

# User-Centered Design

**SWE 632**

**Fall 2021**



# Administrivia

- HW1 due next Tuesday before class

# What We Learned & Looking Ahead

- Examined human cognition
- Have 2 ways to identify usability issues (Heuristics & Principles)
- But... is HCI just identifying usability issues?
- What does design mean?
- How do we learn about user needs?
- How do we build designs?
- How do we evaluate designs?

# Overview of User-Centered Design



# In Class Discussion

- *Today's question:*
  - What does user-centered design mean to you?

# User-centered design



# User-centered design

Who are the  
users?

What are the user's  
needs?

What are the  
user's tasks and  
goals?



How does the product fit  
into the broader context  
of their lives?

What problems may  
users encounter w/  
current ways of doing  
things?

What extreme  
cases may exist?

# Technology-Centered Design

What can this  
technology  
do?

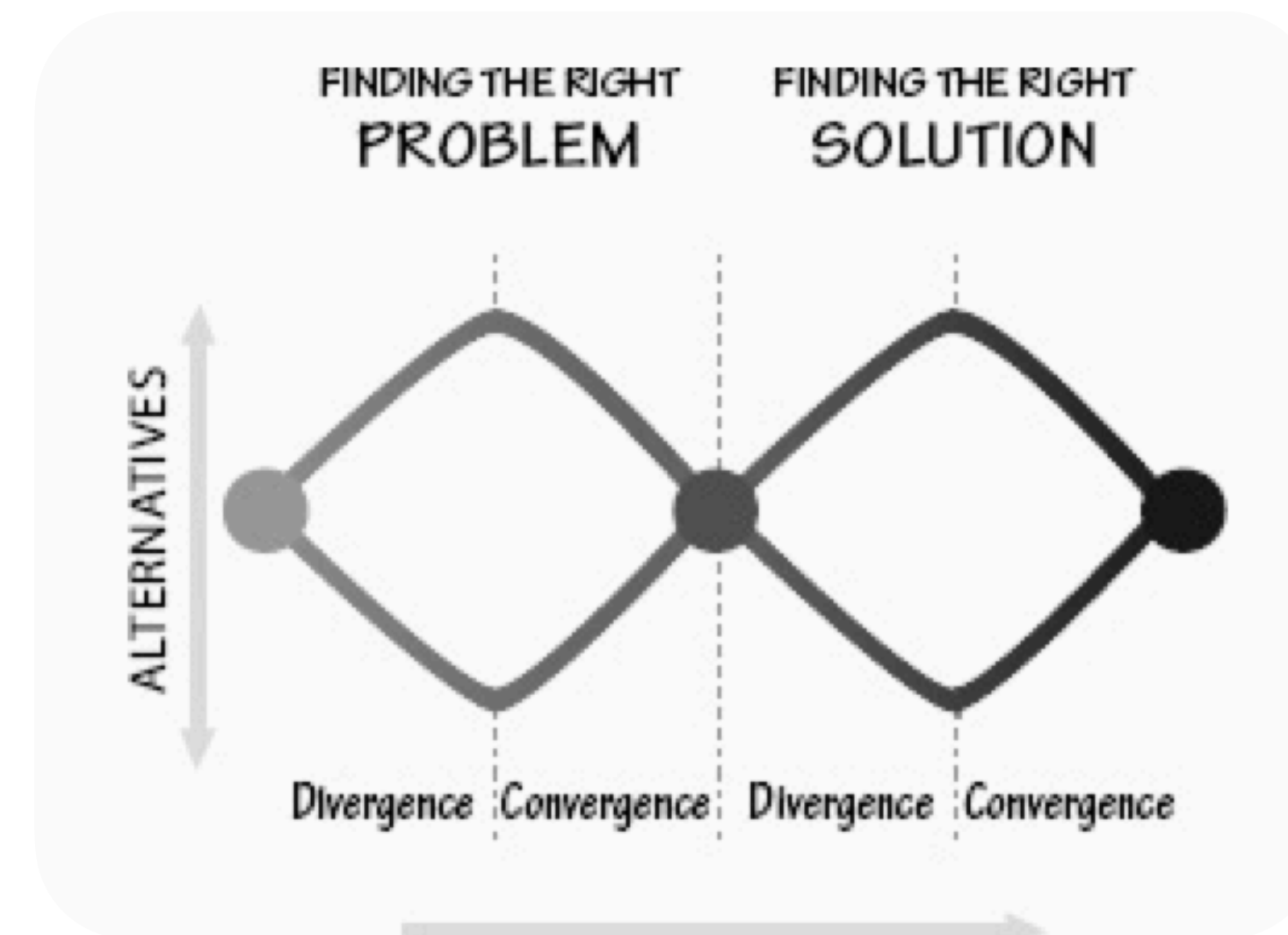


How might  
users use it?

What features  
does it have?

# Double Diamond Model of Design

- Question problem, expand scope, discover fundamental issues
- Converge on problem
- Expand possible solutions
- Converge on solution



# Iterative Model of Design

## Observation

(Re)Define the Problem  
Understand User Needs

## Test

Evaluate what  
you have built



## Idea Generation

Brainstorm  
what to build

## Prototype

Build

# Iteration, Iteration, Iteration

- Repeated study and testing
- Use tests to determine what is working or not working
- Determine what the problem might be, redefining the problem
- Collect more data
- Generate new alternatives

# Observation



# Needfinding (a.k.a. design research)

- Goal: understand user's needs
- Use of methods to gather qualitative data
  - behaviors, attitudes, aptitudes of potential and existing users
  - technical, business, and environmental contexts - domain
  - vocabulary and social aspects of domain
  - how existing products used
- Empowers team w/ credibility and authority, helping inform decisions

# Needfinding vs. market research

## Needfinding

- What users really need
- How they will really use product
- Qualitative methods to study in depth
- Small numbers of participants

## Market research

- Who might purchase item
- What factors influence purchasing
- Quantitative studies w/ focus groups, surveys
- Large numbers of participants

# Example

- Cooper conducted a user study for entry-level video editing product
- Company built professional software, looking to move into consumer software
  - Help connect those w/ computers and video cameras
- Found strongest desire for video editing was parents
- Found 1/12 had successfully connected camera, using work IT guy

# Solving the correct problem

- Practices may sometimes mask deeper problems
- Goal: uncover layers of practices to understand how problems emerge

# Interviews

- May include both current users and potential users w/ related needs
- Questions
  - context of how product fits into lives or work
  - when, why, how is or will product be used
  - what do users need to know to do jobs?
  - current tasks and activities, including those not currently supported
  - goals and motivations of using product
  - problems and frustrations with current products or systems

# Observations

- Most incapable of accurately assessing own behaviors
- May avoid talking about problems to avoid feeling dumb
- Observing yields more accurate data
- Capture behaviors: notes, pictures, video (if possible)

# Contextual inquiry

- Method that includes both interviews and observations
- Next week's lecture

# Idea Generation



# Creativity

- What's the most creative software app you've seen?
- What made it creative?

# Ideation

- Process of generating, developing, communicating new **ideas**
- Guidelines and best practices
  - Generate numerous ideas
  - Number ideas
  - Avoid premature dismissal of ideas
  - Sharpen the **focus** - pose the right problem
  - Build and jump - build to keep momentum on ideas, jump when theme tapers out

# Prototyping

# Prototyping - Building Quickly

- Build quick prototype or mock-up of each potential solution
- “Wizard of Oz” Studies
- Mainly performed to ensure the problem is well understood

