User-Centered Design

SWE 632
Fall 2015

In class exercise

- Today's question:

- What makes great software?

What makes great software?

Administrivia

- HW2 due today

- HW3 due in 1 week

User-centered design

User-centered design

User-centered design

Who are the users?

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

What are the user's needs?

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

What are the user's tasks and goals?

What extreme cases may exist?

Technology-centered design

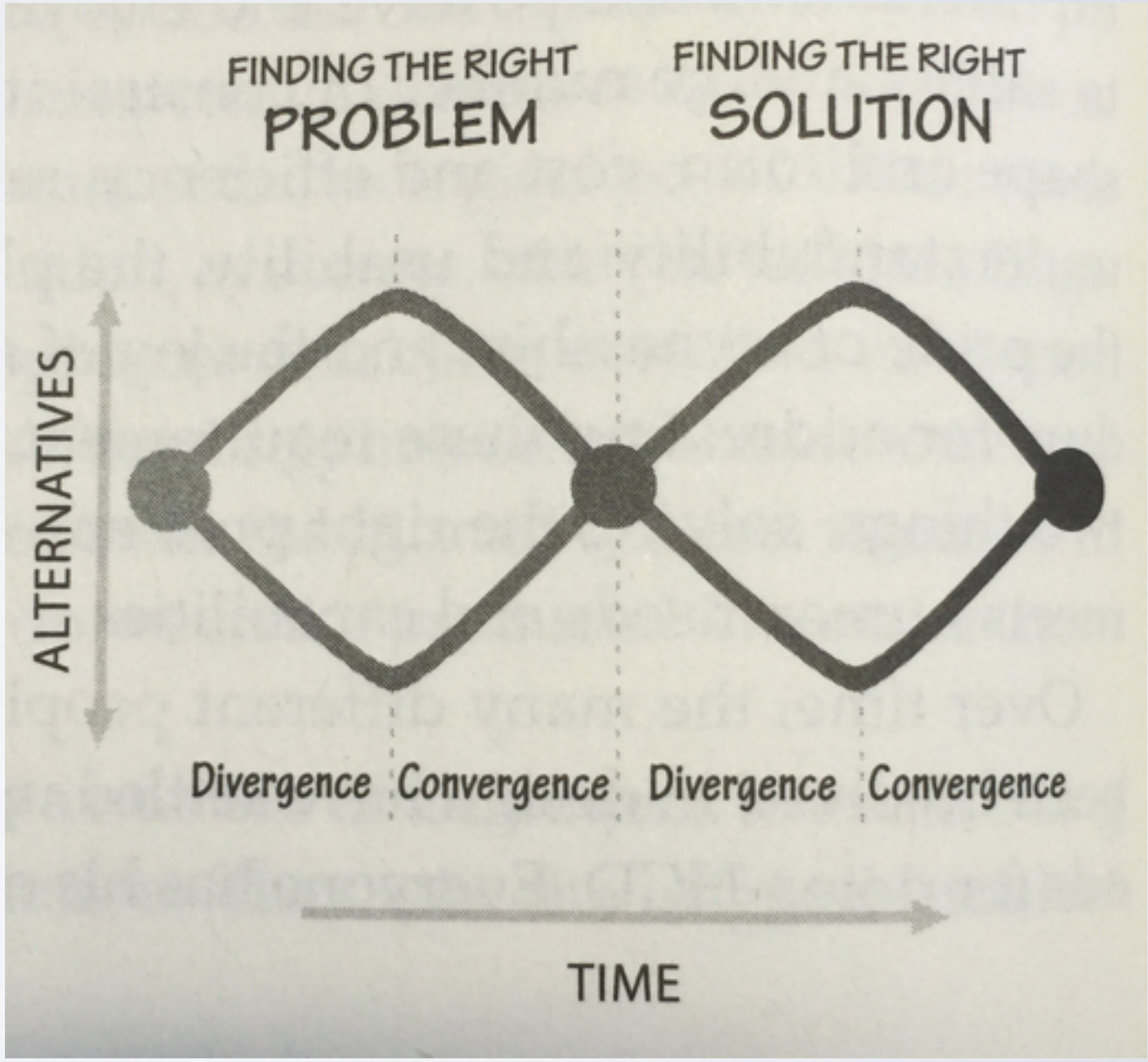
What can this technology do?

How might users use it?

What features does it have?

Double diamond model of design

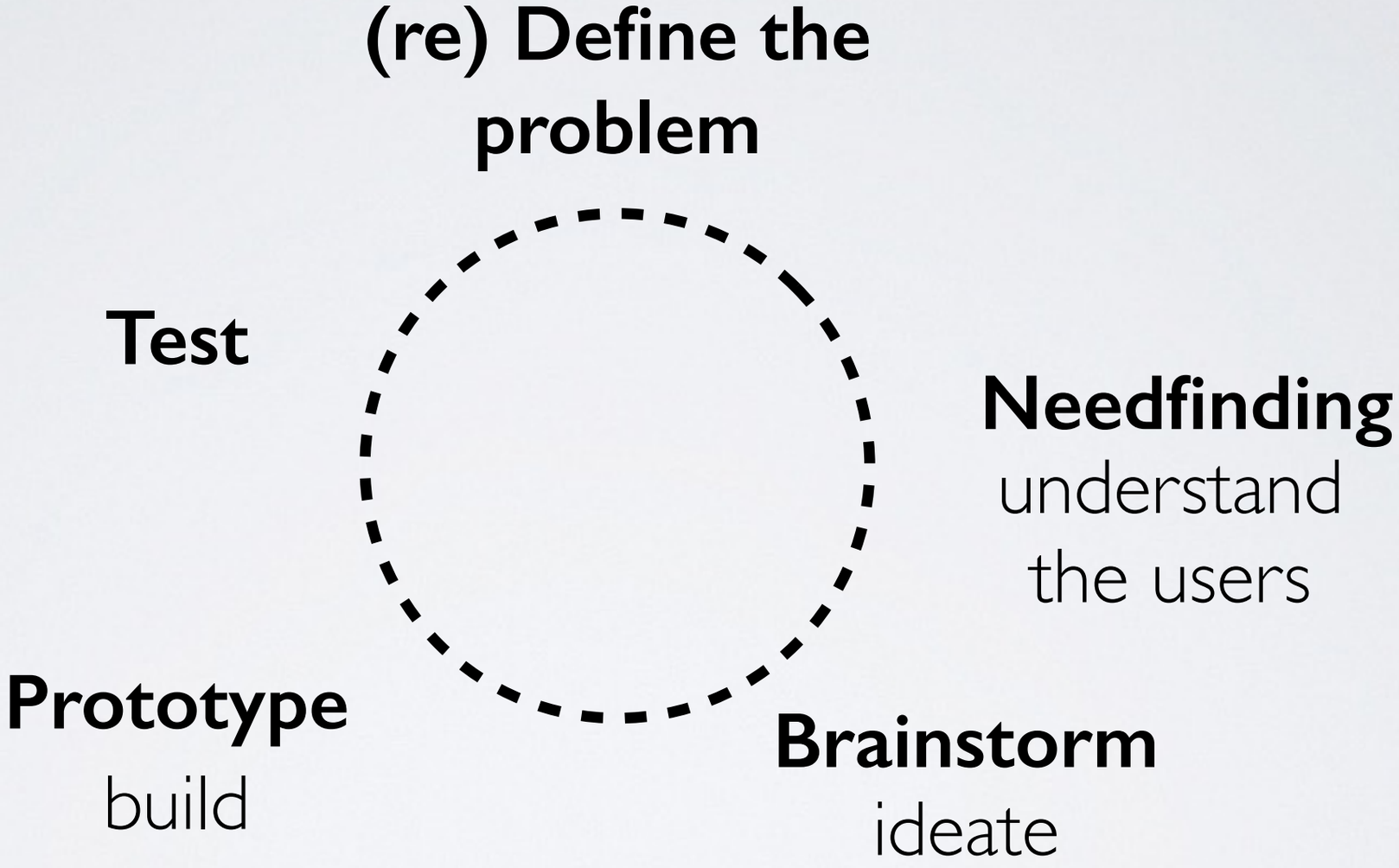
- Question problem, expand scope, discover fundamental issues
- Converge on problem
- Expand possible solutions
- Converge on solution



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

Iterative model of design



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

Conceptual model

Users form "mental models" about how a system works. A well-designed system portrays a strong conceptual model that helps users form an accurate mental model and matches the way users think about their work. The conceptual model is the over-arching "theme" of the design. Scenarios, metaphors, and the navigation model all contribute to a high-level design that demonstrates the conceptual model.

Navigation model

The navigation model is the big picture, or "bird's eye view" of the system. It considers where users start, how they get from here to there, and what all of the major elements will be (such as screens.) A flow diagram of the system elements can represent a navigation model.

User Scenarios

are stories about how real people do their work. They often contain specific people's names and data about how a task is done. Scenarios aid the design team in focusing on real-world people and tasks and can be used in a walkthrough to evaluate design options.

Walkthrough

In a walkthrough, the design team and users meet to step through a design concept and evaluate how well it works with actual tasks. Various walk-through techniques can be used to evaluate early concepts and designs.

