Concept-aware Programming Environments
for Program Comprehension and Modularity

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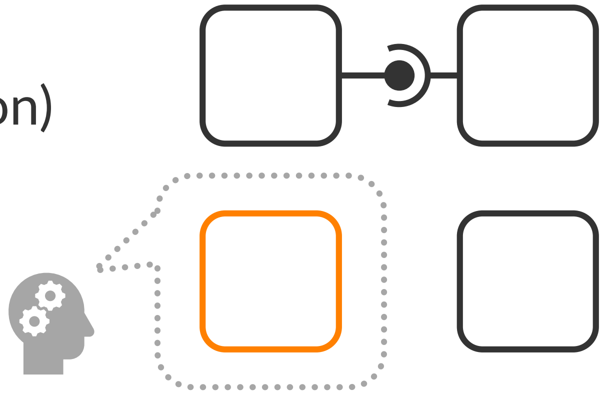
“Working Definitions”

Modularity

The quality of a system that allows parts to…

- change or run independently
(module as unit of variation/distribution)

- be understood independently
(module as **concept**)



Concept

(Named) unit of comprehension and communication

Problem: Architectural Drift

Many software projects start with good modularity

» Low effort to locate and understand concepts

modules
separation of concerns

Problem: Architectural Drift

With growing code bases…

- » Concepts tend to scatter and entangle
- » Programmers need more attention to recognize concepts

modules

separation of concerns

scattering / tangling

Goal

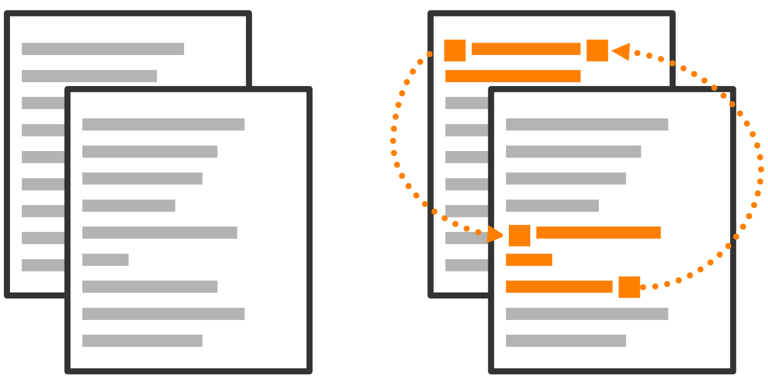
Help programmers...

- Find, navigate, and relate existing concepts to code
- Improve architecture to better express underlying concepts

Working Hypothesis

Modularity may not be perceived,
but **concepts** leave statistically quantifiable **footprints**:

existing module



- shared identifier names
- simultaneous changes
- shared control flow and test coverage
- shared data structures and setup code
- shared authors
- ...

