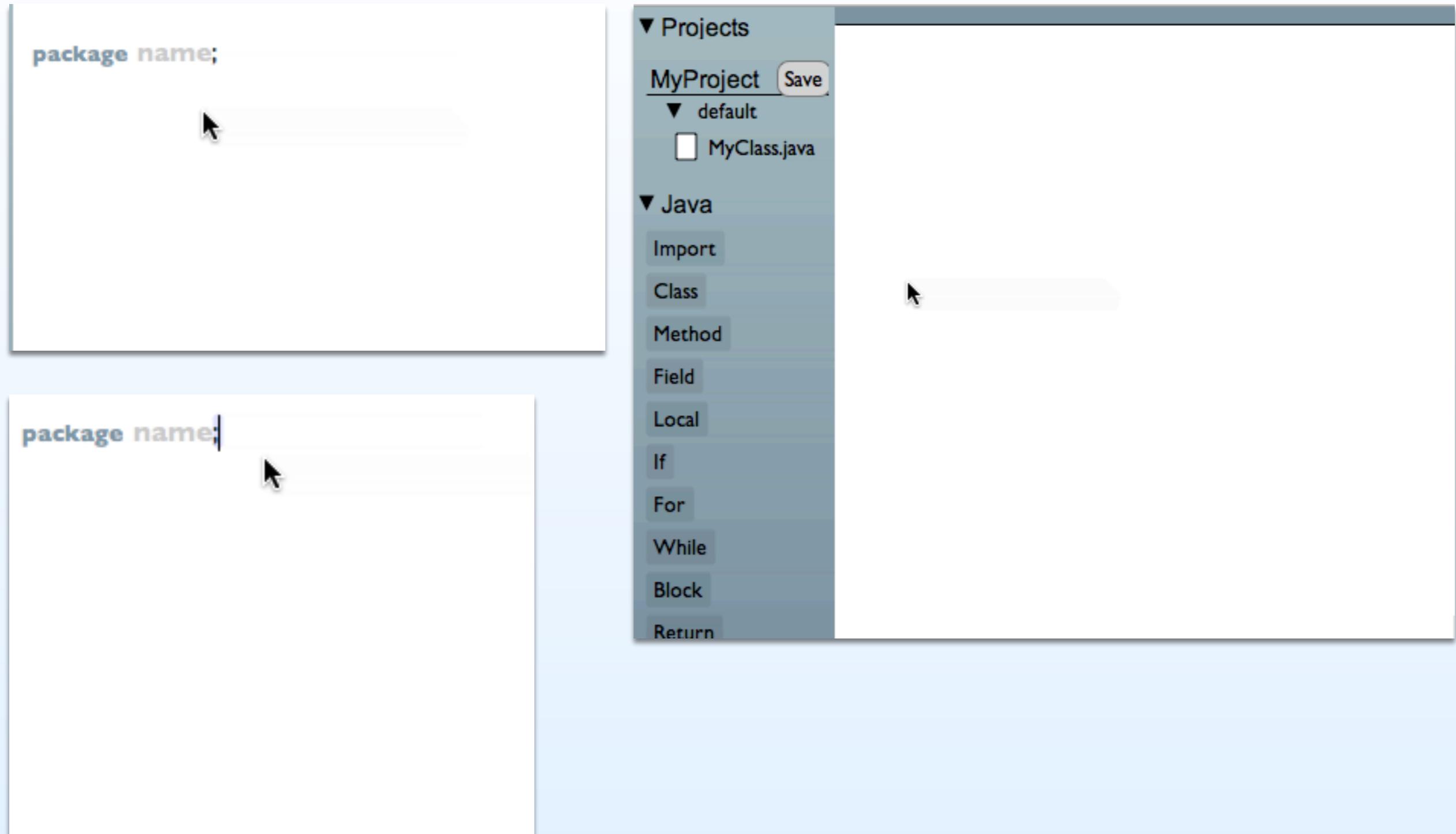


Design code editor toolkit that supports rich media, embedded tools, and alternative views, while still supporting conventional text editing.