# Testing

# Testing - User Centered Evaluation

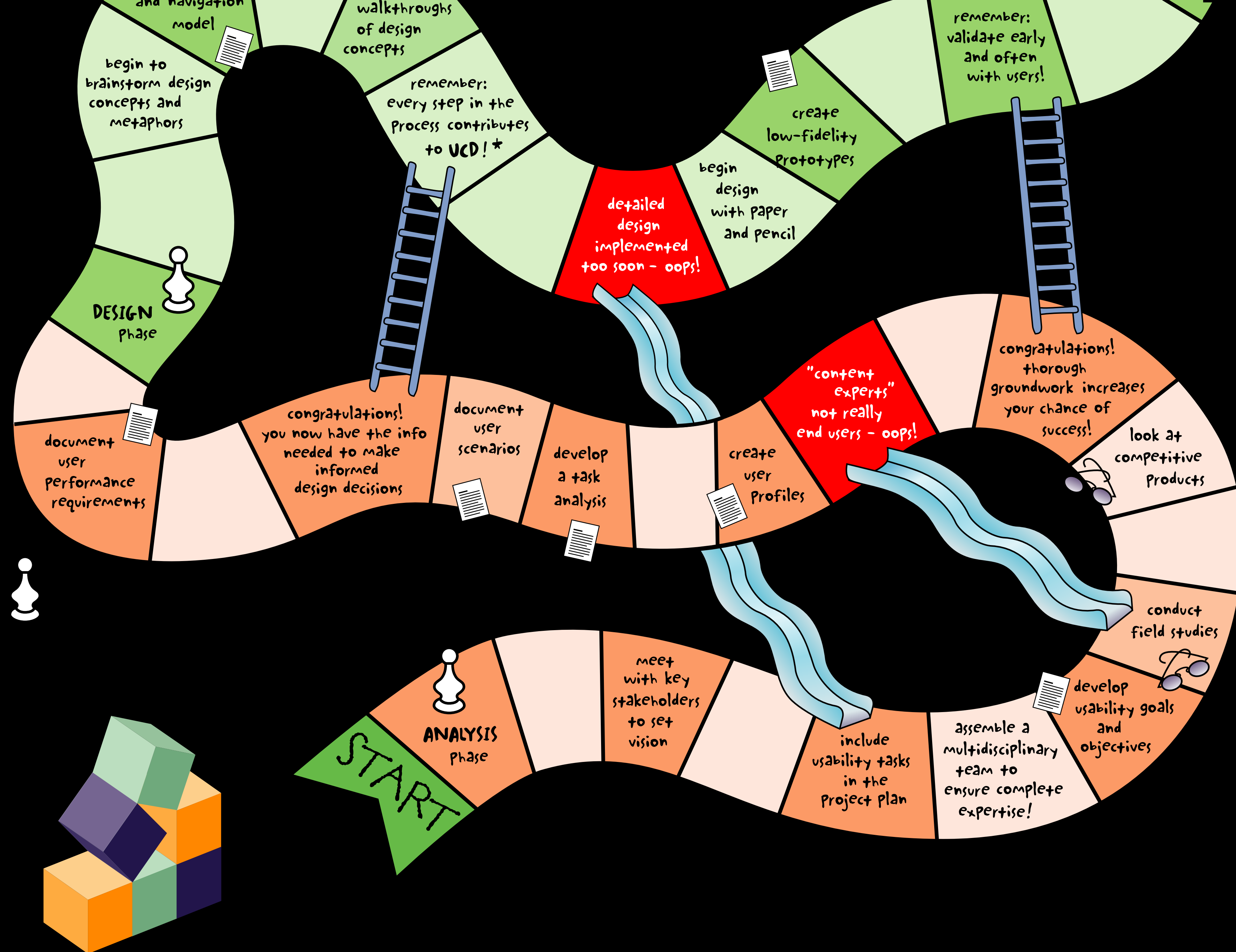
- Test with population similar to target population
- Have them use prototypes as close as possible to intended
- If possible, have two people use a prototype, one guiding the other's use.
- More on this in a future lecture...

# User-Centered Design Considerations

# Fail Fast

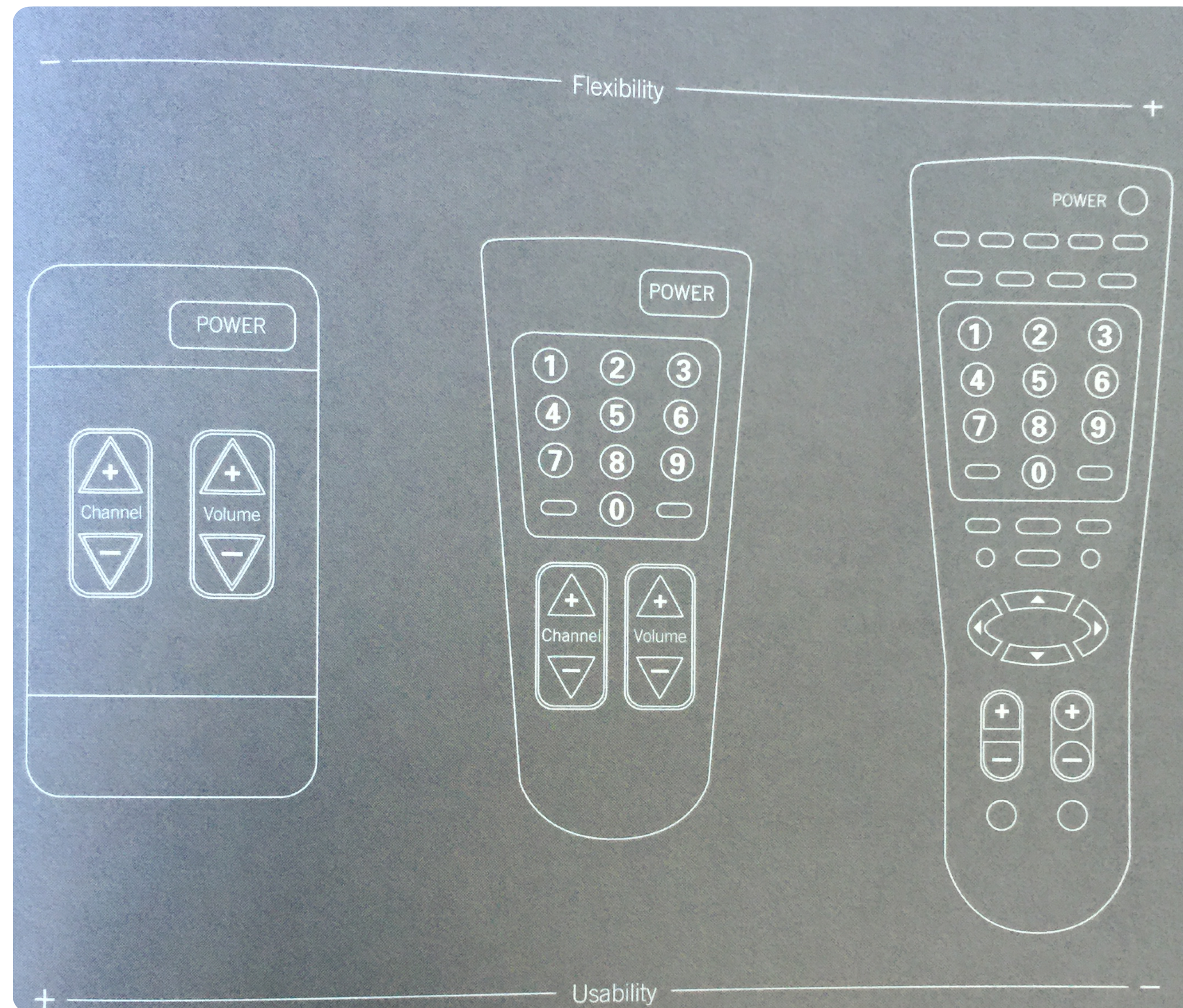
- “*Fail frequently, fail fast*” David Kelley, founder of Ideo
- Failure is learning experience
- Crucial to understand correct problem to solve & ensure solution is appropriate
- Abstract requirements are invariably wrong
- Requirements produced by asking people what they want are wrong







# Flexibility-usability tradeoff



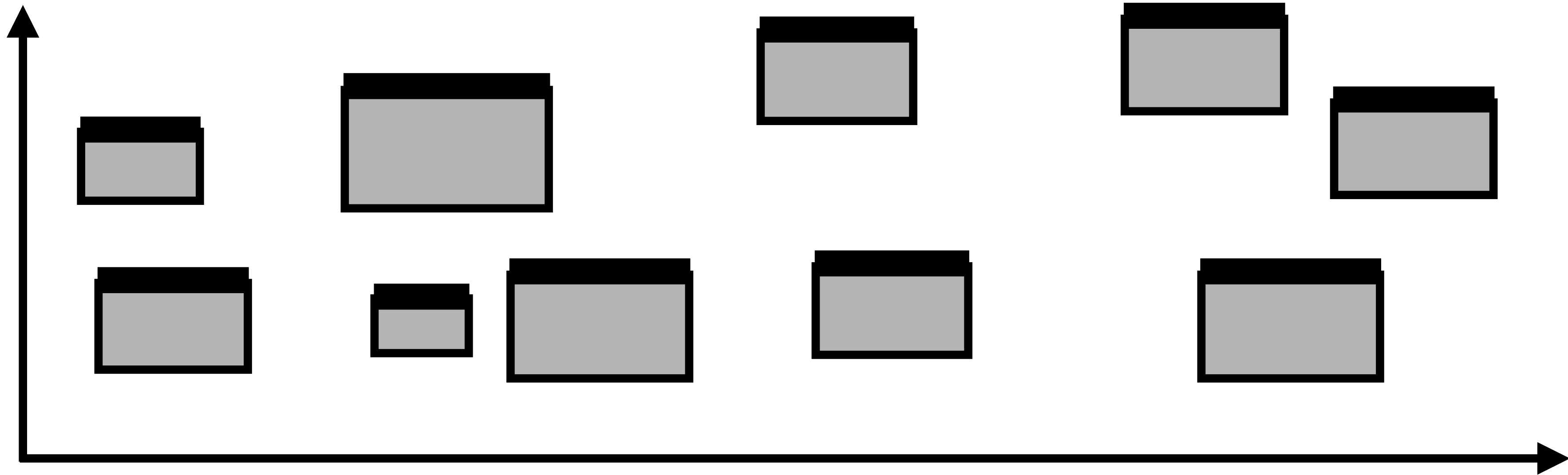


# Flexibility-Usability Tradeoff

- Jack of all trades, master of none
- Better understanding needs enables specialization and optimization for common cases
- System evolution over time:
  - flexibility —> specialization

# **Examples of flexibility / usability tradeoff?**

# Navigating Design Space



- What are key decisions in interaction design?
- What alternatives are possible?
- What are tradeoffs between these alternatives?

