Lase: Locating and Applying Systematic Edits by Learning from Examples

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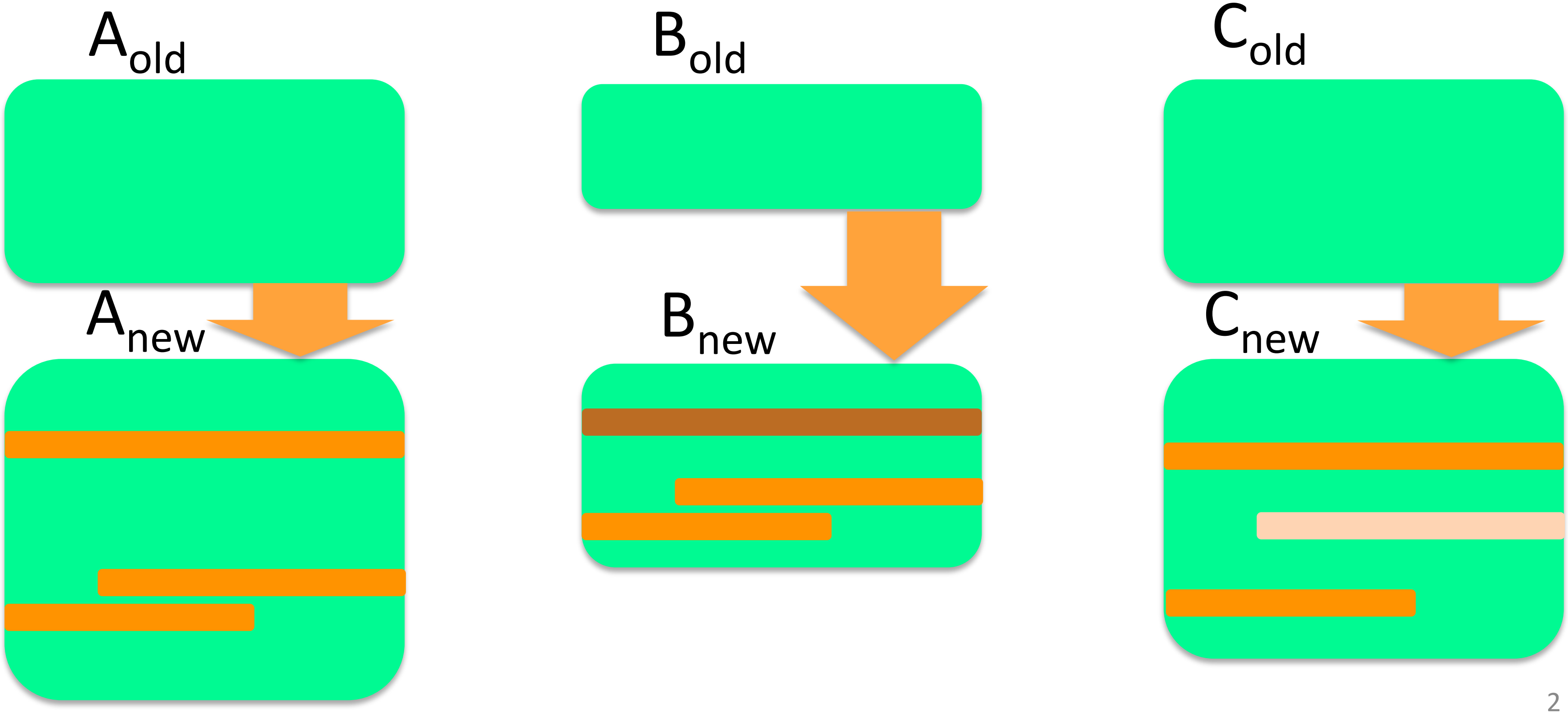
Motivating Scenario