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)
    {
    }
}
```

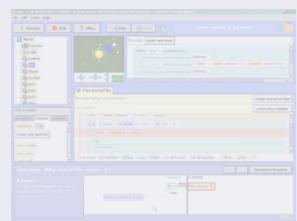
Projects



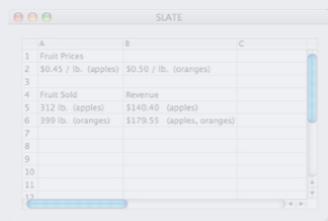
What are the major sources of effort when using an IDE to complete software maintenance tasks?

Jasper

with Michael Coblenz



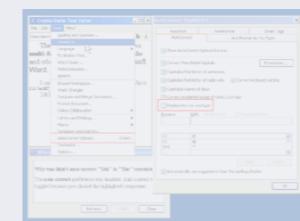
2003



2004



Citrus



2005



public class ImageTransformer {

Rotates an `image` by an `angle` given in degrees.

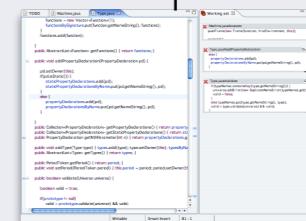
For example,

`transformer.rotate(img, 45)`

performs this operation:



public void rotate(Image img, double degrees)