Working Hypothesis

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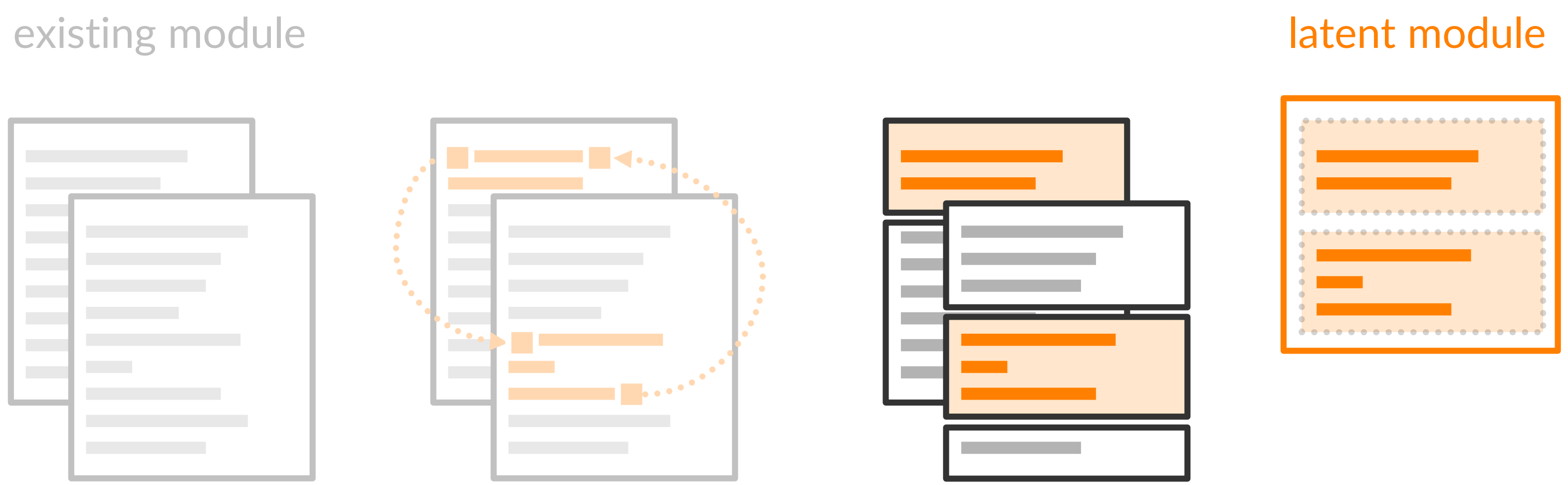
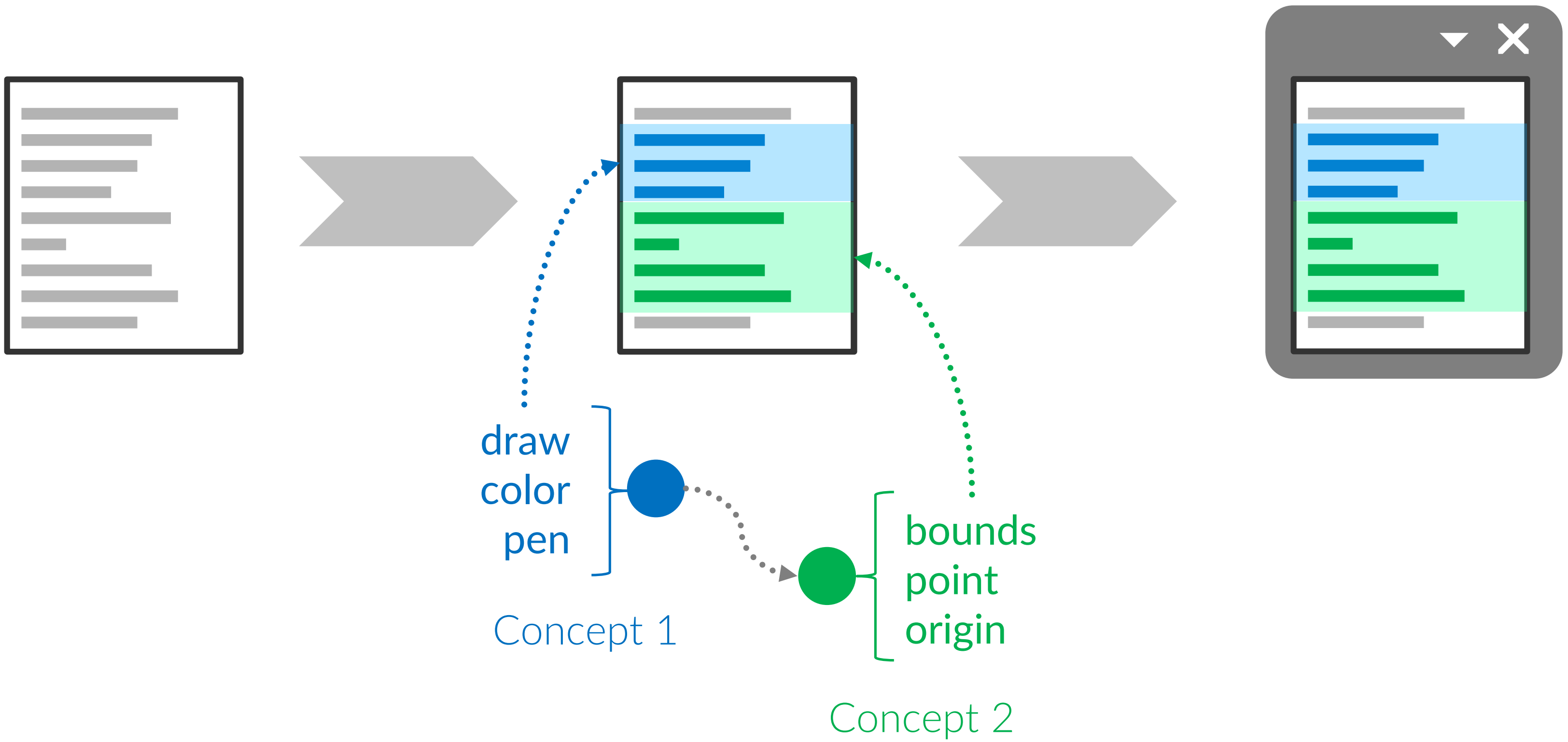


... can we make modularity perceivable by providing a **qualitatively different view** that emphasizes **which concepts** exist and **where** they are implemented/used?