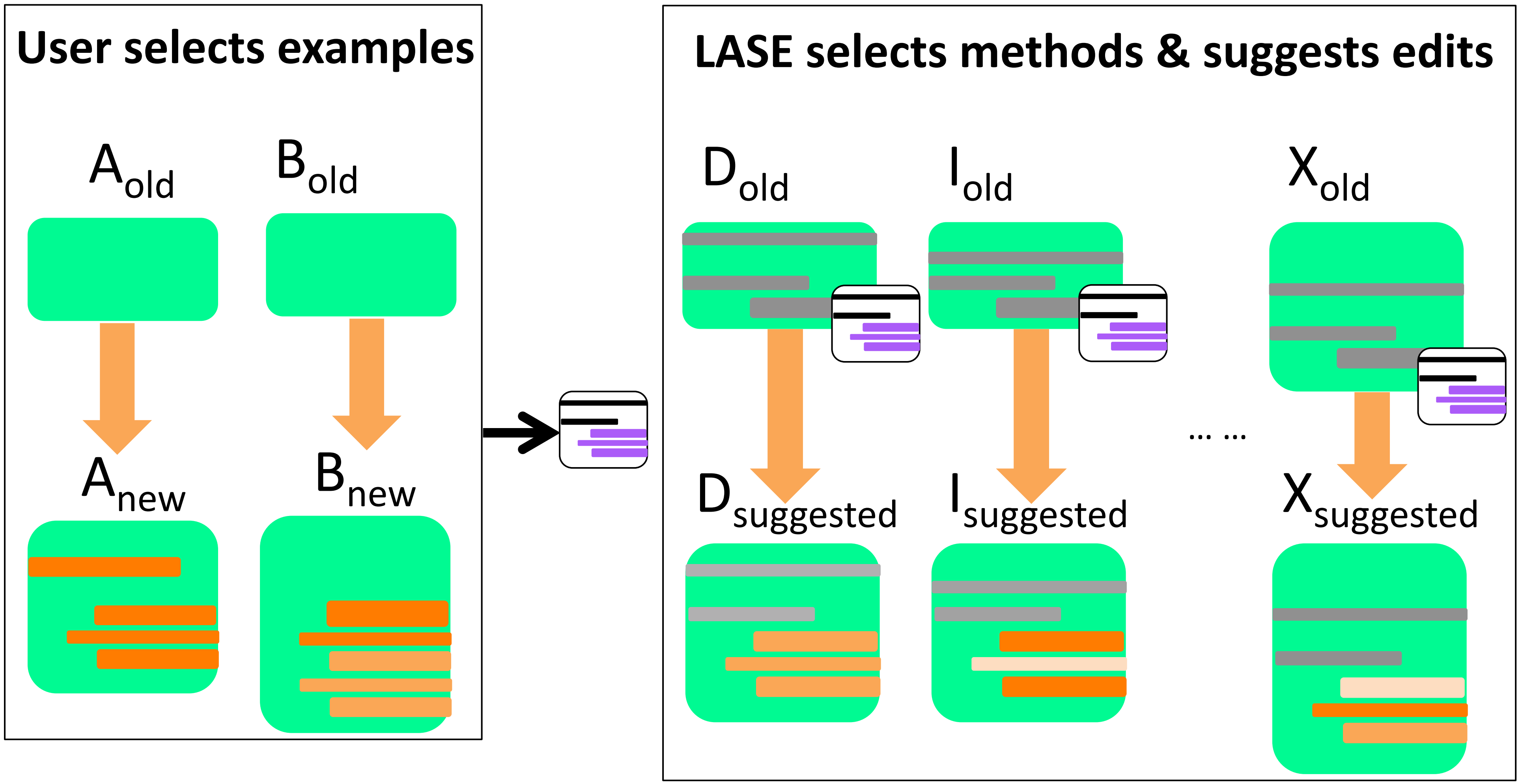
Pat needs to update database transaction code to prevent SQL injection attacks