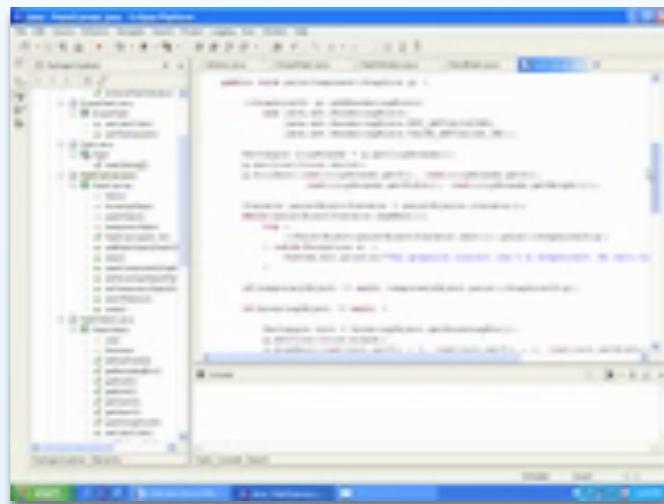
2006



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.

Jasper

Java Aid with Sets of Pertinent Elements for Recall

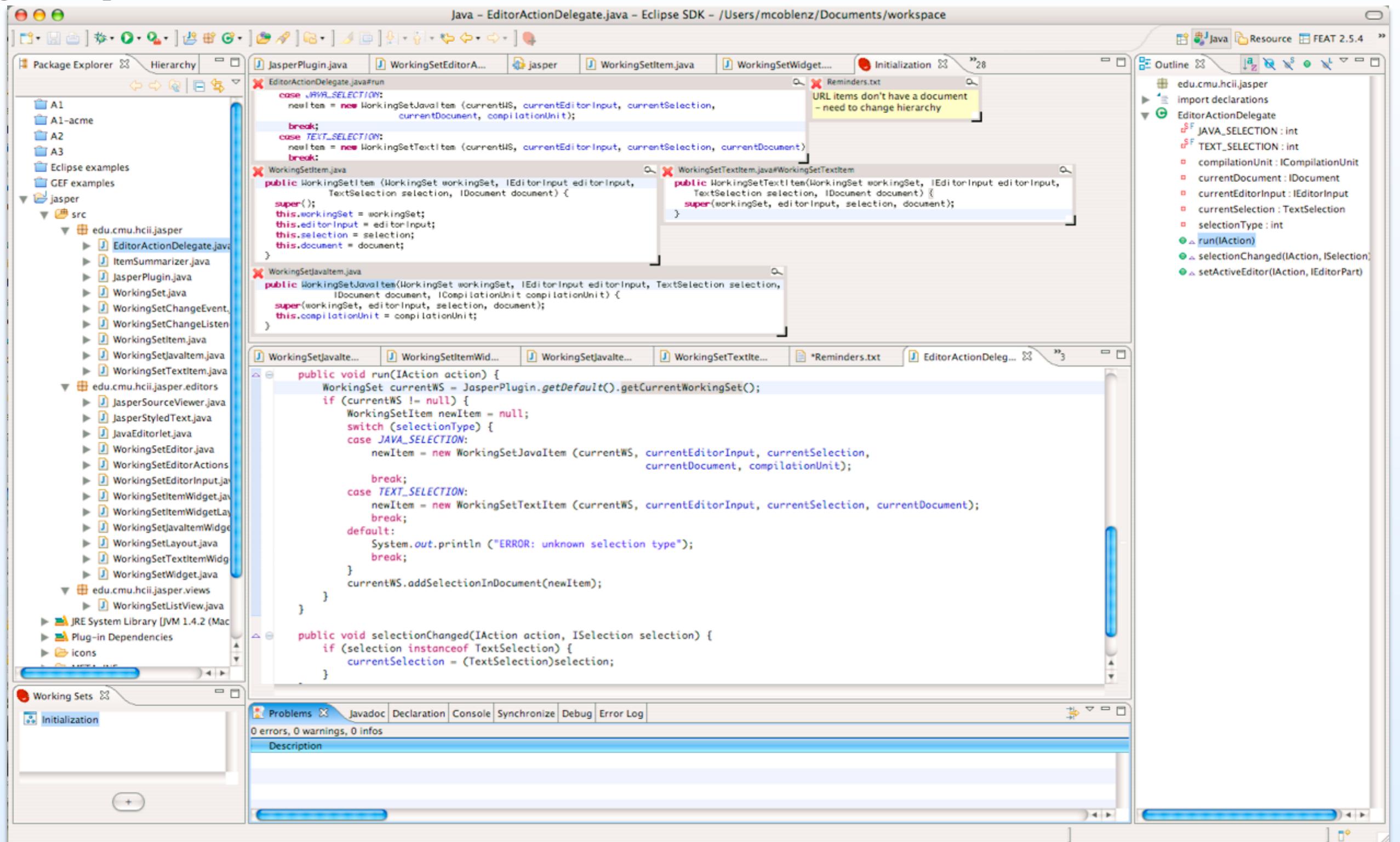


Design a user interface that allows all of the relevant code to be viewed in a single place.

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

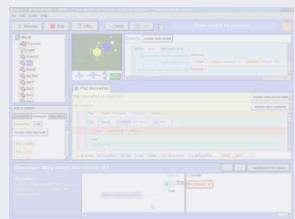


Projects

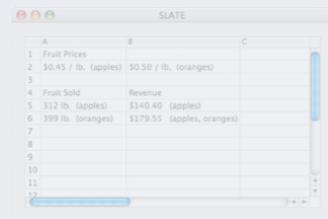


What are the information needs
of bug fixing work at Microsoft?

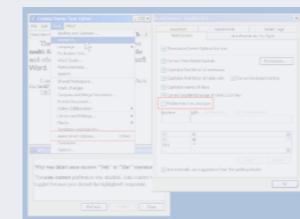
Internship