Approach

1 "Concept Mining" 2 Tooling



Basic Concept Model

concept labels

which concept a name belongs to

```
Canvas » draw: anObject
  ^ anObject drawOn: self
```

```
Morph » drawOn: aCanvas
  aCanvas fillRectangle: self bounds.
```

```
Morph » bounds: newBounds
  self position: newBounds topLeft;
  extent: newBounds extent.
```

concepts

prevalent names & features

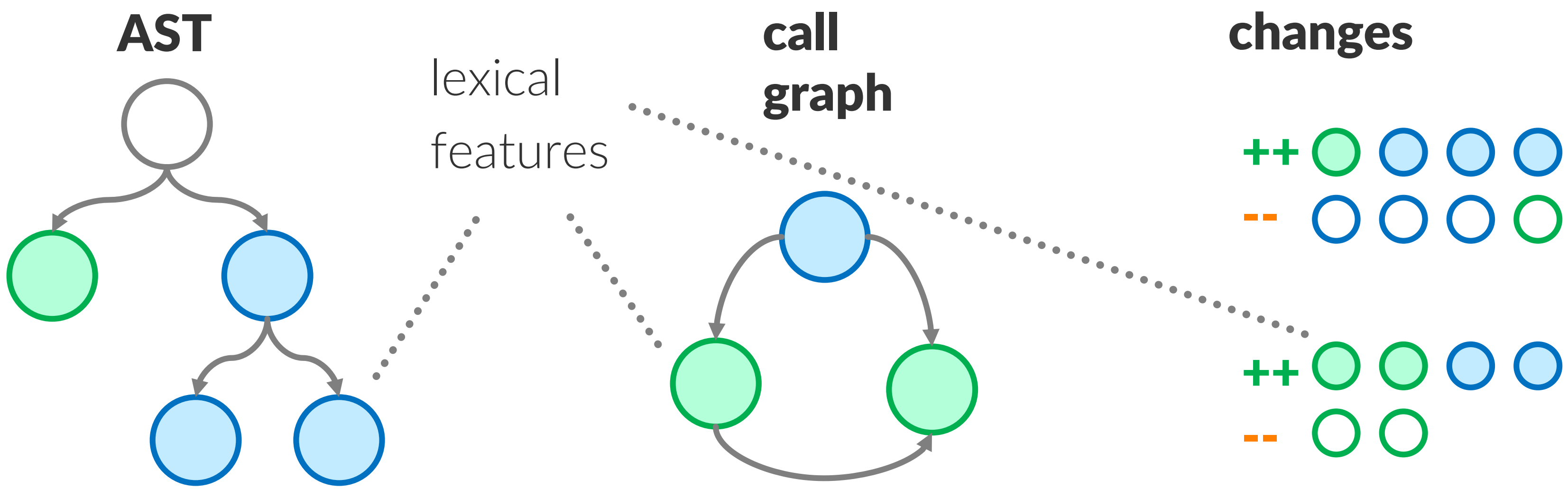
draw, canvas, fill, …

relations

(e.g. usage)