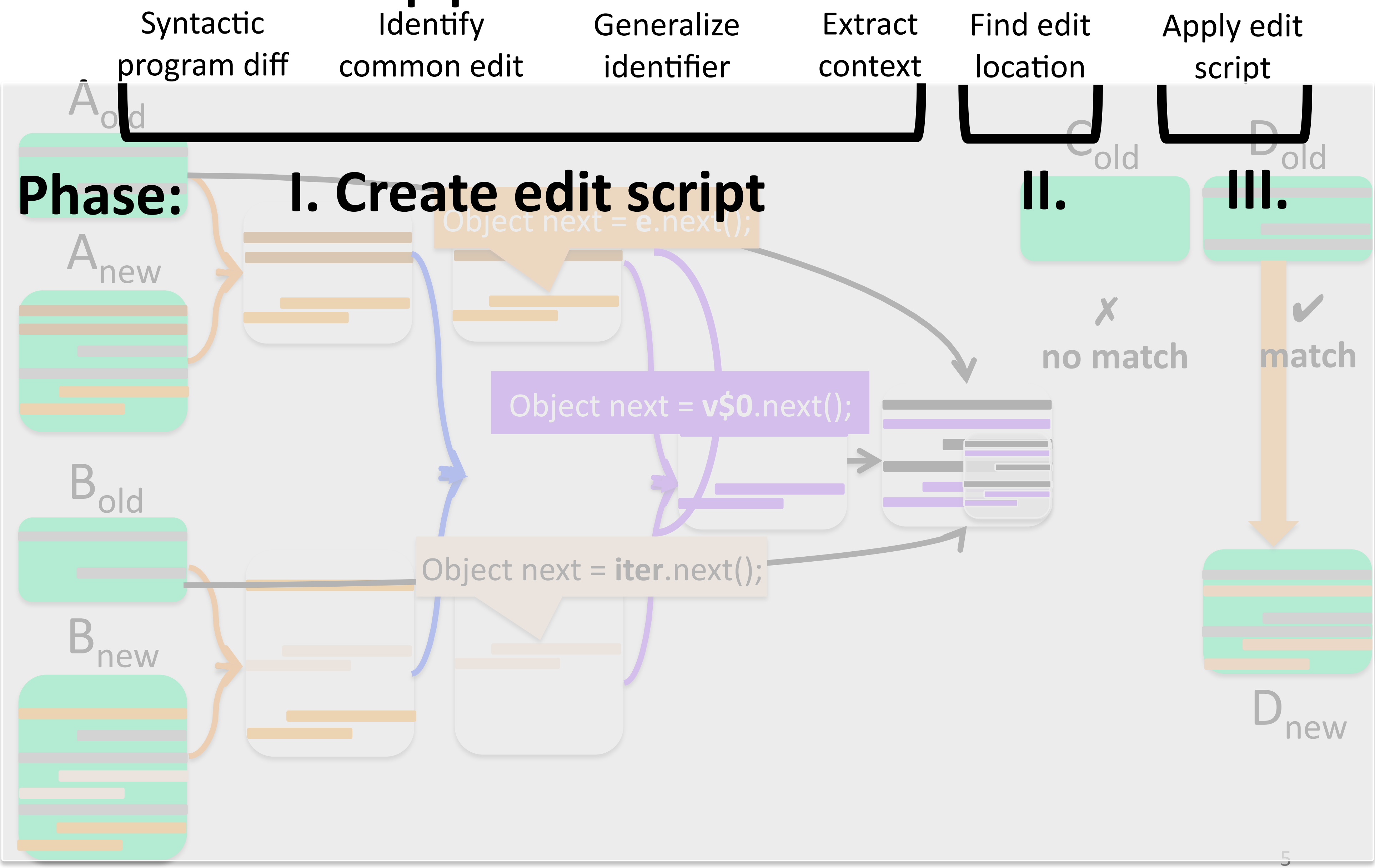
Systematic Editing

- ***Similar but not identical changes*** to multiple contexts
- Manual, tedious, and error-prone
- Source transformation tools require describing edits in a formal language
- Bug fixing tools locate and apply simple or limited stylized code changes
  - Coccinelle, CFix, FixMeUp
- Sydit applies an edit inferred from a code example to user-selected targets

Workflow of Lase



Approach Overview



Step 1. Syntactic Program Diff

Input: m_{old}, m_{new}

Output: Edit operations

operation	**definition**
insert(**u, v, k**)	insert node *u* and position it as the (k+1)th child of node *v*
delete(**u**)	delete node *u*
update(**u, v**)	replace *u* with *v*
move(**u, v, k**)	delete *u* from its current position and insert *u* as the (k+1)th child of *v*

Step 2: Identify Common Edit

- Longest Common Edit Operation Subsequence

Edit script A

insert(Object next = e.next()…)
insert(if(next instanceof MVAction)
insert(((MVAction)next).update())
update(print(next.toString())) to …

Edit script B

insert(Object next = iter.next()…)
update(print(next.getString())) to …
insert(if(next instanceof MVAction)
insert(((MVAction)next).update())
delete(System.out.println(…))

insert(Object next = e.next()…)
insert(if(next instanceof MVAction))
insert(((MVAction)next).update())

insert(Object next = iter.next()…)
insert(if(next instanceof MVAction))
insert(((MVAction)next).update())

Step 3: Generalize Identifier

- Keep the original identifiers if examples agree
- Abstract identifiers if examples disagree