with Rob DeLine



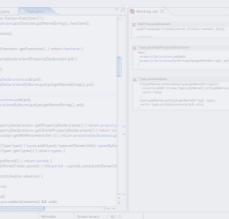
2003



2004



2005



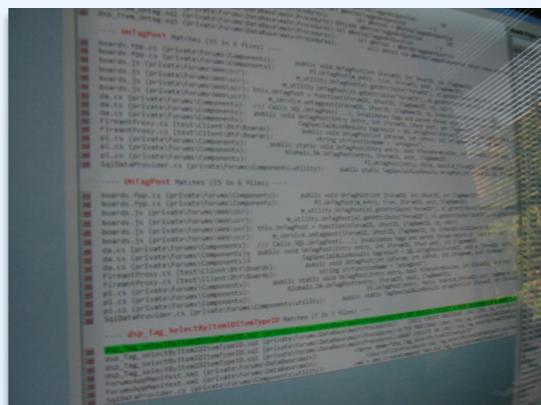
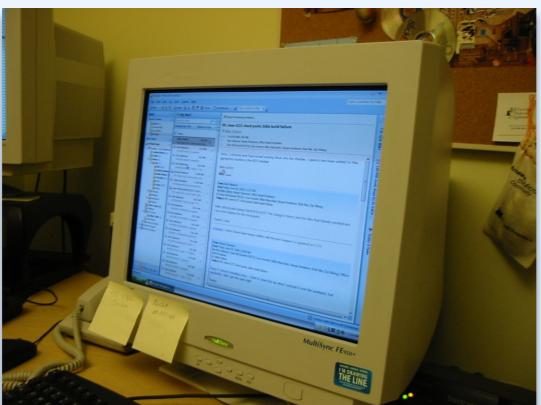
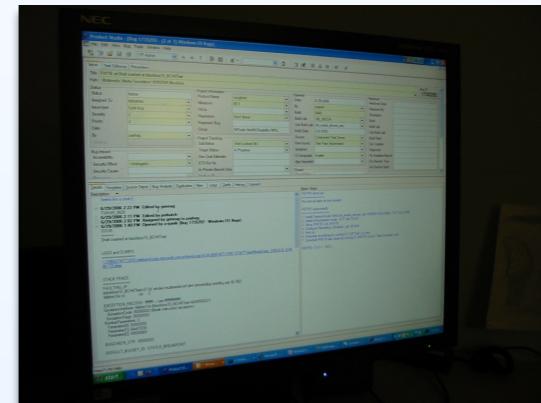
2006



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.

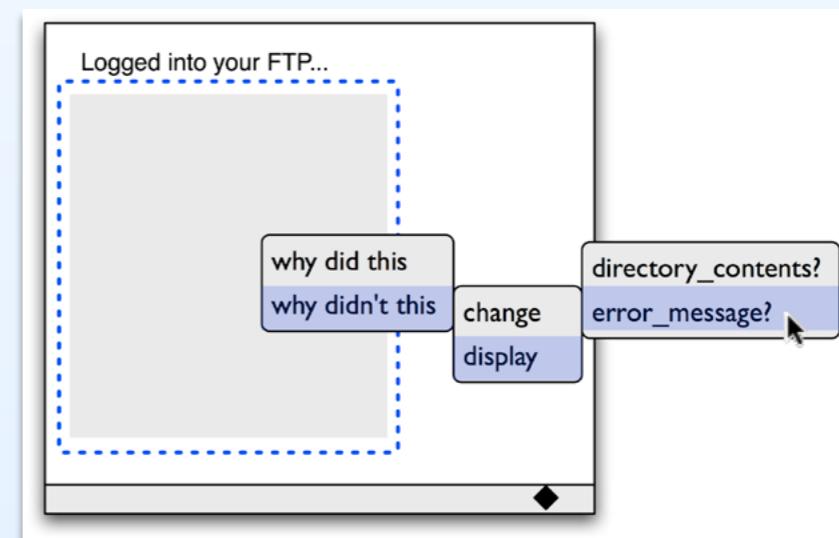
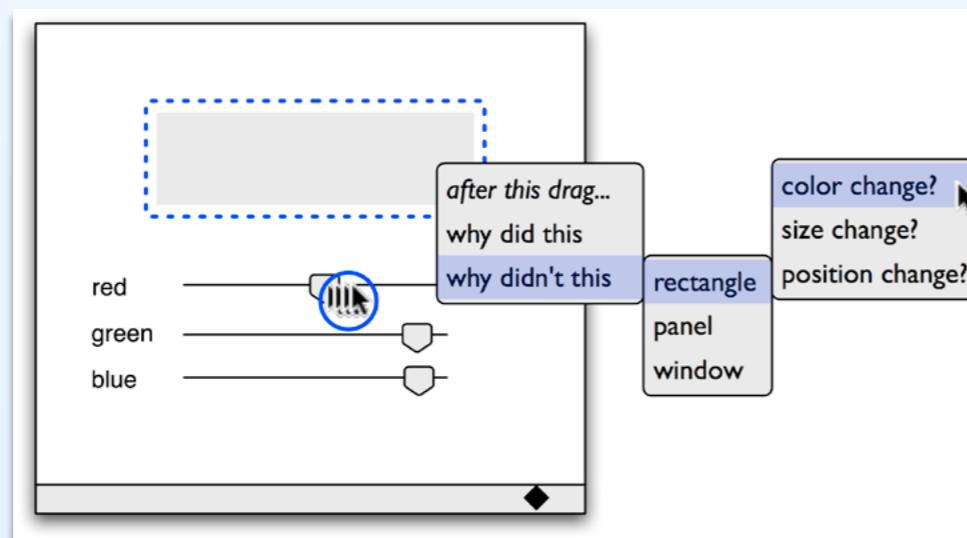
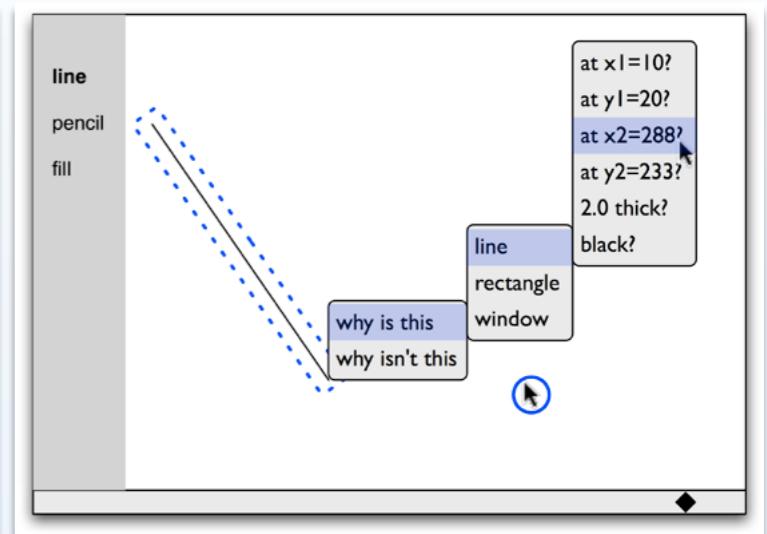
... → **enabled set to false** → **if(enabled) was false** → **setColor Color.grey**

... → **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.BasicTableUIT.paint(BasicTableUIT.java, Compiled Code)
```