Task analysis

helps the team understand what can be done with the system. It can include task frequency, importance, and which user groups will do the task. Task analysis can also incorporate a workflow diagram, which is a good way to show the process behind how users does their work.

User profiles

document the various categories of users and their characteristics. They help a team get a handle on who will be using the system in what ways. User profiles can include information such as demographics, technology experience, subject matter expertise, attitudes and motivations, and frequency of use. Creating posters for different user profiles is a fun and compelling way to make users real for the design team.

Field studies

are an excellent way to obtain information about the users' environments and how they do real work in those environments. Field studies can include both interviewing users and observing their behavior. However, these studies are always conducted in the users' workplaces. Data from field studies drives development of user profiles, task analysis, scenarios, and usability testing protocol.

Multidisciplinary team

The design team should include expertise in usability, human factors, marketing, graphic design, technology, engineering, quality assurance, and performance support. Collaborating with each discipline during the analysis, design, and implementation phases will ensure the design meets usability needs; accomodates the technology being used; portrays the interface in a way that will not jeopardize branding; and reflects the intended functionality.

The Usability Life Cycle

Any project, even a small project, benefits from incorporating usability early on. During the Analysis phase, set goals and determine who will use the product for what purpose. The Design phase is iterative. That is, the design team continuously evaluates whether the design works for users. Ongoing emphasis on usability throughout the Implementation and Deployment phases helps maintain a user-centered focus during last-minute changes and when planning for the next version. As you plan the project, determine what usability steps will best meet your user and business needs– the darker the square, the more important the step.

upa

usability professionals' association

www.upassoc.org

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Meg Ross - digitalMeg
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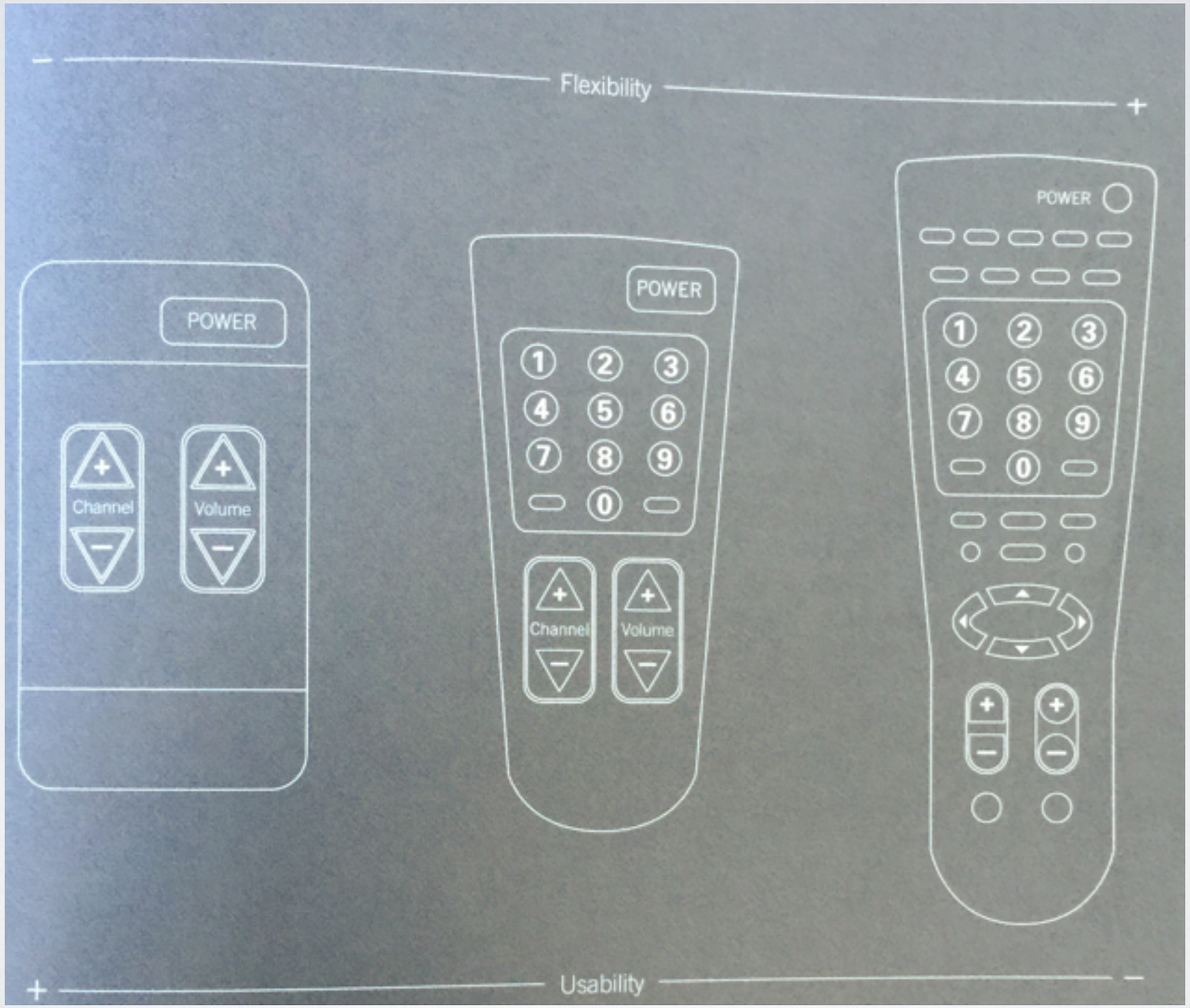
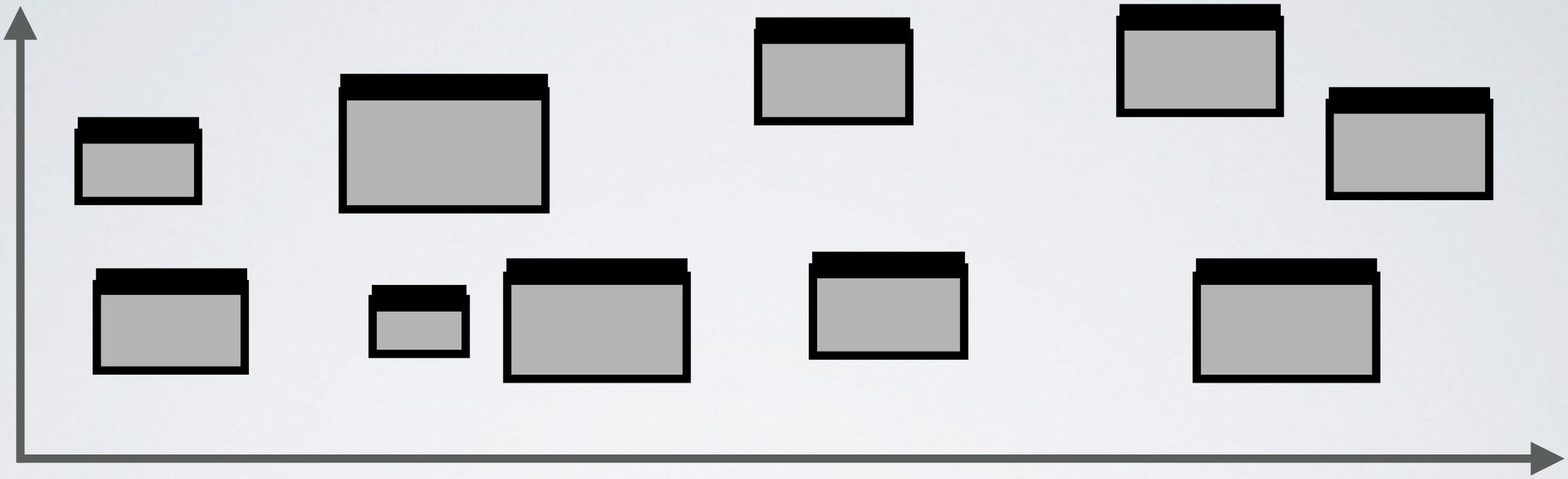
Flexibility-usability tradeoff



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

Navigating a 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

Observations of investigation & debugging in a complex codebase

Participants

13 developers

median 2.5 yrs
industry experience

Tasks

90 minute investigate &
fix design problem

x 2

55 KLOC Java application (jEdit)

Task 1

When painting the last line of a file, Buffer.isFoldStart() doesn't call getFoldLevel(), hence the foldLevelChanged() event might not be sent for the previous line. Identify and fix problems with this design:

Code smells
Ignoring the return value of a getter
Using getter for its effects

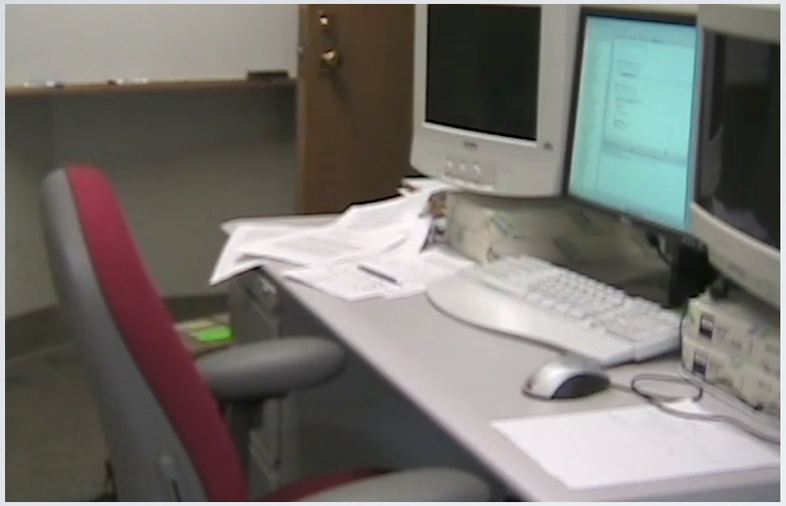
Architecturally questionable
Changing buffer state from another component