bounds, position, extent, …

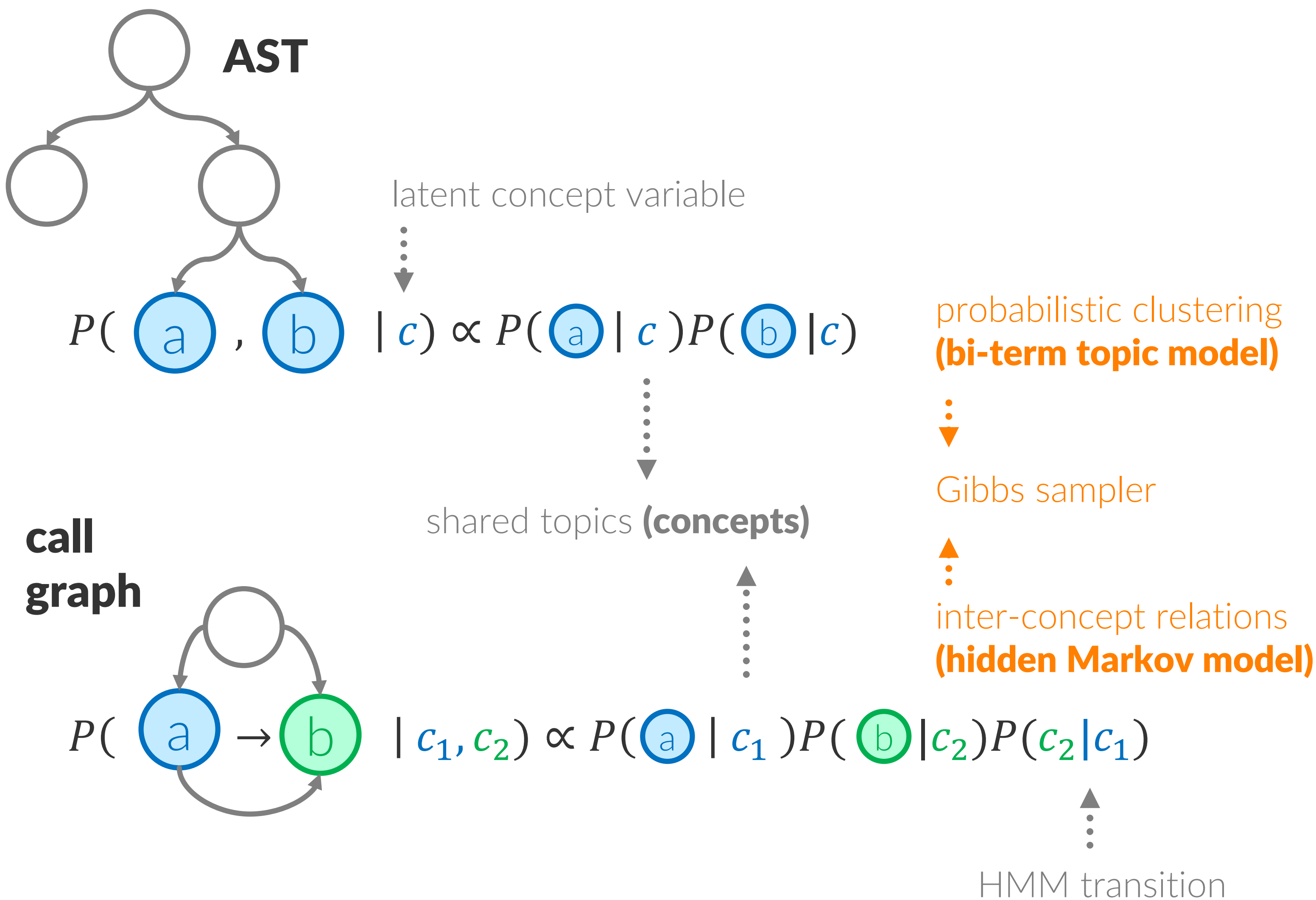
Concept Mining as ML Problem



Multi-view learning: Link concepts to features (names) such that

1. Sharing a concept reflects proximity in AST, call graph, edit history, … — “clusters”
2. Relations between concepts are consistent with individual feature’s relations — “inter-cluster relations”