Object next = **e**.next();

Object next = **iter**.next();

Object next = **v$0**.next();

	Generalized identifier	**Identifier in mA**	**Identifier in mB**
Variable Map	next	next	next
	v$0	e	iter
Method Map	next	next	next
Type Map	Object	Object	Object
	Iterator	Iterator	Iterator

Step 4: Extract Context

```
Iterator e = fActions.values().iterator();
… …
while(e.hasNext())
    Object next = e.next();
```

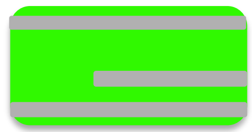
```
Iterator iter = getActions().values().iterator();
… …
while(iter.hasNext())
    Object next = iter.next();
```

```
Iterator v$0 = u$0:FieldAccessOrMethodInvocation.values().iterator();
… …
while(v$0.hasNext())
```

	Generalized identifier	Identifier in mA	Identifier in mB
Uncertain Map	u$0:FieldAccessOrMethodInvocation	fActions	getActions()
Variable Map	v$0	e	iter
Method Map	values	values	values
	iterator	iterator	iterator
	hasNext	hasNext	hasNext
TypeMap	Iterator	Iterator	Iterator

Phase II. Find Edit Locations

D_{old}



```
Iterator e = fActions.values().iterator();
```

```
Iterator v$0 = u$0:FieldAccessOrMethodInvocation.values().iterator();
```

	Generalized identifier	Identifier in mD
Uncertain Map	u$0:FieldAccessOrMethodInvocation	fActions
Variable Map	v$0	e
Method Map	values	values
	iterator	iterator
TypeMap	Iterator	Iterator

Phase III. Applying Edit Script

- Customize general edit scripts
  - Identifier concretization
  - Edit position concretization
- Apply the customized edit scripts

```
Comment[] getLeadingComments(ASTNode node){
-   if (this.leadingComments != null) {
+   if (this.leadingPts >= 0) {
-       int[] range = (int[]) this.leadingComments.get(node);
+       int[] range = null;
+       for (int i = 0; range == null && i <= this.leadingPtr; i++) {
+           if (this.leadingNodes[i] == node) range = this.leadingIndexes[i];
+       }
        if (range != null) {
            int length = range[1] - range[0] + 1;
            Comment[] leadComments = new Comment[length];
            System.arraycopy(this.comments, range[0], leadComments, 0, length);
             return leadComments;
        }
    }
}
```

```
Comment[] getTrailingComments(ASTNode node){
-   if (this.trailingComments != null) {
+   if (this.trailingPts >= 0) {
-       int[] range = (int[]) this.trailingComments.get(node);
+       int[] range = null;
+       for (int i = 0; range == null && i <= this.trailingPtr; i++) {
+           if (this.trailingNodes[i] == node) range = this.trailingIndexes[i];
+       }
        if (range != null) {
            int length = range[1] - range[0] + 1;
            Comment[] trailComments = new Comment[length];
            System.arraycopy(this.comments, range[0], trailComments, 0,
length);
             return trailComments;
        }
    }
}
```

```
public int getExtendedEnd (ASTNode node){
    int end = node.getStartPosition() + node.getLength();
-   if (this.v$_1_ != null) {
+   if (this.trailingPts >= 0) {
-       int[] range = (int[]) this.trailingComments.get(node);
+       int[] range = null;
+       for (int i = 0; range == null && i <= this.v$_1_; i++) {
+           if (this.v$_2_[i] == node) range = this.v$_3_[i];
+       }
        if (range[0] == -1 && range[1] == -1) {
            … …
        } else {
            … …
        }
    }
    return end - 1;
}
```

Outline

- Phase I: Creating Abstract Edit Scripts
  - Syntactic Program Diff
  - Identify Common Edit
  - Generalize Identifier
  - Extract Context
- Phase II: Find Edit Locations
- Phase III: Apply Edit Script
- Evaluation

Test Suite

- 24 repetitive bug fixes that require multiple check-ins [Park et al., MSR 2012]
  - 2 from Eclipse JDT and 22 from Eclipse SWT
  - Each bug is fixed in multiple commits
  - Clones of at least two lines between patches checked in at different times
- 37 systematic edits that require similar changes to different methods

RQ1: Precision, Recall, and Accuracy

Precision (P): What percentage of all *found* locations are correctly identified?

Recall (R): What percentage of all *expected* locations are correctly identified?