Task 2

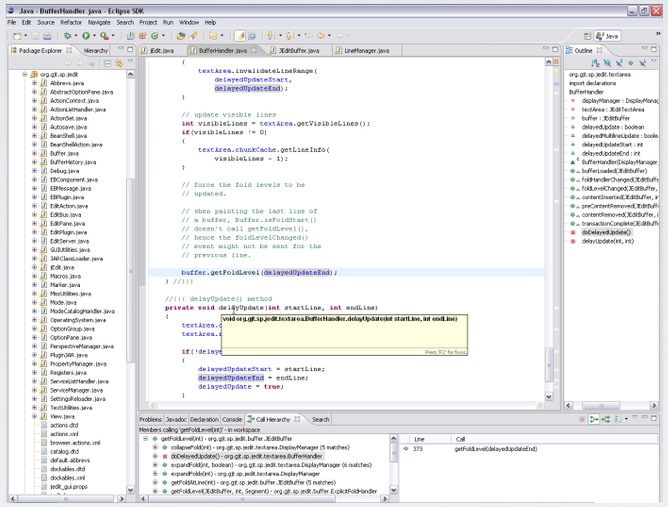
When a file is opened, a number of redundant UI updates are performed that reduce performance. Identify these updates and fix the design to reduce them.

Data collected

Demographic questions
Thinkaloud audio
Post task interviews
Code after changes
Participant typed notes
Notepaper video camera

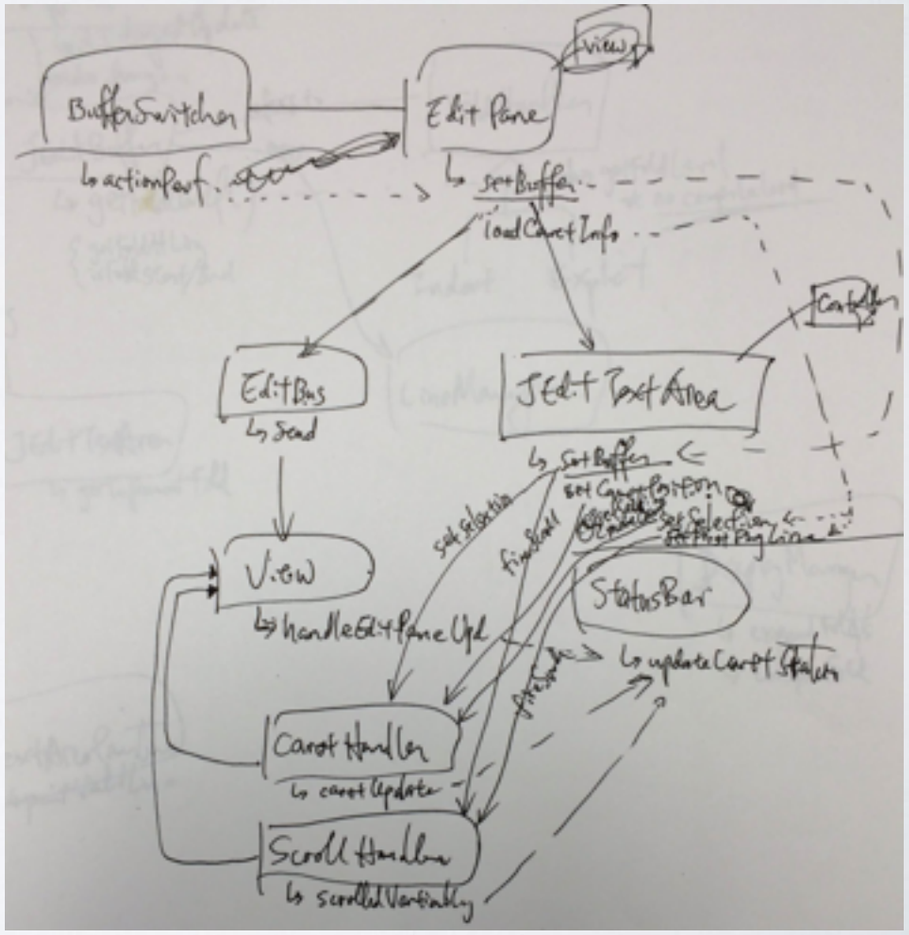


Wide video camera



Camtasia screen video

observer notes



Participant handwritten notes

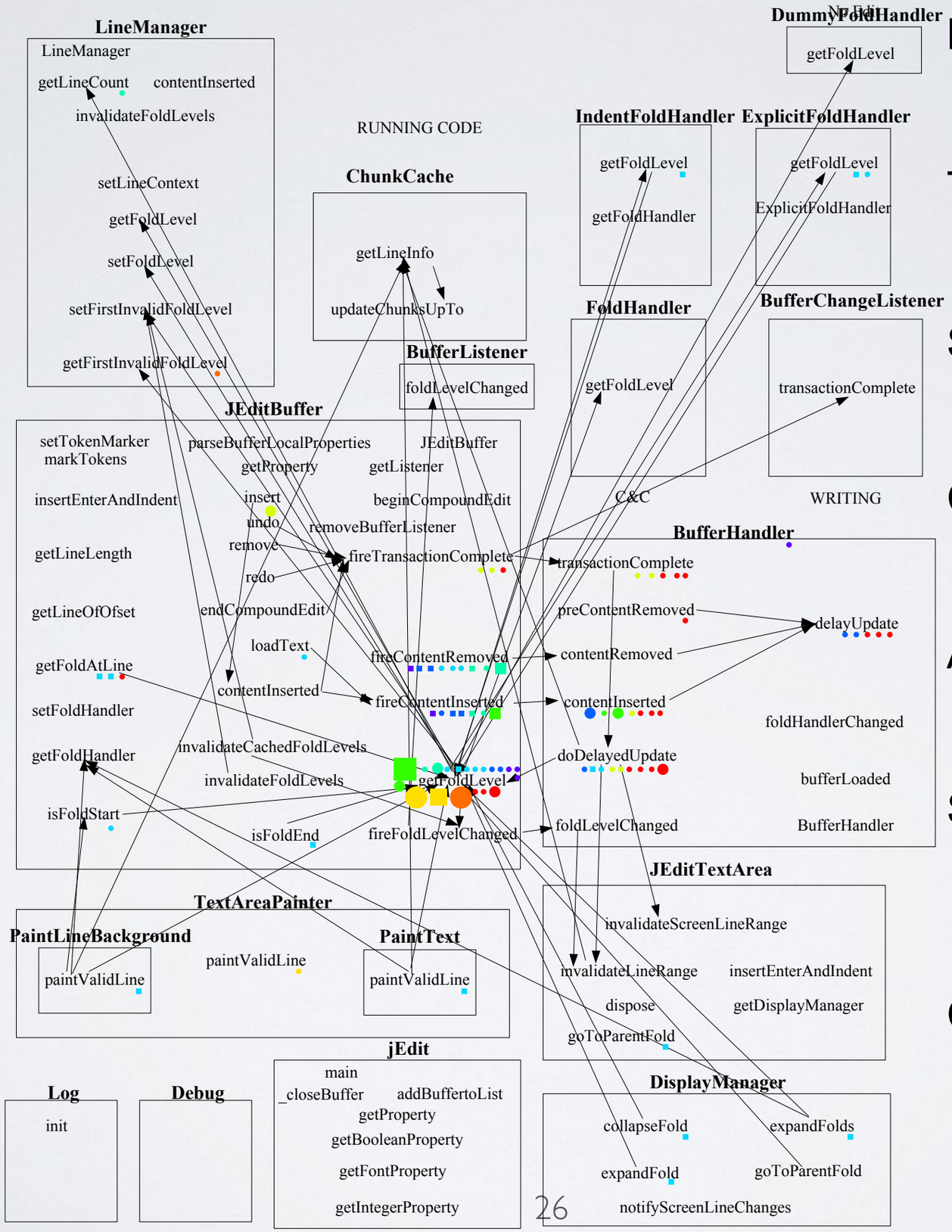
Transcripts and analysis

time code	goal	action	target	think aloud
		Reading	getFoldLevel()	
		Scrolling		So the first thing that I'm going to do is I'm going to separate the functionality from that
				transaction ??? Modifier. And if I have time I'll think about the other [problem]
7:56				
		Scrolling	[top]	
	Add fold level caching	Edit	Start adding field	
		Scrolling		
		ReferencesTo	getFoldLevel()	
				Is there a way to remember this position so I can come back to exactly this place?
				[didn't know] Oh, I can remember the line number, right?
7:57		Scrolling	[top]	
		Edit	added field - int latestFoldLevel = 0	
7:58		OutlineTo	getFoldLevel()	
		Edit	adding method - setFoldLevel()	
		Edit	[copying and pasting code from getFoldLevel()]	
7:59		Reading	getFoldLevel()	
		DPC		Ok, so I'm thinking of having a hash table that associates each line number with the
8:00				fold level of that line. And then when I **Breakdown - LineManager already doing this**
				So then I can have two functions, one which modifies the fold level associated with
				the line number and the other that just gets it from the hashtable.
				So can I look up the hashtable API [yes, allowed to]
		Edit	small fix to setFoldLevel()	
8:01		Scrolling	JEditBuffer.latestFoldLevel	

(11,821 lines)

Hierarchy of goals & actions
Design decisions
Length & reason for breakdowns
Different strategies used for achieving the same goals
Differences in pieces of system explored
Code changes and defects introduced

Analysis - Navigation & Changes



Box
- Class

Text
- Method names

Squares
- Edits

Circles
- Views

Arrows
- A calls B

Size
- Small < 1 min
- Large > 5 mins

Color
- Red first 10 min
- Violet last 10 min

Analysis - Facts

Developers navigated code to answer questions and learn **facts** about code

Examples:

Whenever the window scrolls, the caret status must be updated.