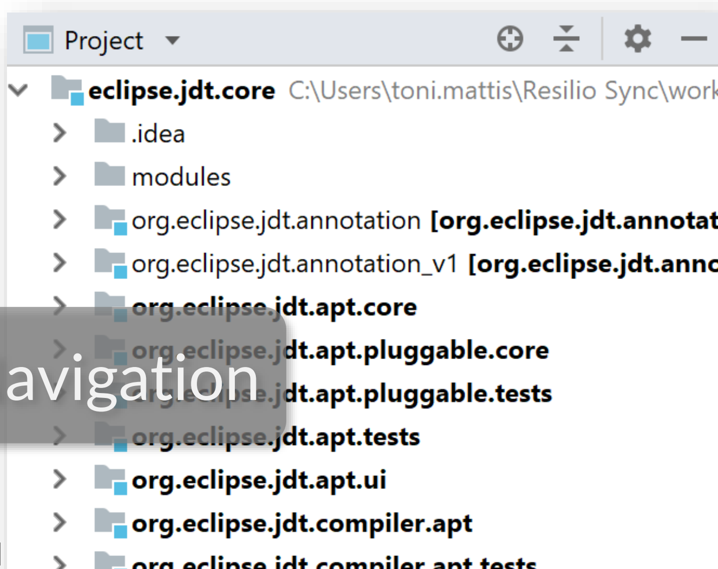
Concept Mining as ML Problem

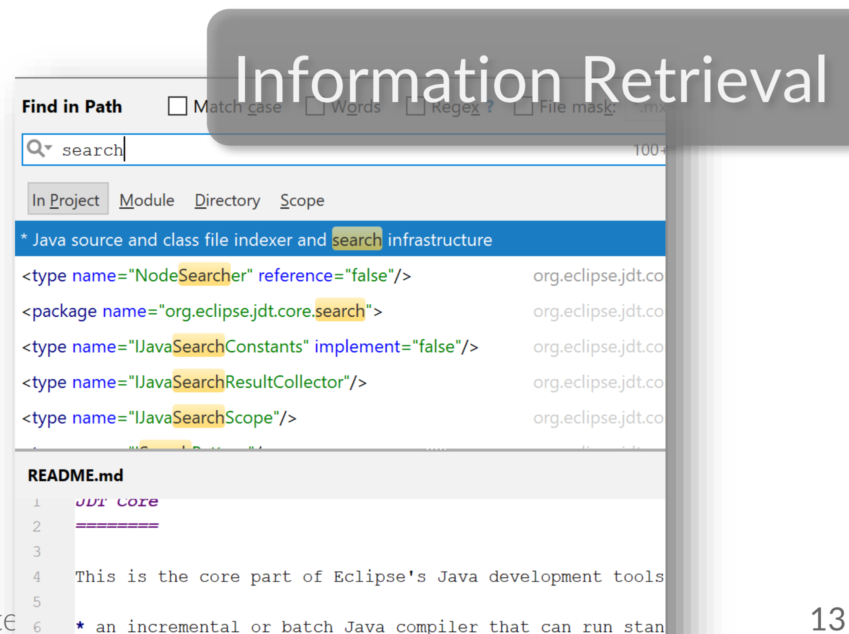


Workflows

» **Reverse Engineering:** Help programmers understand the conceptual structure of a large system

```
grep -r -i --include \*.java "search"
```

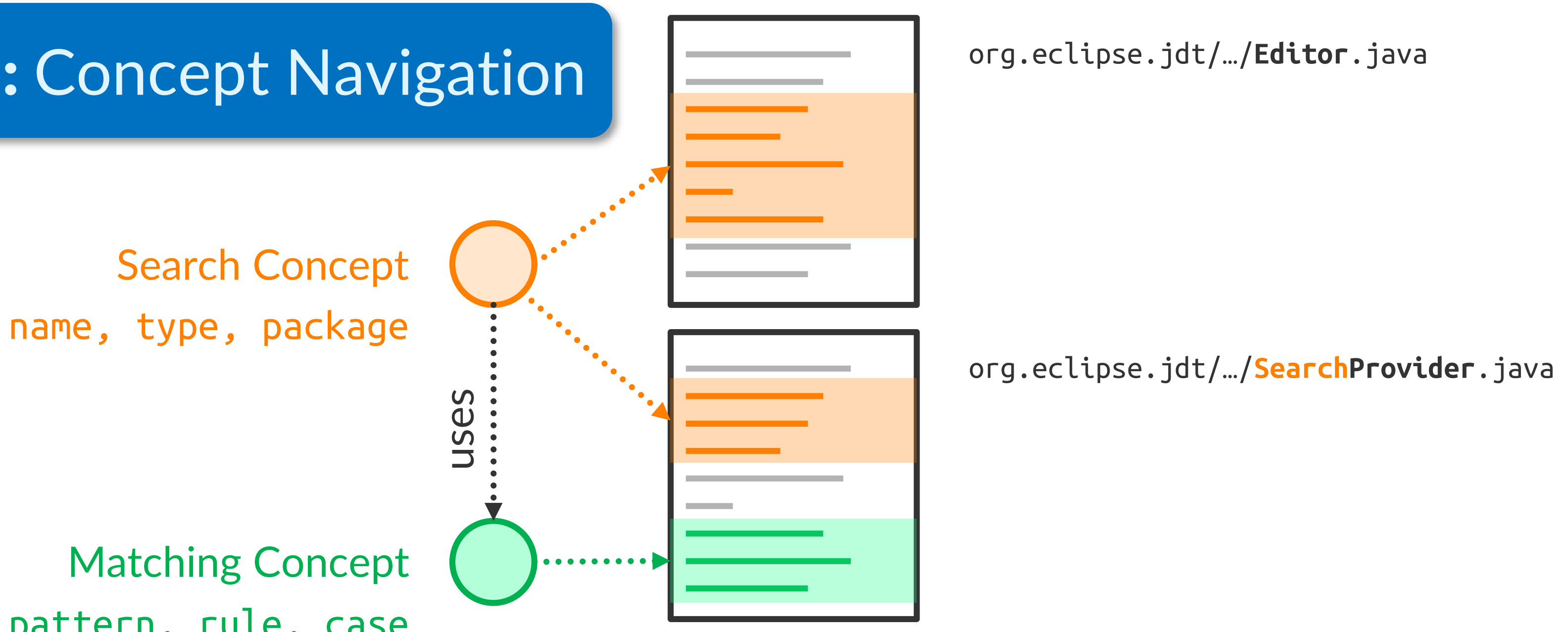




Workflows

» **Reverse Engineering:** Help programmers understand the conceptual structure of a large system