Accuracy (A): How similar is Lase-generated version to developer-generated version?

Index	Bug(patches)	m_i	Edit Location					Operations		
			Σ	✔	P%	R%	A%	E	C	$E_{A\%}$
2	82429(2)	16	13	12	92	75	81	9	9	100
4	139329(3)	6	2	2	100	33	74	6	3	50
7	103863(5)	7	7	7	100	100	100	34	34	100
8	129314(3)	3	4	4	100	100	100	2	2	100
16	95409(3)	7	9	9	100	100	78	4	4	100
24	98198(2)	9	15	15	100	100	95	3	3	100

On average, Lase finds edit locations with 99% precision, 89% recall, and 91% accuracy.

For three bugs, Lase suggests in total 9 edits that developers missed and later confirmed.

RQ2: Sensitivity to number of exemplar edits

- 7 cases in the oracle data set
- Enumerate subsets of exemplar edits

	# of exemplars	P%	R%	A%
Index 4	1	100	17	100
	2	100	51	72
	3	100	82	67
	4	100	96	67
	5	100	100	67
Index 7	1	100	59	100
	2	100	83	100
	3	100	84	100
	4	100	88	100
	5	100	92	100
	6	100	96	100
Index 12	1	100	54	92
	2	78	90	85
	3	49	98	83
	4	31	100	82

As the number of exemplar edits increases,

- P does not change except for case 12

- R is more sensitive to the number of exemplar edits
- R increases as a function of exemplar edits

- A decreases when exemplar edits are different
- A remains the same or may increase when the exemplar edits are very similar

Conclusion

- Lase automates edit location search and program transformation application
- Lase achieves
  99% precision, 89% recall, and 91% accuracy

- Future Work
  – Integrate with ***automated compilation and testing***
  – Automatically detect repetitive change examples to infer program transformations

Thank You !

Questions?

References I

- [Meng et al. 2011] Na Meng, Miryung Kim and Kathryn S. McKinley. Systematic editing: Generating program transformations from an example. In PLDI ‘11.
- [Kamiya et al. 2002] Toshihiro Kamiya and Shinji Kusumoto and Katsuro Inoue. CCFinder: A multilinguistic token-based code clone detection system for large scale source code. In TSE ’02.
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- [Park et al. MSR 2012] J. Park, M. Kim, B. Ray, and D.-H. Bae. An empirical study of supplementary bug fixes. In MSR ’12.

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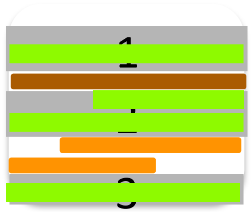
- [Nguyen et al.] H. A. Nguyen, T. T. Nguyen, G. W. Jr., A. T. Nguyen, M. Kim, and T. Nguyen. A graph-based approach to api usage adaptation. In OOPSLA ’10.
- [Cordy et al.] J. R. Cordy, C. D. Halpern, and E. Promislow. Txl: A rapid prototyping system for programming language dialects. Computer Languages, 1991.
- [Gulwani et al.] S. Gulwani. Dimensions in program synthesis. In PPDP ’10.
- [Weimer et al.] W. Weimer, T. Nguyen, C. Le Goues, and S. Forrest. Automatically finding patches using genetic programming. In ICSE ’09.

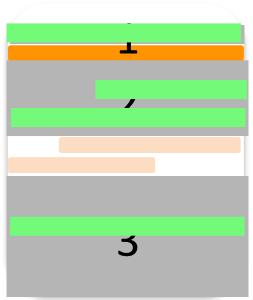
Step 4: Common Edit Context Extraction

- Extract all potential common context
- Refine the common context
  - Consistent identifier mapping
  - Embedded subtree isomorphism
  - Program dependence equivalence

Step 4: Common Edit Context Extraction (1/4)

- Finding common *text* with clone detection (CCFinder [Kamiya et al. 2002])





Step 4: Common Edit Context Extraction (2/4)

- Identifier generalization

```
Iterator e = fActions.values().iterator();
while (e.hasNext()) {
```