# Hierarchy of Design Decisions

- What are you (*re*)designing?
  - The width of the text input
  - The maximum length of a valid username
  - When in the signup process users enter their username
  - If the user must create a username when signing up
  - Whether users are anonymous or have a login
  - If users can interact with other users in your application

# Picking the Right Level of Redesign

- Where are the user's pain points
- What are the underlying causes
- What would be the value to the user of addressing issue
- What do you have time to build (or change)

# Activities and Tasks

- *Activity* - set of tasks performed together for a common goal
  - Go shopping
- *Task* - component of an activity, organized cohesive set of operations towards a single low-level goal
  - Drive to market
  - Find shopping basket
  - Find item in store
  - Pay for items



# Activities and Tasks

- Activities are *hierarchical*
- High-level activities spawn other activities, spawn tasks
- Software supports tasks and activities
- Important to design for *activities*, not just tasks
  - Support whole activity seamlessly
  - Ensure interactions between tasks do not interfere

# Example - iPod

- Supports entire activity of listening to music
  - discovering music
  - purchasing music
  - getting it into music player
  - developing playlists
  - sharing playlists
  - listening to music
  - ecosystem of external speakers and accessories



# Example of a Design Process

- How do you get from let's make listening to music better to designing an iPod??
- Iterative design...
  - But what does that actually look like more concretely?
  - What insights into activity help inspire design?
  - How does watching users help lead to these insights?
  - How do insights translate into an actual real design?
  - How do know the new design is actually better?

# In-Class Activity

- Redesign PatriotWeb
- Consider: at what level are you redesigning it? What's the problem (at this level)? How are you making it better?

# Example

# Domain: Debugging

- *Design goal:* how do we better support activity of debugging in large, complex codebases?
- Build a better debugging tool (?)
  - What should it do? How would it help?
    - Design a better watch window? Support new types of breakpoints?
  - What's really the key steps in debugging that lead users to struggle the most?

# Domain: Debugging

# Developers Ask Reachability Questions

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# ABSTRACT

## **ABSTRACT**

A reachability question is a search across feasible paths through a program for target statements matching search criteria. In three separate studies, we found that reachability questions are common and often time consuming to answer. In the first study, we observed 13 developers in the lab and found that half of the bugs served 13 developers inserted were associated with reachability questions. In the second study, 460 professional software developers reported asking questions that may be answered using reachability questions more than 9 times a day, and 82% rated one or more as at least somewhat hard to answer. In the third study, we observed 17 developers in the field and found that 9 of the 10 longest activities were associated with reachability questions. These findings suggest that answering reachability questions is an important part of difficulty understanding large, complex programs.

## **Categories and Subject Descriptors**

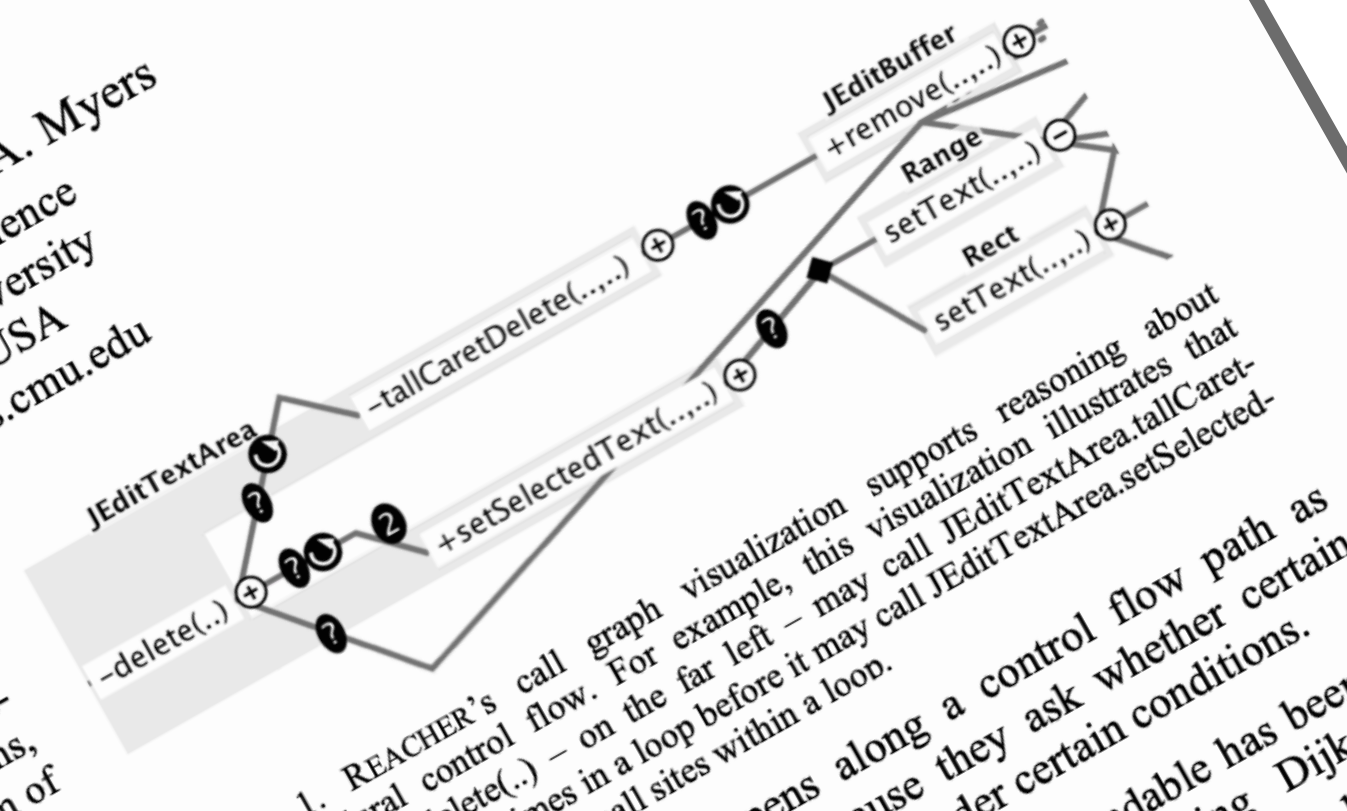
D.2.6 [Software Engineering]: Software Testing; D.2.7 [Software Engineering]: Testing and Debugging; E.5 [Performance Evaluation]: Performance Analysis; F.4.1 [Mathematical Logic and Formal Languages]: Mathematical Logic; I.2.2 [Artificial Intelligence]: Programming Methodology; K.4 [Computational Social Science]: Human Factors; O.4 [Computer Systems Organization]: Operating Systems; O.5 [General and Theoretical]: Design Methods; O.6 [Systems Management]: Software Management; O.7 [Systems Management]: Software Development Processes

## Categories and Subjects

Human Computer  
School of  
Carnegie

# Visualizing Call Graphs

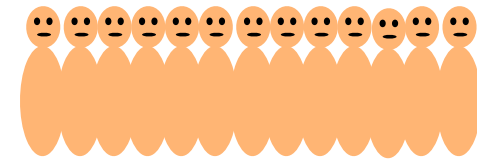
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# Observing Developers

## Participants



17 professional developers

## Tasks

~90 minutes

picked one of their own coding tasks involving unfamiliar code

Interesting. This looks like, this looks like the code is approximately the same but it's refactored. But the other code is.

Changed what flags it's ???

He added a new flag that I don't care about. He just renamed a couple things.

# Transcripts

Well.

So the change seemed to have changed some of the way these things are registered,

but I didn't see anything that talked at all about whether the app is running or whether the app is booted. So it seems like, this was useless to me.