Whenever the cursor moves, the caret status must be updated.

Whenever the buffer changes, the caret status should be updated once.

EditBus is for low frequency events, not high frequency events like buffer edits

When the buffer change EditBus message is sent, the text area has not yet been updated with the new buffer's info.

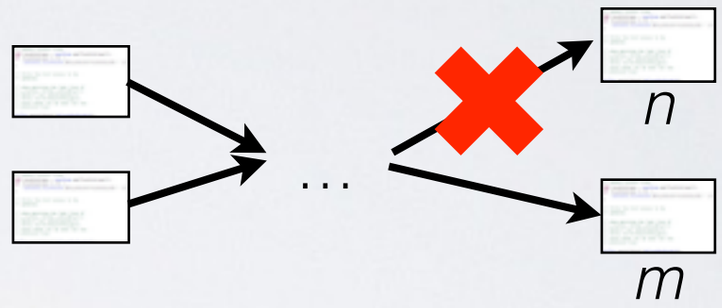
Developers sometimes were **unsuccessful** answering their questions.

made optimistic or pessimistic assumptions

Developers sometimes made **false assumptions**

Examples of false beliefs and questions answered incorrectly

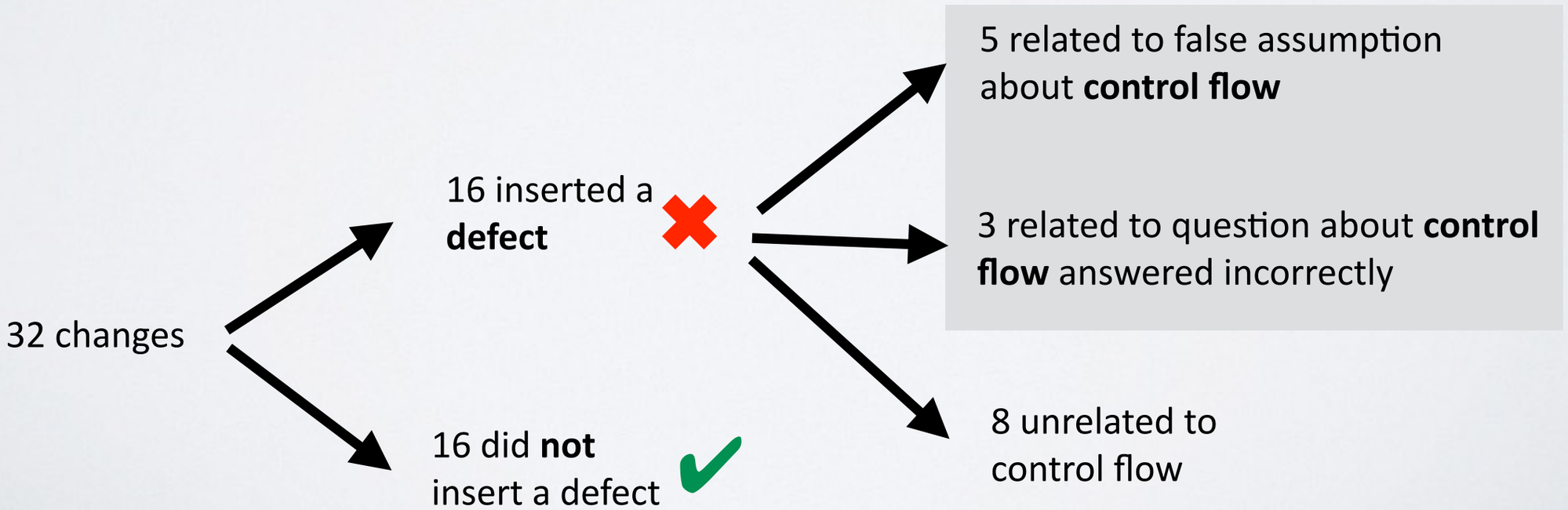
False assumption	**Correct fact about control flow**
Method *m* need not invoke method *n*, as it is only called in a situation in which *n* has already been called.	*m* is called in several additional situations in which *n* has not been called.



Question answered incorrectly	**Correct fact about control flow**
Why is calling *m* necessary?	*m* indirectly calls a function that updates the screen.

Findings

- Developers seek task-relevant information by asking **questions** and **navigating** code to learn facts about code
- Developers built **mental models** (sometimes externalized in sketches and notes) of control flow
- Developers sometimes hold **false beliefs** about code
  because they answered questions incorrectly
  or made false assumptions
- False beliefs about **control flow** led developers to introduce defects



Limitations

Study of developers making changes to codebase they've **never seen before**

➡ Maybe developers working with unfamiliar code in a familiar codebase do not have these challenges?

Two tasks in a **single** codebase

➡ Maybe other tasks or codebases do not have these challenges?

Are these challenges typical of real world software development?

Observations of developers in the field

Participants

17 professional developers

Tasks

~90 minutes
picked one of **their** own coding tasks involving unfamiliar code

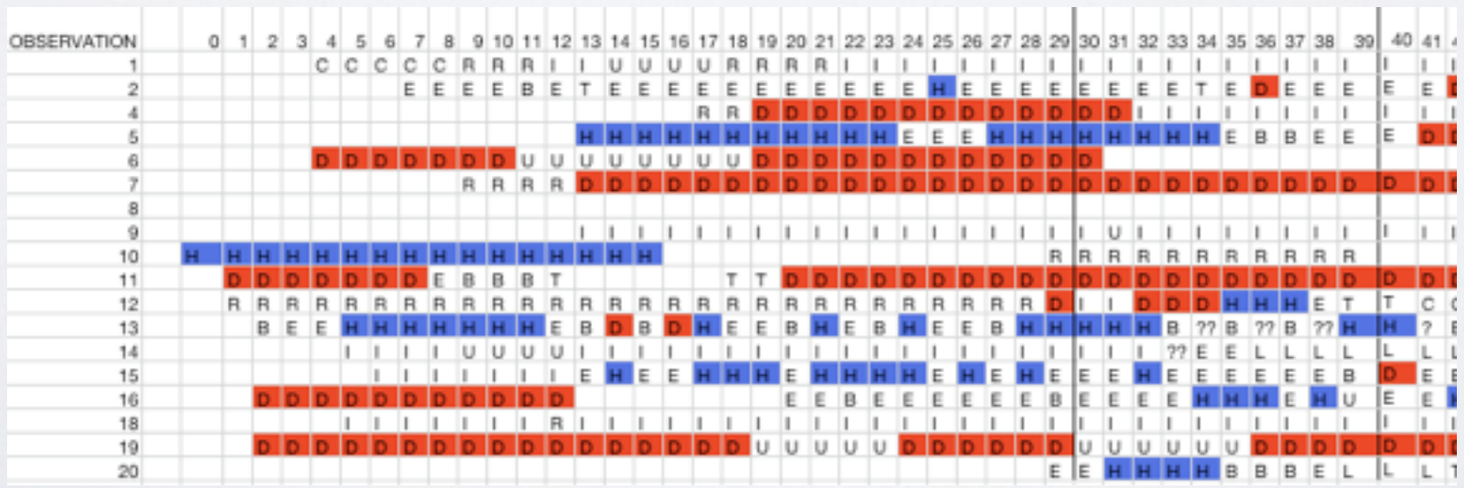
Transcripts

> 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.
>
> 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.