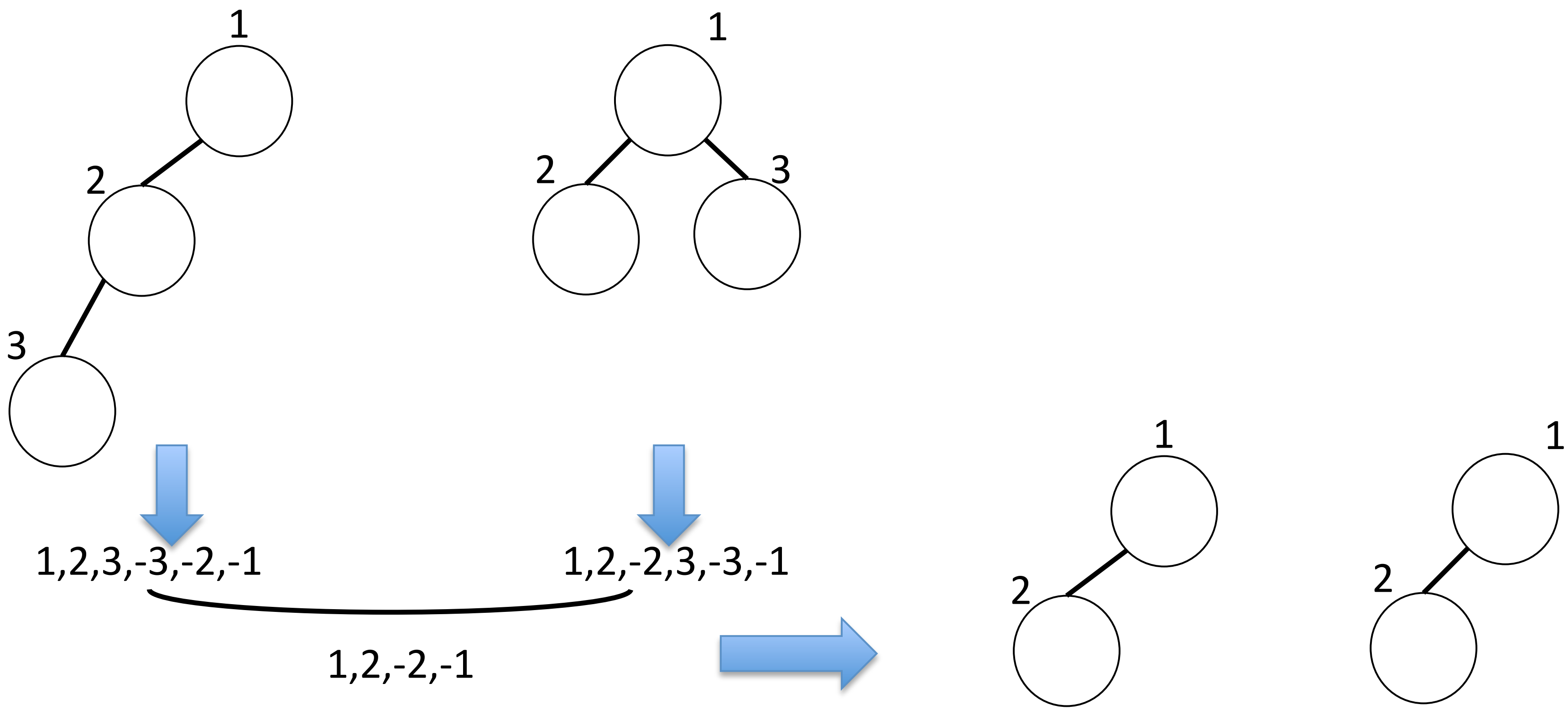
```
Iterator iter = getActions().values().iterator();
while (iter.hasNext()) {
```

```
Iterator v$0 = u$0:FieldAccessOrMethodInvocation.values().iterator();
while (v$0.hasNext()) {
```

	Abstract identifier	Identifier in mA	Identifier in mB
Uncertain Map	u$0:FieldAccessOrMethodInvocation	fActions	getActions()
Variable Map	v$0	e	iter
Method Map	values	values	values
	iterator	iterator	iterator
	hasNext	hasNext	hasNext
TypeMap	Iterator	Iterator	Iterator

Step 4: Common Edit Context Extraction (3/4)

- Maximum Common Embedded Subtree Extraction (MCESE) [Lozano et al. 2004]



Step 4: Common Edit Context Extraction (4/4)

ence analysis

Iterator e = fActions.values().iterator();

while (**e**.hasNext()) {

Object next = e.next();

	Abstract identifier	Identifier in mA	Identifier in mB
Variable Map	v$0	e	iter
Method Map	values	values	values
… ….			

?When more than two examples?