Goal: Concept Navigation



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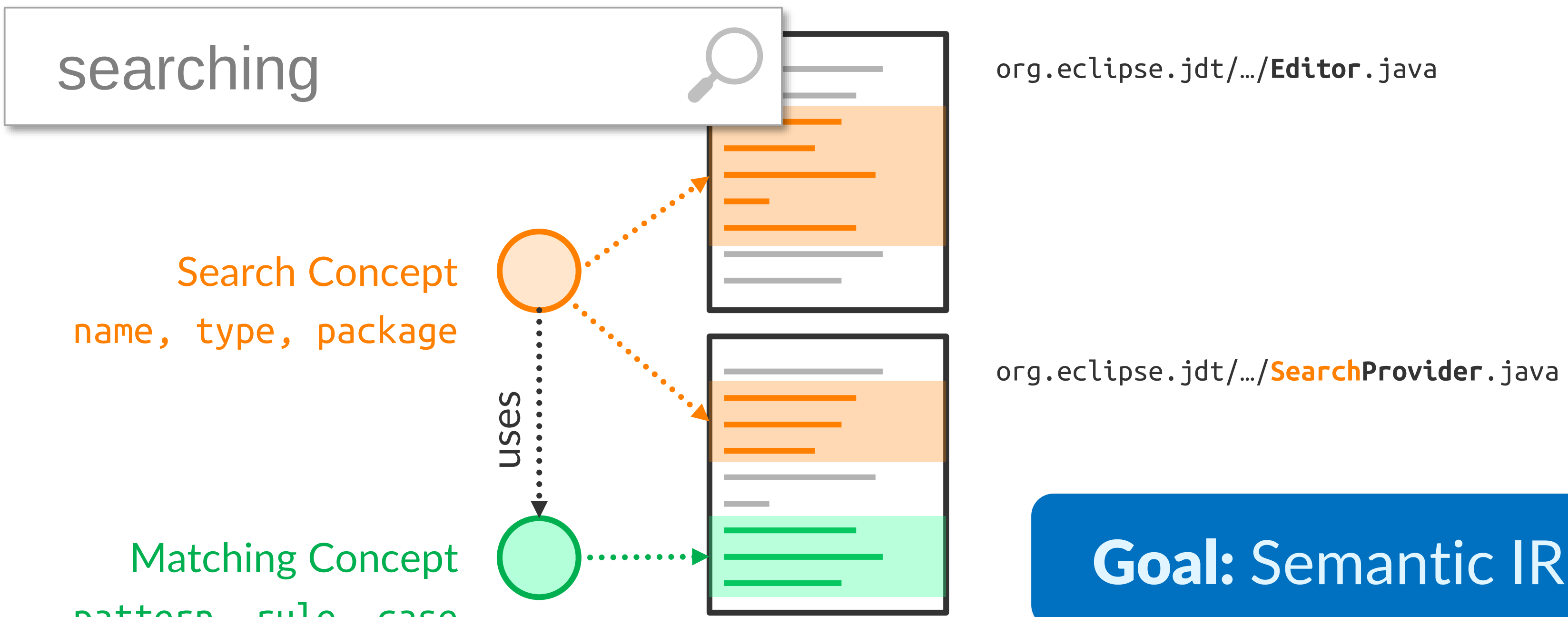
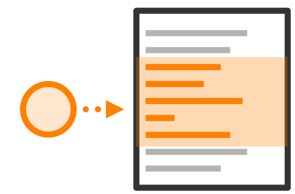
» **Reverse Engineering:** Help programmers understand the conceptual structure of a large system