(annotated with observer notes about goals and actions)

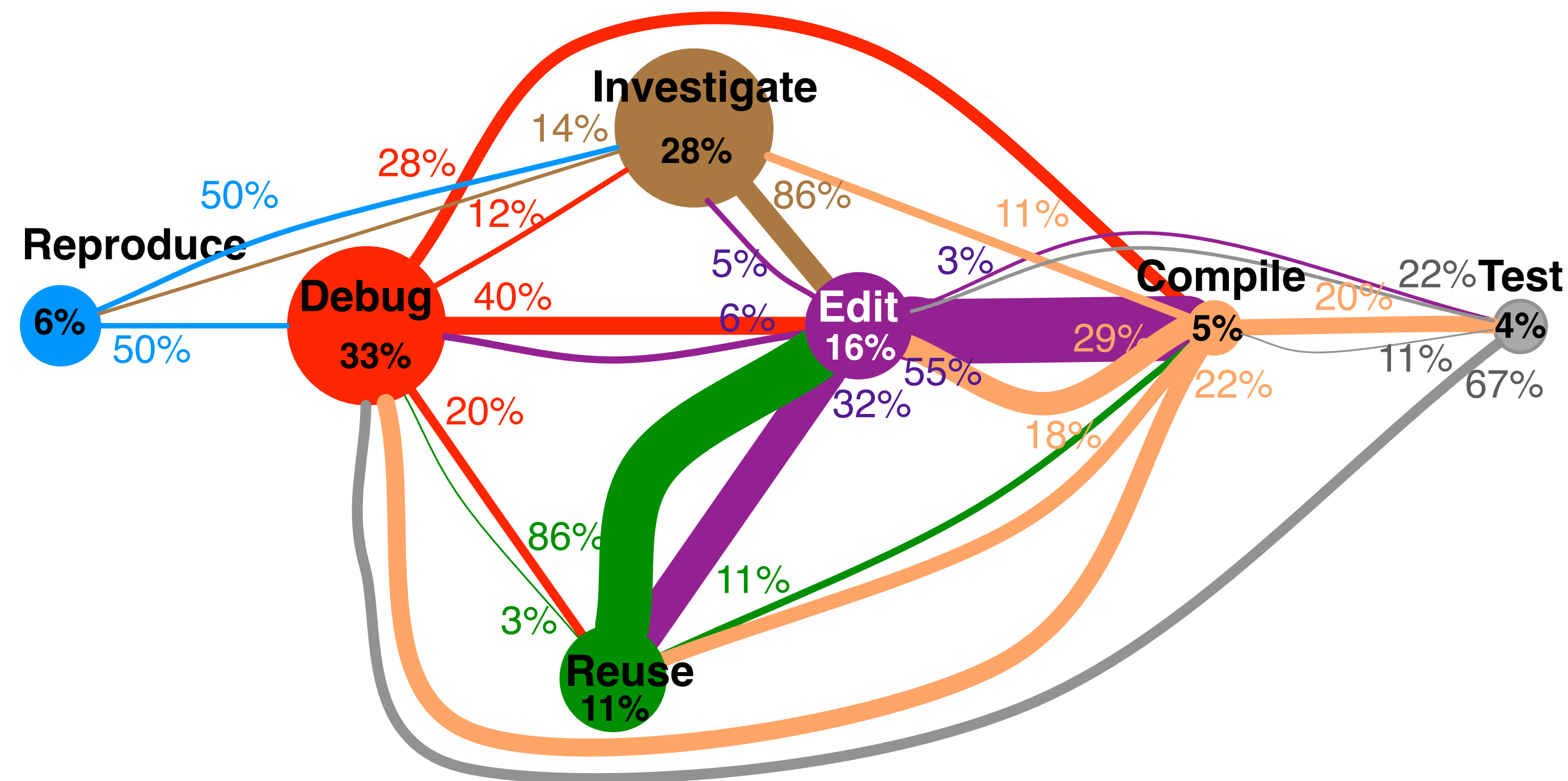
(386 pages)

## Activities

[illegible]



# Coding Activities



Circle size: % of time

Edge thickness: % of transitions observed

# Longest Activities: Control Flow

## 4 out of the 5 longest investigation activities

Primary question	Time (m)	Related control flow question
How is this data structure being mutated in this code?	83	Search downstream for <b>writes</b> to data structure
“Where [is] the code assuming that the tables are already there?”	53	<b>Compare</b> behaviors when tables are or are not loaded
How [does] application state change when <i>m</i> is called denoting startup completion?	50	Find field <b>writes</b> caused by <i>m</i>
“Is [there] another reason why <i>status</i> could be non-zero?”	11	Find statements through which values <b>flow</b> into status

## 5 out of the 5 longest debugging activities

Where is method <i>m</i> generating an error?	66	Search downstream from <i>m</i> for <b>error</b> text
What resources are being acquired to cause this deadlock?	51	Search downstream for <b>acquire</b> method calls
“When they have this attribute, they must use it somewhere to generate the content, so where is it?”	35	Search downstream for <b>reads</b> of attribute
“What [is] the test doing which is different from what my app is doing?”	30	<b>Compare</b> test traces to app traces
How are these thread pools interacting?	19	Search downstream for <b>calls</b> into thread pools

1. I am a 35-year-old male, 6'2", 180 lbs, with a background in software development. I am currently looking for a job in the tech industry, preferably in a role that involves problem-solving and learning new technologies. I have a Bachelor's degree in Computer Science from the University of California, Berkeley, and have worked for several tech companies, including Google and Facebook. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

2. I am a 28-year-old female, 5'6", 140 lbs, with a background in marketing and sales. I am currently looking for a job in the marketing industry, preferably in a role that involves creative problem-solving and strategic thinking. I have a Bachelor's degree in Marketing from the University of Texas at Austin, and have worked for several marketing agencies, including Ogilvy and Mather. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

3. I am a 30-year-old male, 6'0", 170 lbs, with a background in engineering and product development. I am currently looking for a job in the engineering industry, preferably in a role that involves problem-solving and technical expertise. I have a Bachelor's degree in Mechanical Engineering from the University of Michigan, and have worked for several engineering firms, including General Motors and Ford. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

4. I am a 25-year-old female, 5'4", 130 lbs, with a background in business and management. I am currently looking for a job in the business industry, preferably in a role that involves strategic thinking and leadership. I have a Bachelor's degree in Business Administration from the University of Wisconsin-Madison, and have worked for several business firms, including Amazon and Microsoft. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

5. I am a 32-year-old male, 6'1", 175 lbs, with a background in finance and investment. I am currently looking for a job in the finance industry, preferably in a role that involves strategic thinking and financial expertise. I have a Bachelor's degree in Finance from the University of Pennsylvania, and have worked for several finance firms, including Goldman Sachs and JP Morgan Chase. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

6. I am a 29-year-old female, 5'5", 135 lbs, with a background in law and legal affairs. I am currently looking for a job in the law industry, preferably in a role that involves strategic thinking and legal expertise. I have a Bachelor's degree in Law from the University of California, Los Angeles, and have worked for several law firms, including Skadden, Arps, Slate, Fierman & LLP. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

7. I am a 31-year-old male, 6'3", 185 lbs, with a background in science and research. I am currently looking for a job in the science industry, preferably in a role that involves problem-solving and research expertise. I have a Bachelor's degree in Science from the University of California, San Diego, and have worked for several science firms, including Pfizer and Merck. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

8. I am a 27-year-old female, 5'3", 125 lbs, with a background in education and teaching. I am currently looking for a job in the education industry, preferably in a role that involves strategic thinking and teaching expertise. I have a Bachelor's degree in Education from the University of Illinois at Chicago, and have worked for several education firms, including K-12 schools and higher education institutions. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

9. I am a 33-year-old male, 6'4", 190 lbs, with a background in construction and engineering. I am currently looking for a job in the construction industry, preferably in a role that involves problem-solving and engineering expertise. I have a Bachelor's degree in Construction Management from the University of Florida, and have worked for several construction firms, including Skanska and Bechtel. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

10. I am a 26-year-old female, 5'2", 120 lbs, with a background in healthcare and medical research. I am currently looking for a job in the healthcare industry, preferably in a role that involves strategic thinking and medical expertise. I have a Bachelor's degree in Healthcare Administration from the University of Washington, and have worked for several healthcare firms, including Kaiser Permanente and UnitedHealthcare. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

11. I am a 34-year-old male, 6'5", 195 lbs, with a background in energy and power. I am currently looking for a job in the energy industry, preferably in a role that involves problem-solving and energy expertise. I have a Bachelor's degree in Energy Engineering from the University of Texas at Dallas, and have worked for several energy firms, including ExxonMobil and Chevron. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