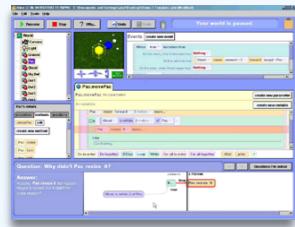


Conclusions

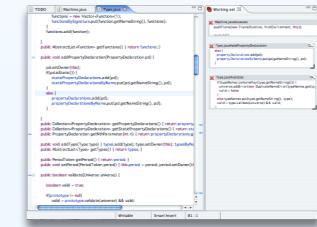
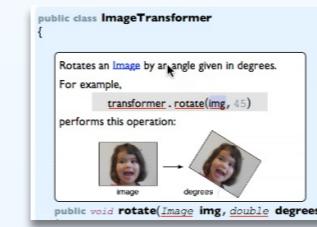
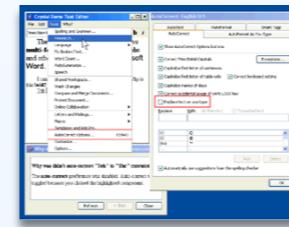
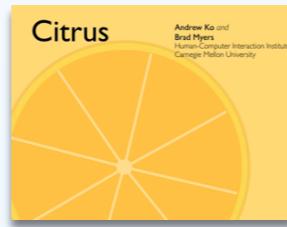
Software development is complex and social work.

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

Questions?



SLATE		
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.		
13.		
14.		
15.		
16.		
17.		



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



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