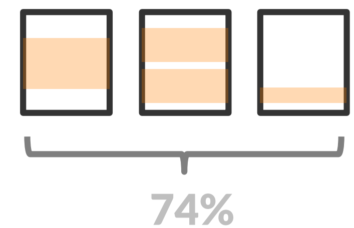
Goal: Semantic IR

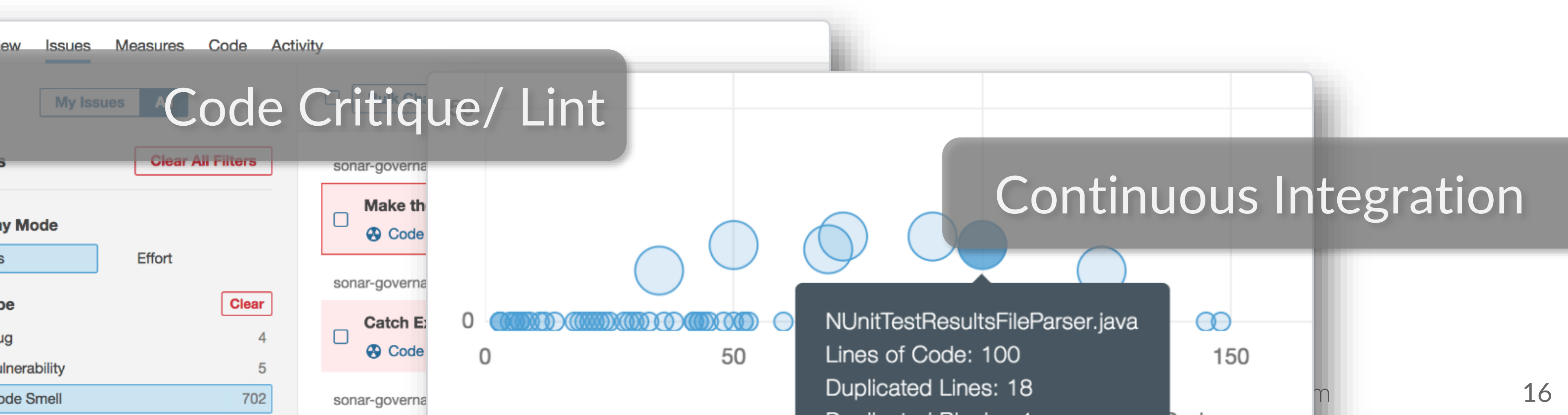
Workflows

- **Reverse Engineering:** Help programmers understand the conceptual structure of a large system



- **Metrics:** Quantify how architecture deviates from conceptual structure





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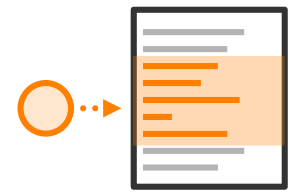

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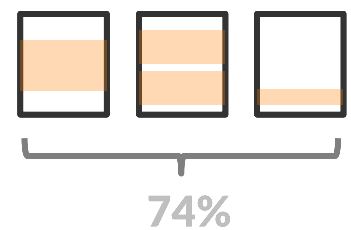
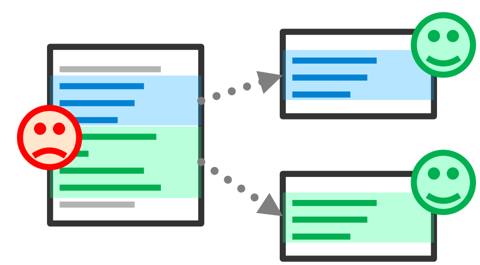
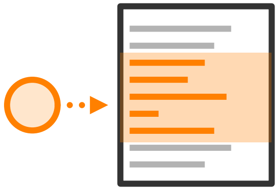


» **Forward Engineering:** Maintain and improve modularity by real-time feedback and recommendations

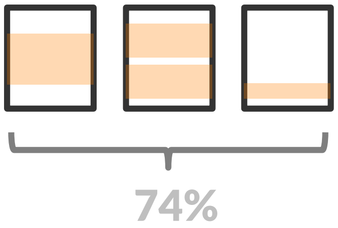


Scenarios

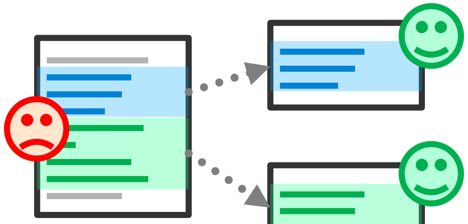
- **Reverse Engineering**
  - Semantic Information Retrieval
  - Semantic Navigation



- **Metrics**
  - Modularity Metrics (Coupling, Cohesion, …)
  - Concept Linting / Code Critique Tools



- **Forward Engineering**
  - Automated Refactorings
  - Recommendation based on concepts



Example: Live Assistance

```
User » query: sql
    | cursor |
    ...
```

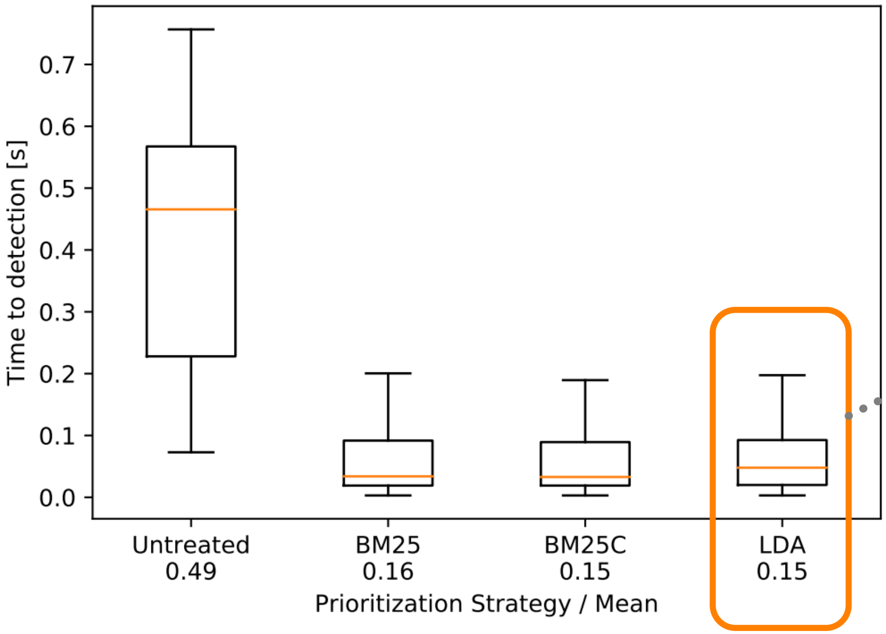
"database" concept is not exposed by class **User**.