12. I am a 24-year-old female, 5'1", 115 lbs, with a background in food and beverage. I am currently looking for a job in the food industry, preferably in a role that involves strategic thinking and food expertise. I have a Bachelor's degree in Food Science from the University of California, Davis, and have worked for several food firms, including Nestle and Unilever. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

13. I am a 36-year-old male, 6'6", 200 lbs, with a background in transportation and logistics. I am currently looking for a job in the transportation industry, preferably in a role that involves problem-solving and logistics expertise. I have a Bachelor's degree in Transportation Management from the University of Michigan, and have worked for several transportation firms, including FedEx and UPS. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

14. I am a 23-year-old female, 5'0", 110 lbs, with a background in media and communications. I am currently looking for a job in the media industry, preferably in a role that involves strategic thinking and media expertise. I have a Bachelor's degree in Media Studies from the University of Wisconsin-Madison, and have worked for several media firms, including NBC and CBS. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

15. I am a 37-year-old male, 6'7", 205 lbs, with a background in agriculture and farming. I am currently looking for a job in the agriculture industry, preferably in a role that involves problem-solving and farming expertise. I have a Bachelor's degree in Agriculture from the University of California, Davis, and have worked for several agriculture firms, including Monsanto and DuPont. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

16. I am a 22-year-old female, 4'11", 105 lbs, with a background in fashion and design. I am currently looking for a job in the fashion industry, preferably in a role that involves strategic thinking and design expertise. I have a Bachelor's degree in Fashion Design from the University of California, Los Angeles, and have worked for several fashion firms, including LVMH and Chanel. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

17. I am a 38-year-old male, 6'8", 210 lbs, with a background in aviation and flight. I am currently looking for a job in the aviation industry, preferably in a role that involves problem-solving and flight expertise. I have a Bachelor's degree in Aviation from the University of Texas at Austin, and have worked for several aviation firms, including Delta and American Airlines. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

18. I am a 21-year-old female, 4'10", 100 lbs, with a background in sports and athletics. I am currently looking for a job in the sports industry, preferably in a role that involves strategic thinking and sports expertise. I have a Bachelor's degree in Sports Management from the University of Wisconsin-Madison, and have worked for several sports firms, including Nike and Adidas. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

19. I am a 39-year-old male, 6'9", 215 lbs, with a background in music and entertainment. I am currently looking for a job in the music industry, preferably in a role that involves problem-solving and music expertise. I have a Bachelor's degree in Music from the University of California, Los Angeles, and have worked for several music firms, including Sony Music and Warner Bros. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

20. I am a 20-year-old female, 4'9", 95 lbs, with a background in dance and performance. I am currently looking for a job in the dance industry, preferably in a role that involves strategic thinking and dance expertise. I have a Bachelor's degree in Dance from the University of Wisconsin-Madison, and have worked for several dance firms, including American Ballet Theatre and New York City Ballet. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

21. I am a 40-year-old male, 6'10", 220 lbs, with a background in theater and drama. I am currently looking for a job in the theater industry, preferably in a role that involves problem-solving and theater expertise. I have a Bachelor's degree in Theater from the University of California, Los Angeles, and have worked for several theater firms, including Broadway and Off Broadway. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

22. I am a 19-year-old female, 4'8", 90 lbs, with a background in film and video. I am currently looking for a job in the film industry, preferably in a role that involves strategic thinking and film expertise. I have a Bachelor's degree in Film from the University of Wisconsin-Madison, and have worked for several film firms, including Paramount Pictures and Warner Bros. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

23. I am a 41-year-old male, 6'11", 225 lbs, with a background in television and broadcasting. I am currently looking for a job in the television industry, preferably in a role that involves problem-solving and television expertise. I have a Bachelor's degree in Television from the University of California, Los Angeles, and have worked for several television firms, including NBC and CBS. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

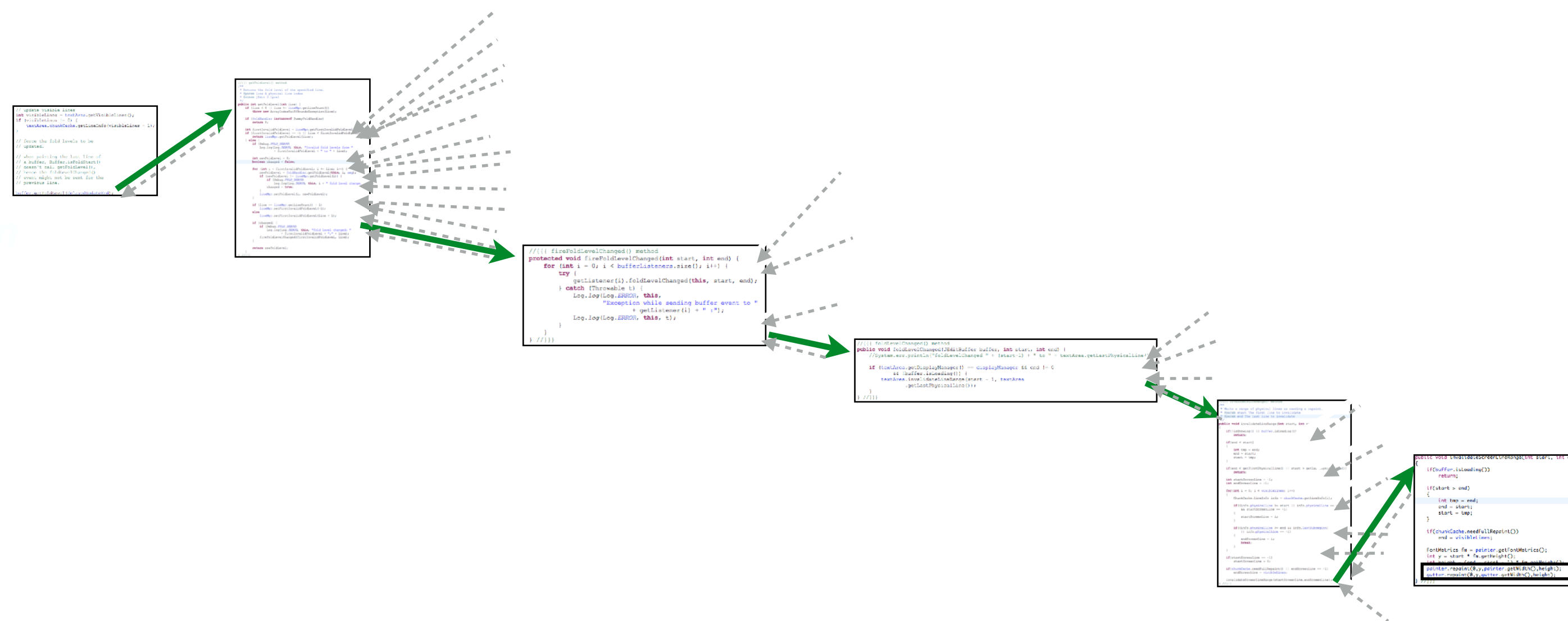
24. I am a 18-year-old female, 4'7", 85 lbs, with a background in journalism and news. I am currently looking for a job in the journalism industry, preferably in a role that involves strategic thinking and journalism expertise. I have a Bachelor's degree in Journalism from the University of Wisconsin-Madison, and have worked for several journalism firms, including The New York Times and The Washington Post. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

25. I am a 42-year-old male, 7'0", 230 lbs, with a background in politics and government. I am currently looking for a job in the politics industry, preferably in a role that involves problem-solving and politics expertise. I have a Bachelor's degree in Politics from the University of California, Los Angeles, and have worked for several politics firms, including the White House and Congress. I am looking for a job that offers a competitive salary, health benefits, and a flexible work schedule. I am also looking for a job that offers a challenging environment and the opportunity to work on interesting projects. I am confident that I have the skills and experience to excel in a role like this, and I am excited about the possibility of joining your team.

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# Why was this Hard to Answer?

Hard to pick the *control flow path* that leads from starting point to target  
Guess and check: which path leads to the target?



# Why are Control Flow Questions Common?

Helps answer questions about:

*Causality*

What does this do? What causes this to happen?

*Ordering*

Does A happen before B?

*Choice*

Does x always occur? In which situations does x occur?