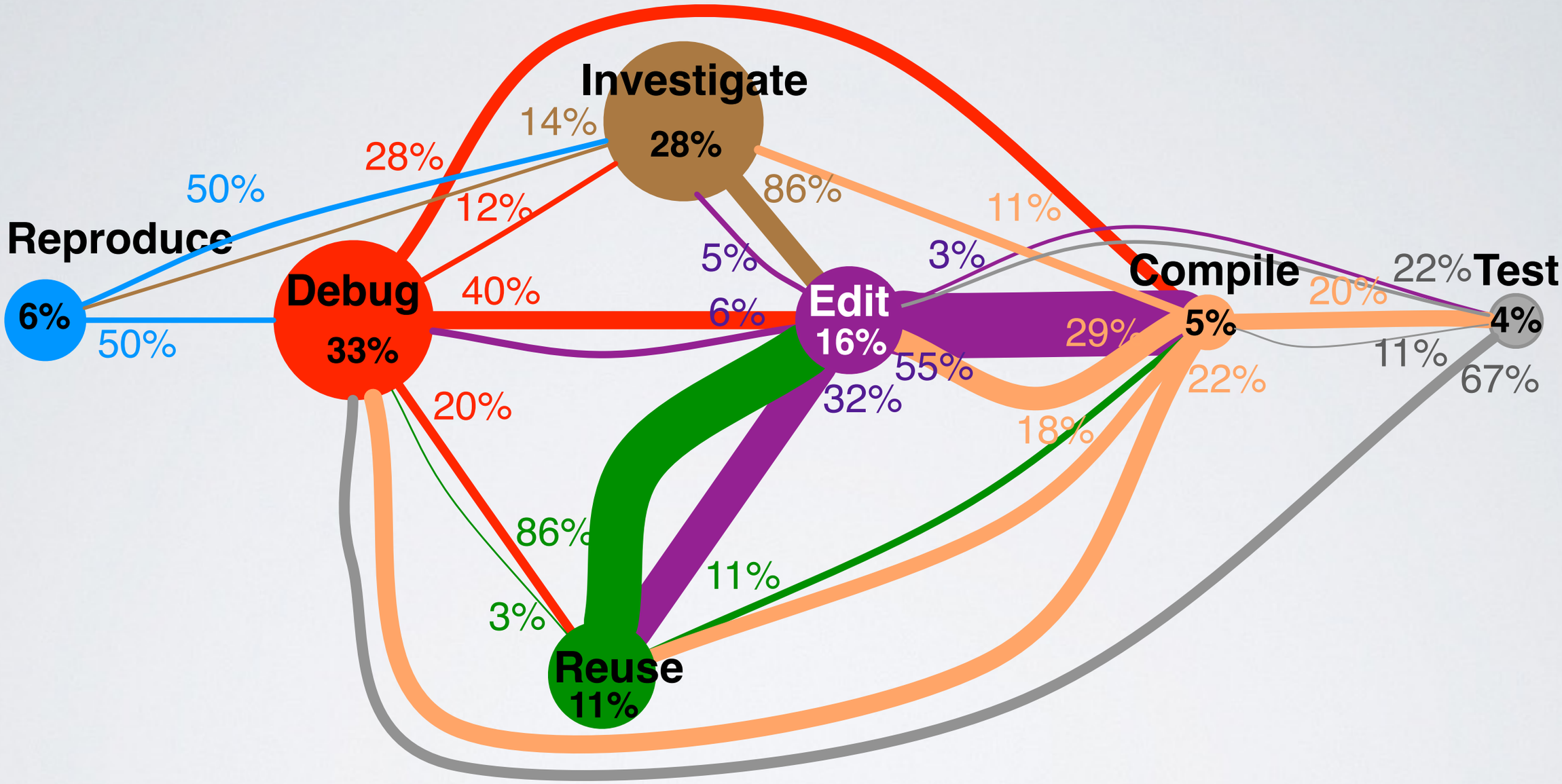
(annotated with observer notes about goals and actions)

(386 pages)

Activities



Coding activities working with unfamiliar code



Circle size: % of time

Edge thickness: % of transitions observed

Longest activities related to control flow questions

4 out of the 5 longest investigation activities

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

5 out of the 5 longest debugging activities

Where is method *m* generating an error?	66	Search downstream from *m* for **error** text
What resources are being acquired to cause this deadlock?	51	Search downstream for **acquire** method calls
“When they have this attribute, they must use it somewhere to generate the content, so where is it?”	35	Search downstream for **reads** of attribute
“What [is] the test doing which is different from what my app is doing?”	30	**Compare** test traces to app traces
How are these thread pools interacting?	33 19	Search downstream for **calls** into thread pools

Longest debugging activity

Where is method *m* generating an error?

Rapidly found method *m* implementing command
Unsure **where** it generated error

static call traversal

Statically traversed calls looking for something that would generate error

debugger

Tried debugger

grep

Did string **search** for error, found it, but many callers

debugger

Stepped in debugger to find something relevant

static call traversal

Statically **traversed** calls to explore

debugger

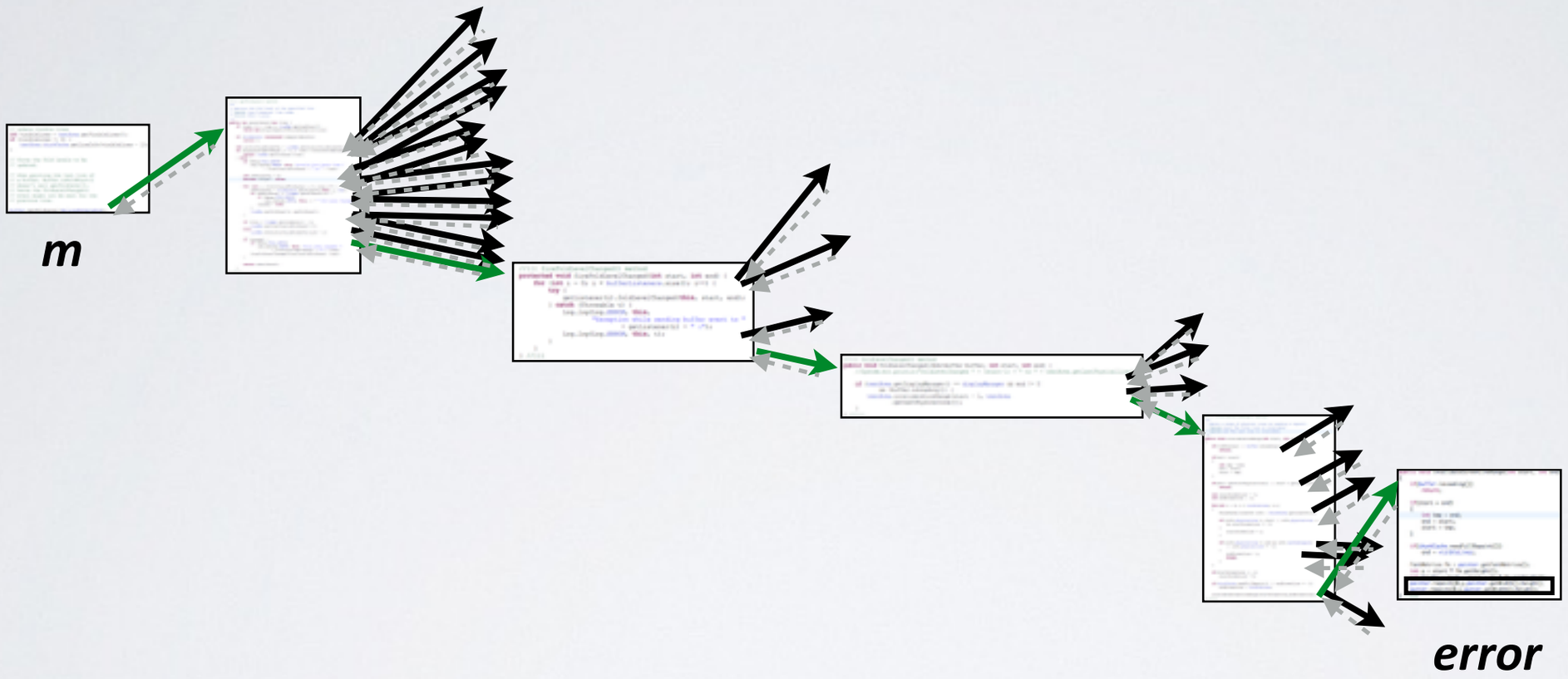
Went back to **stepping** debugger to inspect values
Found the answer

(66 minutes)

Why was this question so 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 frequent?