- move method to **DBConnection**
- rename method
- add "database" concept to **User**

Example: Conceptual Test Prioritization

» Keep track of which concepts are touched during program modification

» **RQ:** How much faster can we detect errors by prioritizing tests by conceptual relatedness?



Python web framework with seeded faults

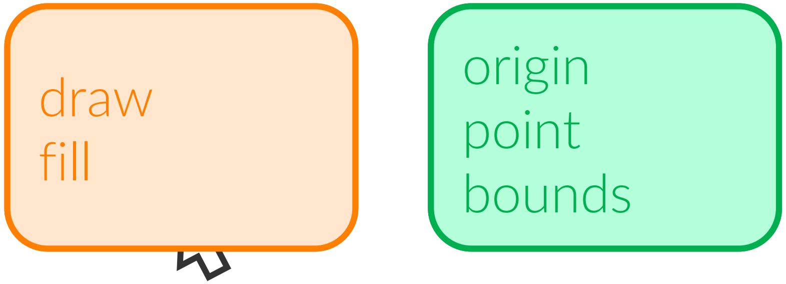
Simple topic model to detect concepts

Recall

77.2% after 0.1s
93.4% after 1.0s

Challenge: Programmer Override

» Programmer override
  › Concept stability under added constraints



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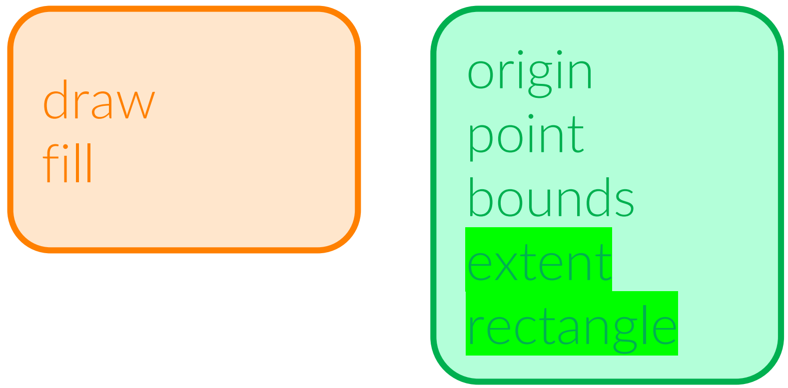

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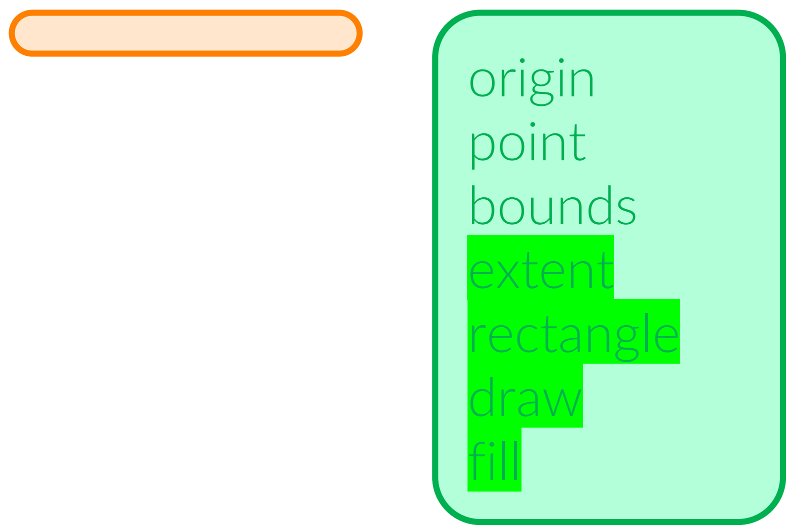

Open Questions

- How do our user interfaces need to look like to
  - help programmers understand the **conceptual context** they are currently exploring, editing, debugging, …
  - keep programmers **aware of modularity issues** without distracting them?
- How can we balance the trade-off between **automated** (potentially surprising) and **manual** concept maintenance?
- How can the proposed concept model be maintained **collectively**?