When scattered across a codebase, finding statements to answer these questions can be hard.

lab observations

Defect-related false assumptions  
& incorrectly answered questions  
related to **control flow**

field observations

Primary questions from longest  
investigation & debugging  
activities related to **control flow**



**Reachability Questions**  
(common characteristics of evidence sought)

lab observations

Defect-related false assumptions  
& incorrectly answered questions  
related to **control flow**

field observations

Primary questions from longest  
investigation & debugging  
activities related to **control flow**



## Reachability Questions

(common characteristics of evidence sought)

A search along **feasible**  
**paths** **downstream** or  
**upstream** from a  
statement for **target**  
**statements** matching  
**search criteria**

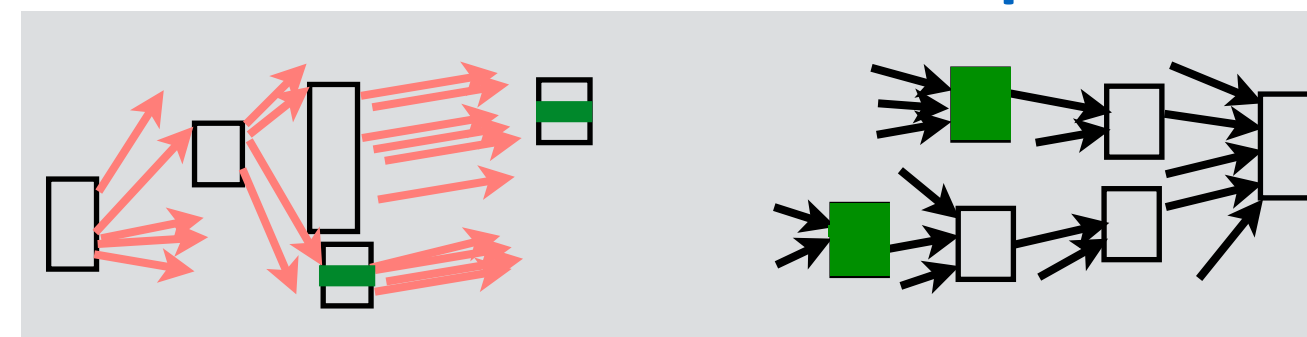
**feasible paths**

filter

compare

**downstream**

**upstream**



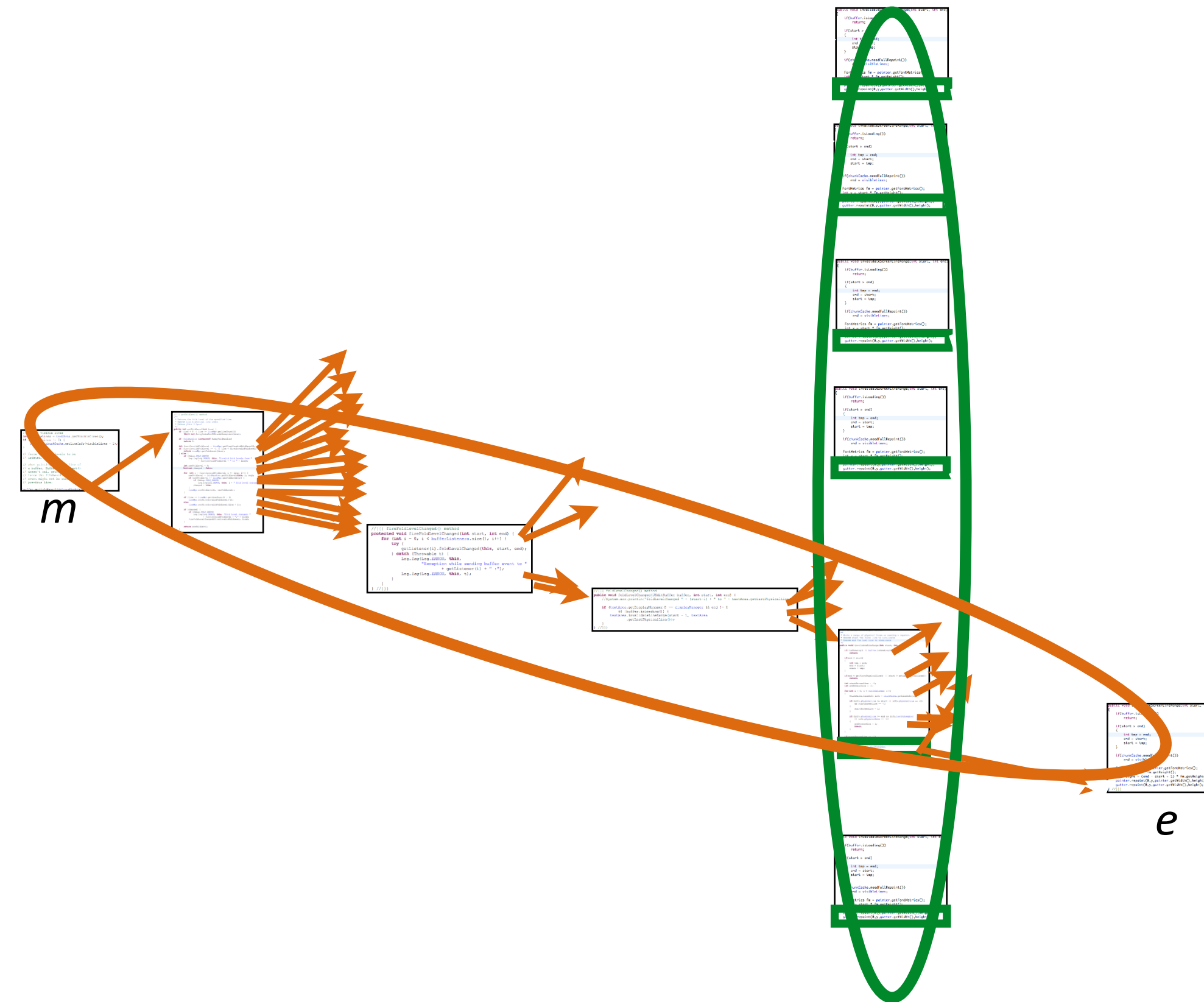
**search criteria**

identifier  
statement type (field  
write/read, library call)

**feasible**  
**paths**  $\cap$  **statements matching**  
**search criteria**

# Reachability Question Example

A search along **feasible paths downstream** or **upstream** from a statement ( $m$ ) for **target statements** matching **search criteria** (calls to method  $e$ )



feasible  
paths



statements matching  
search criteria



# Longest Activities: Control Flow

## 4 out of the 5 longest investigation activities

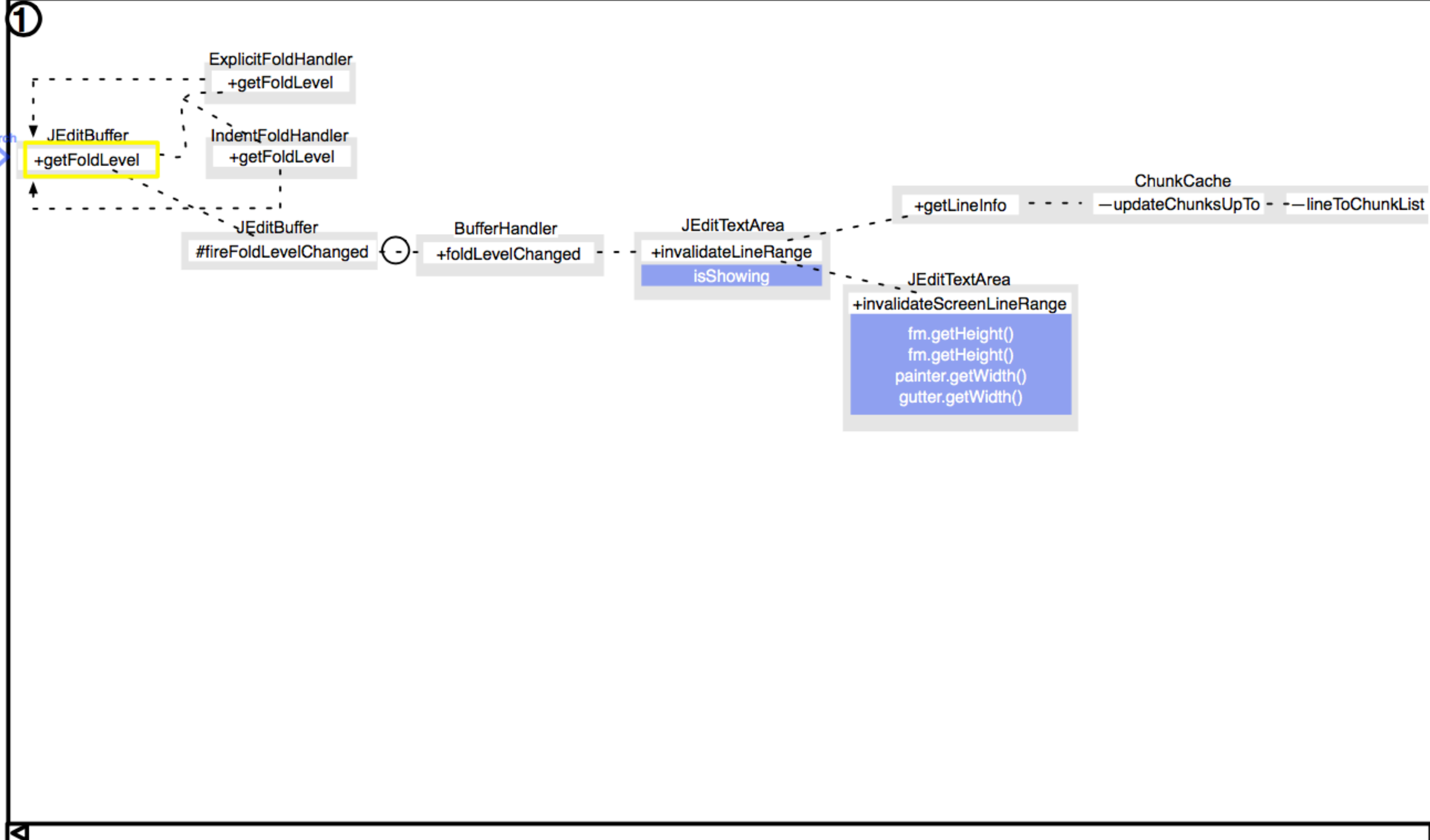
Primary question	Time (m)	Related control flow question
How is this data structure being mutated in this code?	83	Search downstream for <b>writes</b> to data structure
“Where [is] the code assuming that the tables are already there?”	53	<b>Compare</b> behaviors when tables are or are not loaded
How [does] application state change when <i>m</i> is called denoting startup completion?	50	Find field <b>writes</b> caused by <i>m</i>
“Is [there] another reason why <i>status</i> could be non-zero?”	11	Find statements through which values <b>flow</b> into status