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)

37

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)

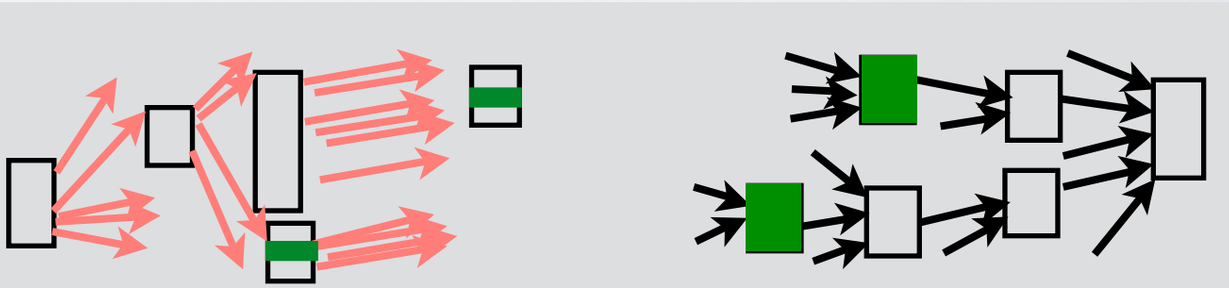
A search along **feasible paths** **downstream** or **upstream** from a statement for **target statements** matching **search criteria**

feasible paths ∩ statements matching search criteria

feasible paths

filter compare

downstream **upstream**



search criteria

identifier

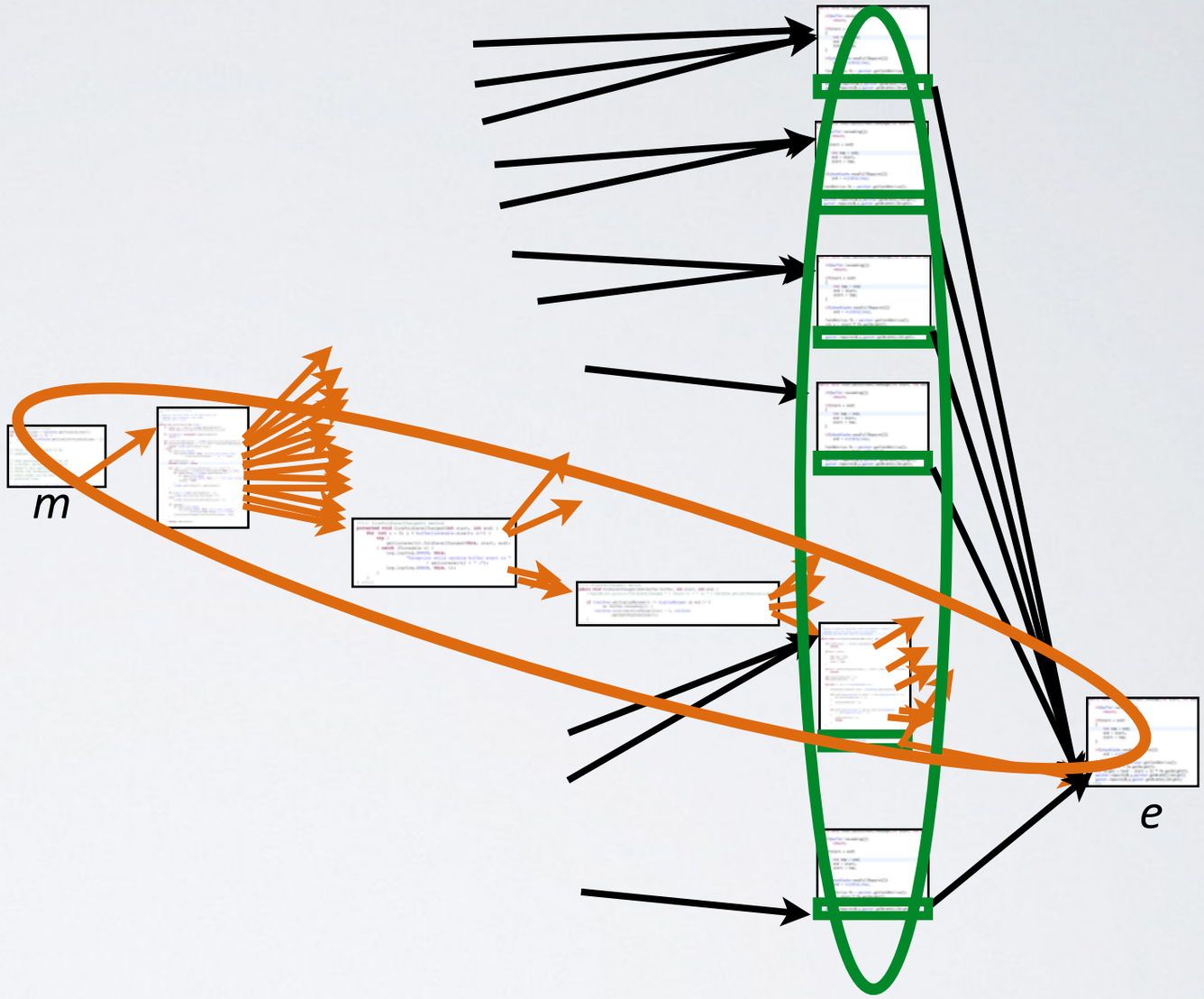
statement type (field write/read, library call)

38

Reachability question: example

Where is method *m* generating an error?

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 related to reachability questions

4 out of the 5 longest investigation activities

Primary question	**Time** (mins)	**Related reachability question**
How is this data structure being mutated in this code?	83	Search downstream for **writes** to data structure
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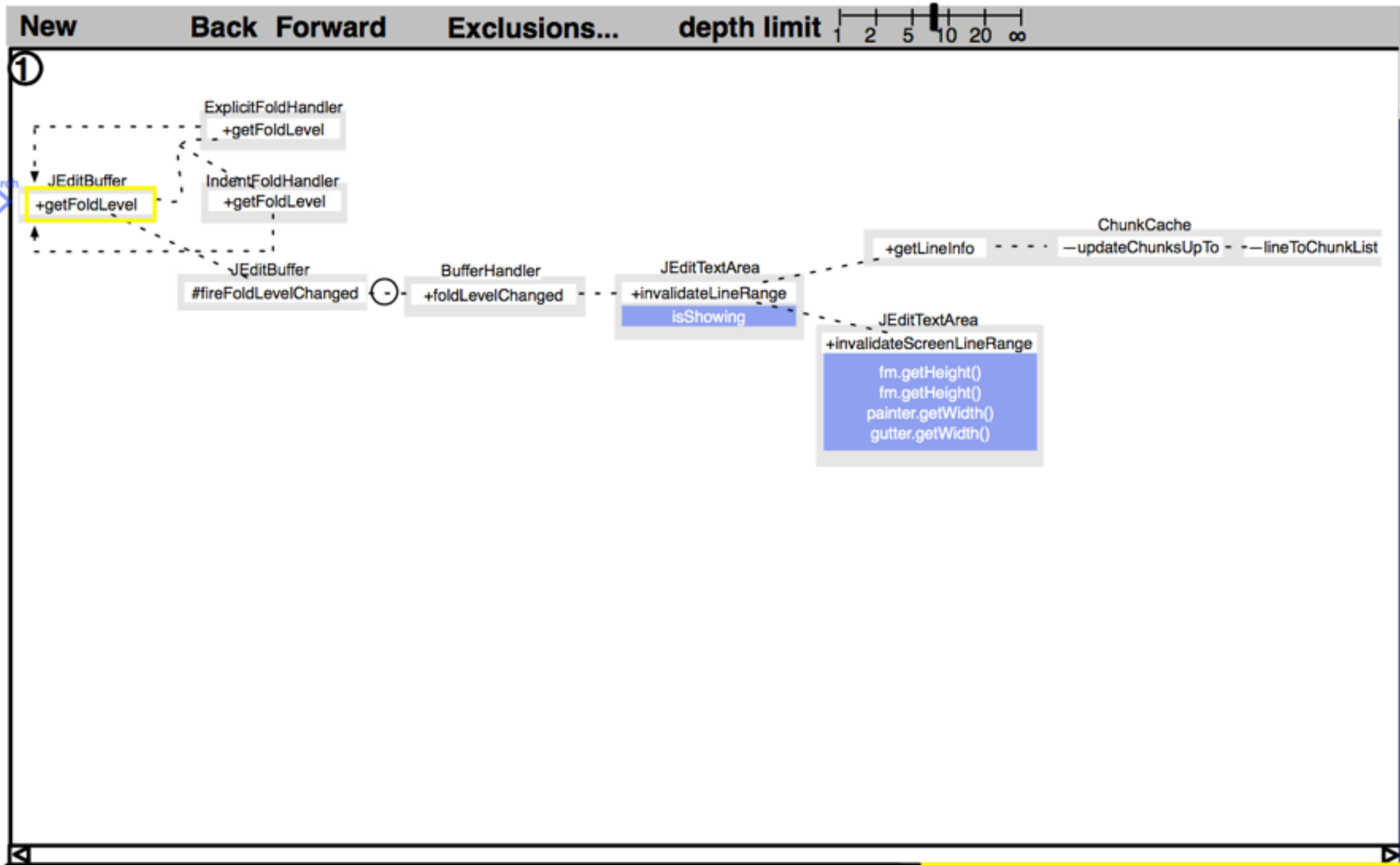
Overall findings

- Found that developers can construct **incorrect** mental models of control flow, leading them to insert **defects**

- Found that 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 question**s

- Built formalism describing information needs in reachability questions


New
Back
Forward
Exclusions...
depth limit
1
2
5
10
20
∞
ALL
EXTERNAL CALLS
FIE
WRITES
①
ExplicitFoldHandler
+getFoldLevel
search
JEditBuffer
+getFoldLevel
IndentFoldHandler
+getFoldLevel
JEditBuffer
#fireFoldLevelChanged
BufferHandler
+foldLevelChanged
JEditTextArea
+invalidateLineRange
isShowing
ChunkCache
+getLineInfo
—updateChunksUpTo
—lineToChunkList
JEditTextArea
+invalidateScreenLineRange
fm.getHeight()
fm.getHeight()
painter.getWidth()
gutter.getWidth()
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);

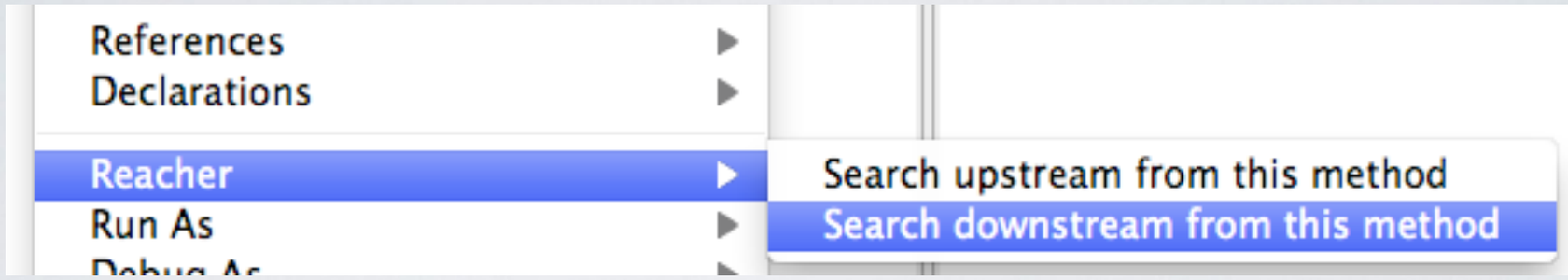
Paper prototype study

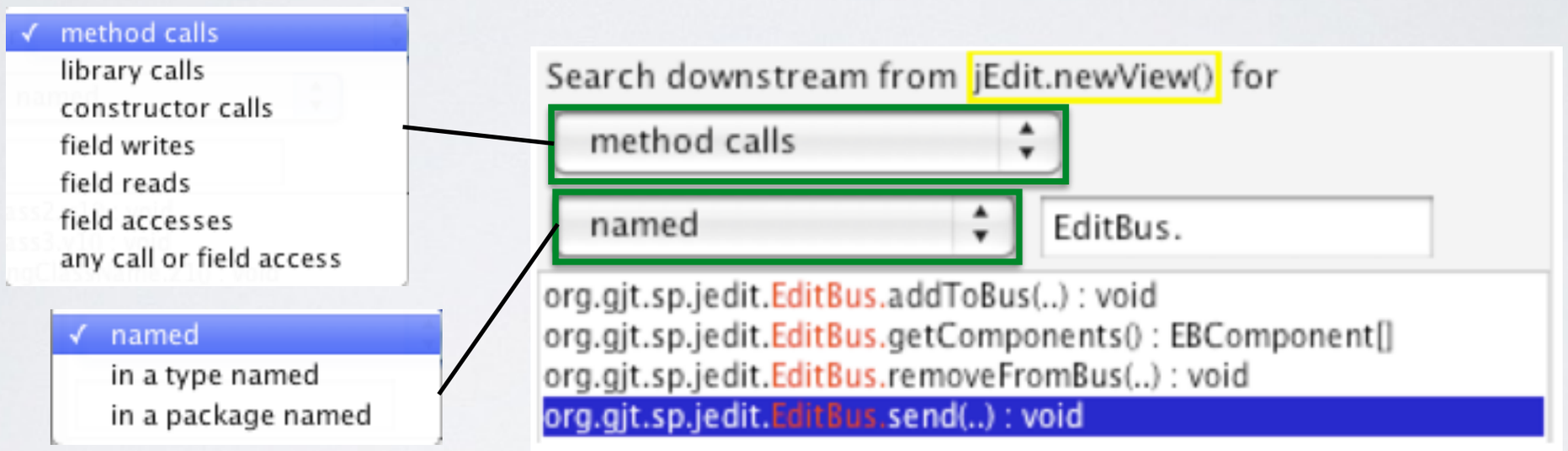
- Built mockups of interface for task from lab study
- Asked 1 participant to complete lab study task with Eclipse & mockup of Reacher
  - Paper overlay of Reacher commands on monitor
  - Experimenter opened appropriate view
- Asked to think aloud, screen capture + audio recording

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

Step 2: 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 *struct* being mutated in this code (between *o* and *d*)?	Search downstream for *struct* class, scoping search to matching type names and searching for field writes.
How [does] application state change when *m* is called denoting startup completion?	Search downstream from *m* for all field writes

Step 3: Help developers understand paths and stay oriented

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

Challenges:
control flow paths can be

complex

long

repetitive

developers get lost and disoriented navigating code

Approach:

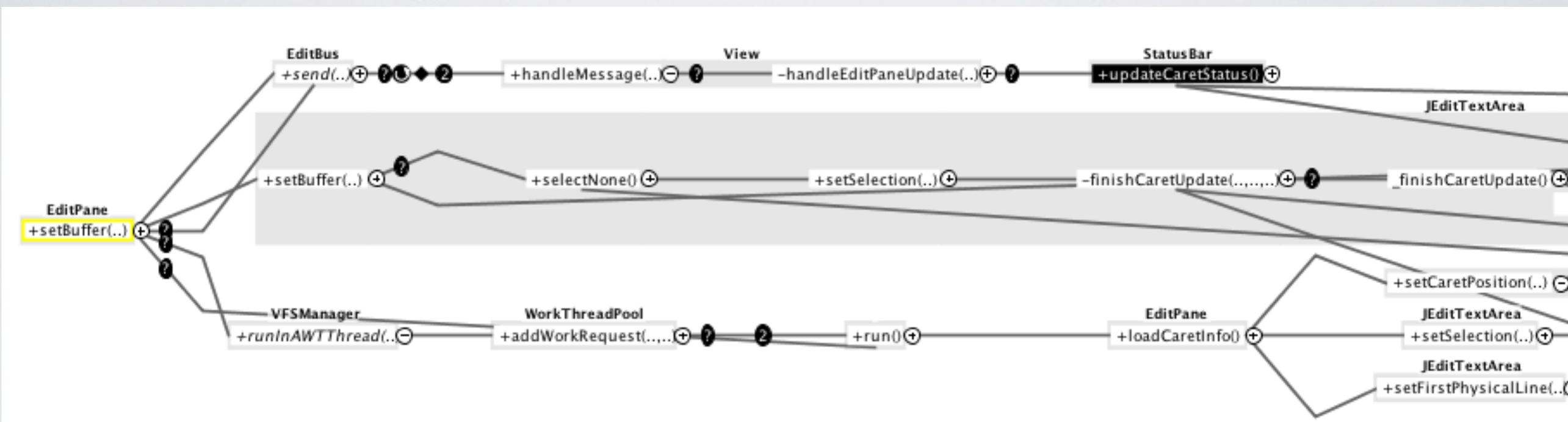
visually encode properties of path

hide paths by default

coalesce similar paths

use visualization to support navigation

Example


EditBus
+send(..)
View
+handleMessage(..)
-handleEditPaneUpdate(..)
StatusBar
+updateCaretStatus()
JEditTextArea
+setBuffer(..)
+selectNone()
+setSelection(..)
-finishCaretUpdate(..,..,..)
_finishCaretUpdate()
EditPane
+setBuffer(..)
+setCaretPosition(..)
VFSManager
+runInAWTThread(..
WorkThreadPool
+addWorkRequest(..,..
+run()
EditPane
+loadCaretInfo()
JEditTextArea
+setSelection(..)
JEditTextArea
+setFirstPhysicalLine(..

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

(order counterbalanced)

Tasks

Based on developer questions in lab study.

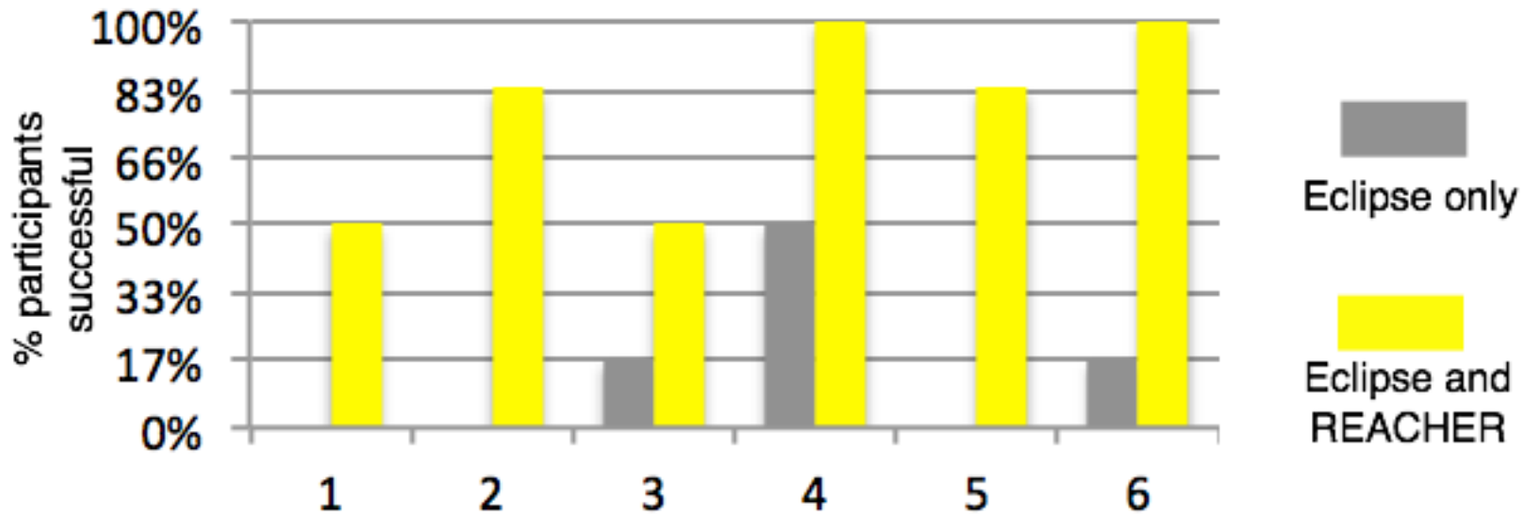
Example:

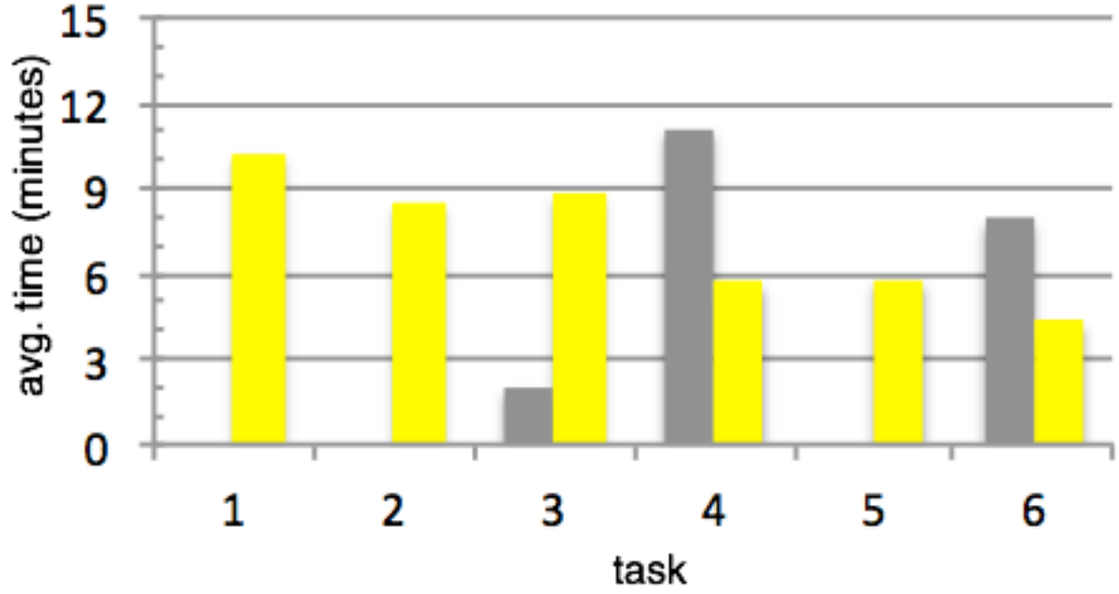
When a new view is created in jEdit.newView(View), what messages, in what order, may be sent on the EditBus (EditBus.send())?

Results

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

(not enough successful to compare time)





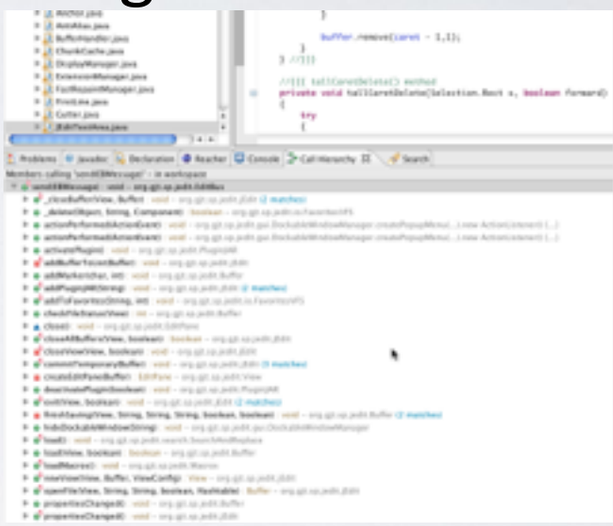
Task time includes only participants that succeeded.

REACHER helped developers stay oriented

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."

Needfinding

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 bother 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 time

Ideation

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

Design in the world of business

Norman's law of product development

- *The day a product development process starts, it is behind schedule and above budget.*

- Teams often not budgeted time for understanding users, iterating design

- In some markets, competitive forces can (sometimes) drive design evolution

Featuritis

- Existing customers like the product, but express wish for more feature, functions, capability

- Competing company adds features, producing **competitive** pressure to match and exceed

- Customers are satisfied but market saturated, leading to pressure for new features

- Leads products towards more power, but also more **complexity**

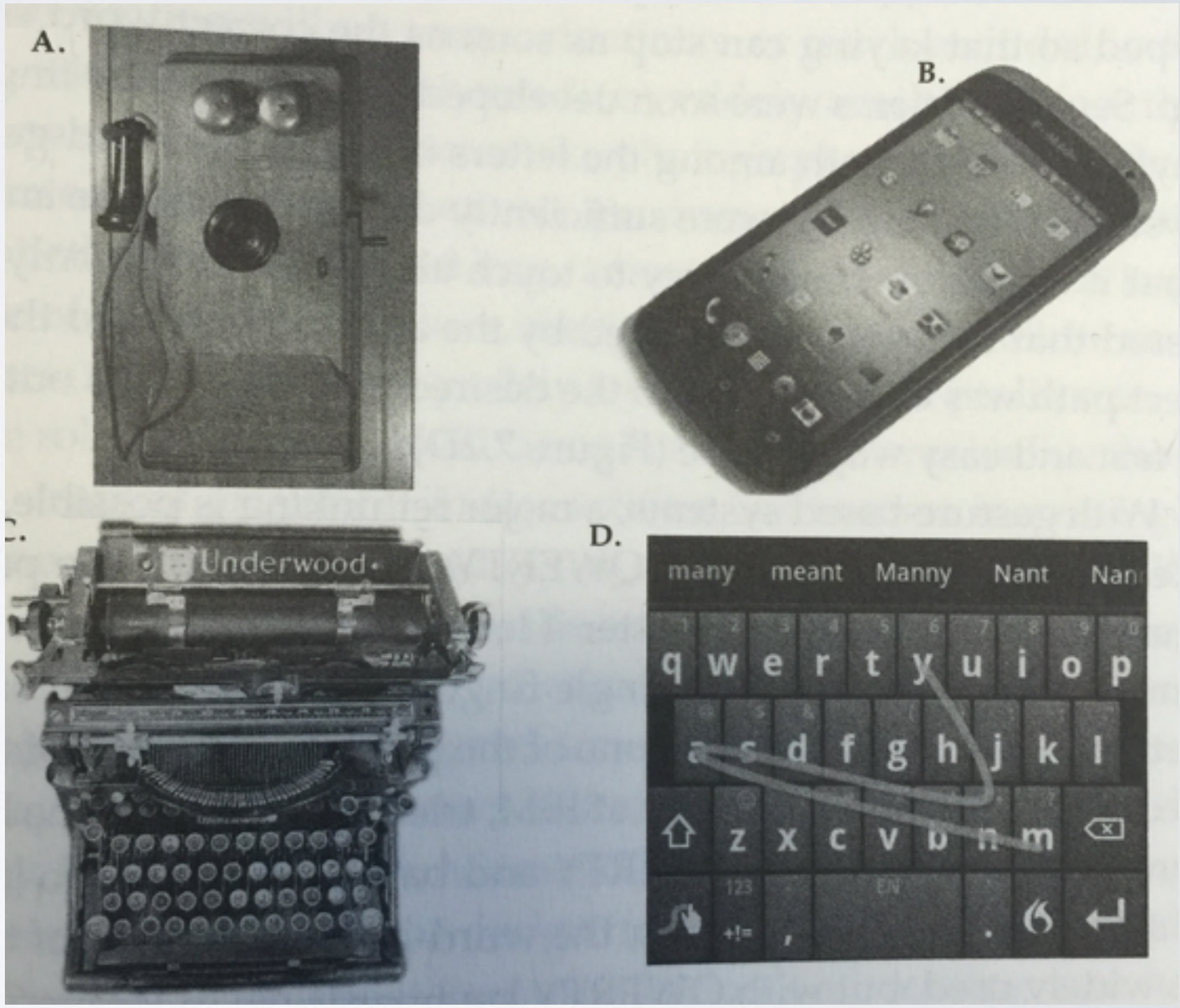
- Antidote: focus on customer and strengths, strengthen even more

Legacy problems

- Users used to existing version of system
- Changing system functionality may force users into relearning how to use system
- Discourages design innovation

Technology changes

- Fundamental user needs stable
- Technology enables new ways for these to be addressed



Group activity

Group activity

- In groups of 3 or 4
- Scenario: Your customers tell you, our organization is large, and we all just get too much email that wastes too much time. Build us a new communication and messaging system.
- Answer the following questions:
  - What would you focus on learning through needfinding?
  - What problems and practices might lead to this issue?
  - Make an (arbitrary) choice on which you think it is
  - Based on this choice, generate design ideas for addressing these issues