## 5 out of the 5 longest debugging activities

Where is method <i>m</i> generating an error?	66	Search downstream from <i>m</i> for <b>error</b> text
What resources are being acquired to cause this deadlock?	51	Search downstream for <b>acquire</b> method calls
“When they have this attribute, they must use it somewhere to generate the content, so where is it?”	35	Search downstream for <b>reads</b> of attribute
“What [is] the test doing which is different from what my app is doing?”	30	<b>Compare</b> test traces to app traces
How are these thread pools interacting?	19	Search downstream for <b>calls</b> into thread pools

# Insights

- Developers can construct incorrect mental models of control flow, leading them to insert **defects**
- The longest investigation & debugging activities involved a single primary question about control flow
- Found evidence for an underlying cause of these difficulties  
Challenges answering reachability questions



① downstream from `JEditBuffer.getFoldLevel`

search for external calls

```
public int getFoldLevel(int line) : 1463 - 1475
{
    if (line < 0 || line >= lineMgr.getLineCount())
        throw new ArrayIndexOutOfBoundsException(line);

    if (foldHandler instanceof DummyFoldHandler)
        return 0;

    int firstInvalidFoldLevel = lineMgr.getFirstInvalidFoldLevel();
    if (firstInvalidFoldLevel == -1 || line < firstInvalidFoldLevel) {
        return lineMgr.getFoldLevel(line);
    } else {
        if (Debug.FOLD_DEBUG)
            Log.log(Log.DEBUG, this, "Invalid fold levels from "
                + firstInvalidFoldLevel + " to " + line);
    }
}
```

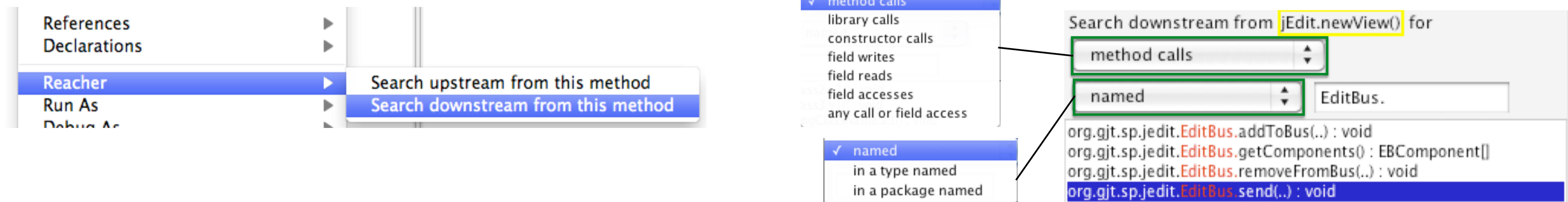
# Paper Prototype Study

- Built mockups of interface for task from lab study
- Asked 1 participant to complete lab study task with Eclipse & mockup of *Reacher*
  - Paper overlay of *Reacher* commands on monitor
  - Experimenter opened appropriate view
- Asked to think aloud, screen capture + audio recording

# Study results

- Used *Reacher* to explore code, unable to complete task
- Barriers discovered
  - Wanted to see methods before or after, not on path to origin or destination
  - Switching between downstream and upstream confusing, particularly search cursor
  - Found horizontal orientation confusing, as unlike debugger call stacks
  - Wanted to know when a path might execute

# Find Statements Matching Search Criteria



Examples of observed reachability questions Reacher supports	Steps to use Reacher
What resources are being acquired to cause this deadlock?	Search downstream for each method which might acquire a resource, pinning results to keep them visible
When they have this attribute, they must use it somewhere to generate the content, so where is it?	Search downstream for a field read of the attribute
How are these thread pools interacting?	Search downstream for the thread pool class
How is data structure <i>struct</i> being mutated in this code (between <i>o</i> and <i>d</i> )?	Search downstream for <i>struct</i> class, scoping search to matching type names and searching for field writes.
How [does] application state change when <i>m</i> is called denoting startup completion?	Search downstream from <i>m</i> for all field writes

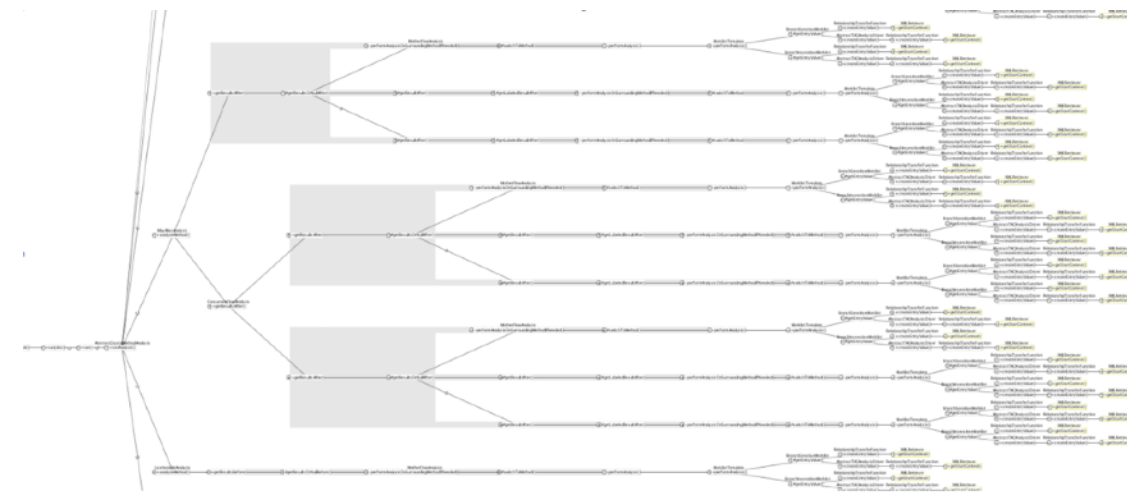
# Help Developers Understand Paths

Goal: help developers reason about control flow by summarizing statements along paths in **compact** visualization

Challenges:

control flow paths can be

Approach:



complex

long

repetitive

**visually encode** properties of path

**hide** paths by default

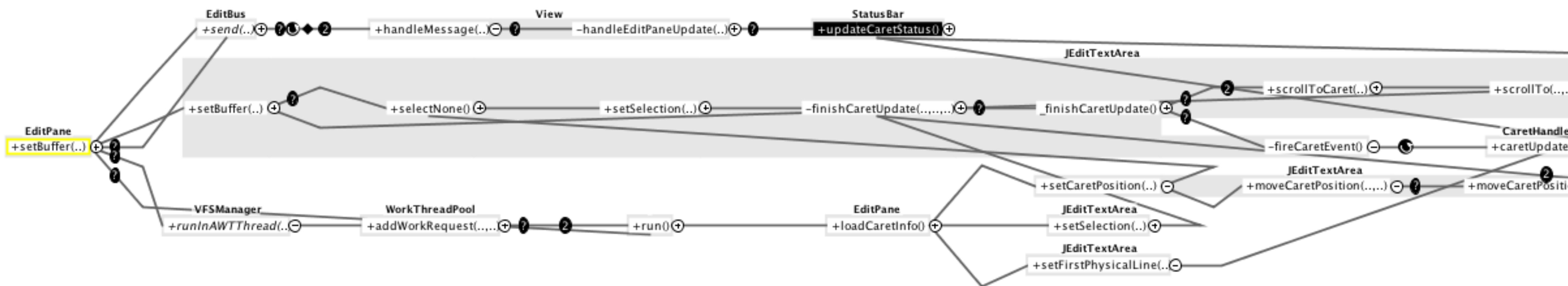
**coalesce** similar paths

developers get lost and disoriented navigating code

use visualization to support navigation



# Example





# Evaluation

Does REACHER enable developers to answer reachability questions faster or more successfully?

## Method

12 developers

15 minutes to answer **reachability** question x 6

Eclipse only on 3 tasks

Eclipse w/ REACHER on 3 tasks

## Tasks

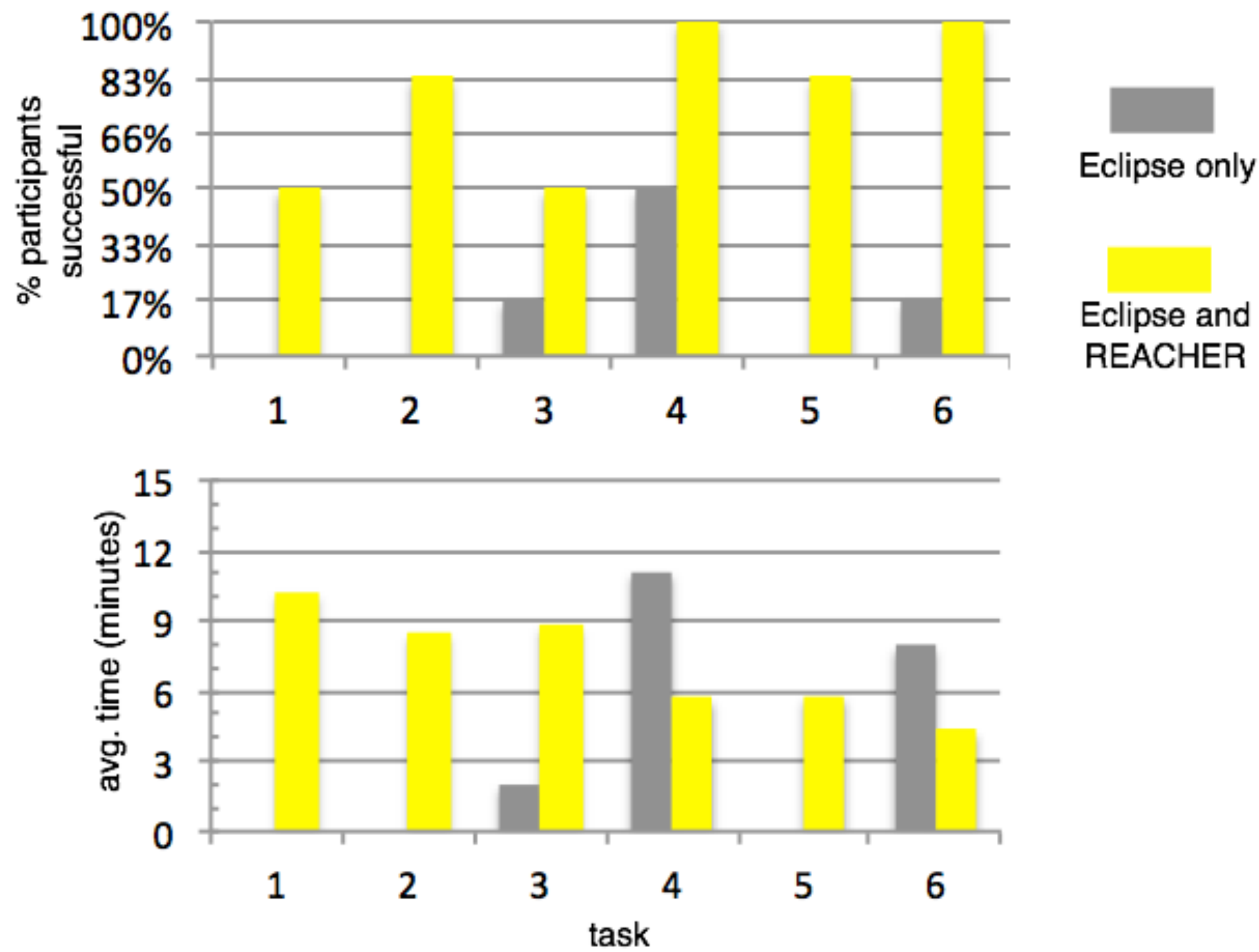
Based on developer questions in lab study.

Example:

When a new view is created in `jEdit.newView(View)`, what messages, in what order, may be sent on the EditBus (`EditBus.send()`)?

# Results

Developers with REACHER were **5.6** times more **successful** than those working with Eclipse only.

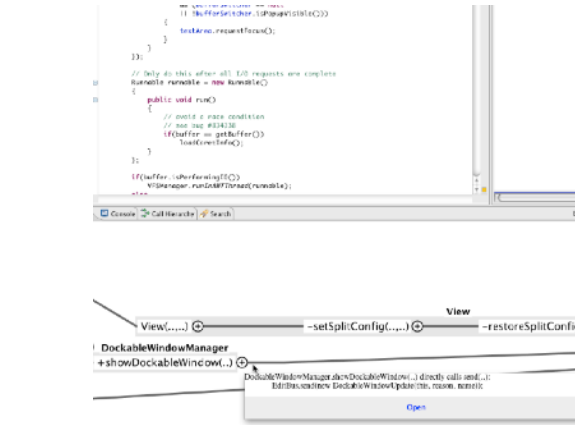


Task time includes only participants that succeeded.

# More Results

Participants with **REACHER** used it to jump between methods.

*“It seems pretty cool if you can navigate your way around a complex graph.”*



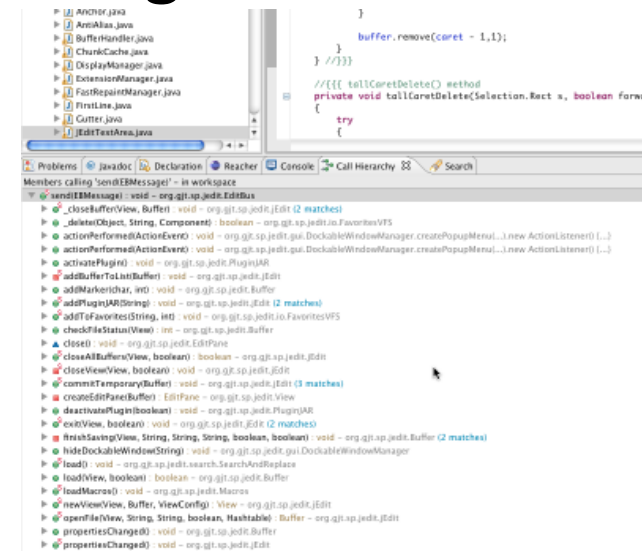
When **not** using REACHER, participants often reported being lost and confused.

*“Where am I? I’m so lost.”*

*“These call stacks are horrible.”*

*“There was a call to it here somewhere, but I don’t remember the path.”*

*“I’m just too lost.”*



Participants reported that they liked working with REACHER.

*“I like it a lot. It seems like an easy way to navigate the code. And the view maps to more of how I think of the call hierarchy.”*

*“Reacher was my hero. ... It’s a lot more fun to use and look at.”*

*“You don’t have to think as much.”*

# Reflection on Design Process

- Started with a goal: make debugging in large, complex codebases better
- Observed users to build *insight* into what key challenge was
- Rather than address usability challenges of existing debugging tools, designed new way to debug
- Gathered evidence that it worked better

**10 Minute Break**

# In-Class Activity

- Form groups of 2 or 3
- A venture capitalist just gave your group \$5M to build a new consumer software product (mobile, web, desktop, etc.)
- Brainstorm an idea: what's the product? how will it help?
- Answer following questions
  - What do you know now
    - Who are the users? What are their tasks and goals? What problems do they encounter? How will your tool help?
  - What would like to learn through needfinding that you don't already know?
  - How would you use an interview / survey / or other method to answer these questions?