

Mastery: Shifted-Code-Aware Structured Merging

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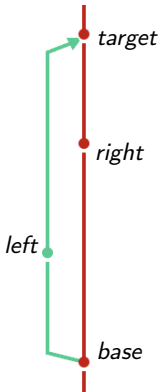
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1 Introduction

2 Algorithm

3 Evaluation

Three-way merging

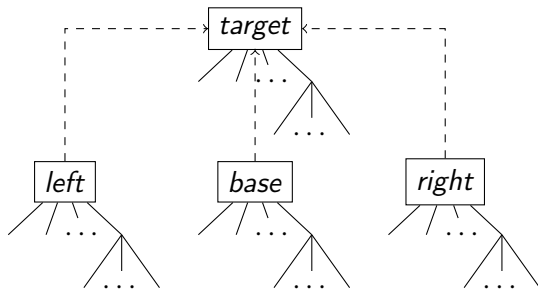


Three-way merging: integrate consistent changes introduced by the two branches.

Unstructured merging:

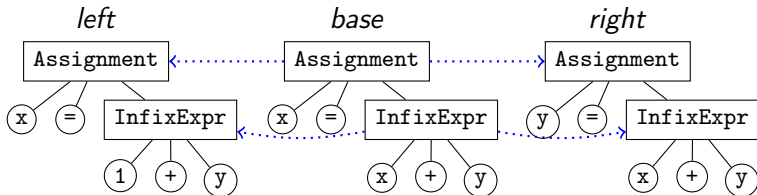
- broadly used in practice;
- recognizes source programs as lines;
- merge accuracy is unsatisfying.

Structured merging



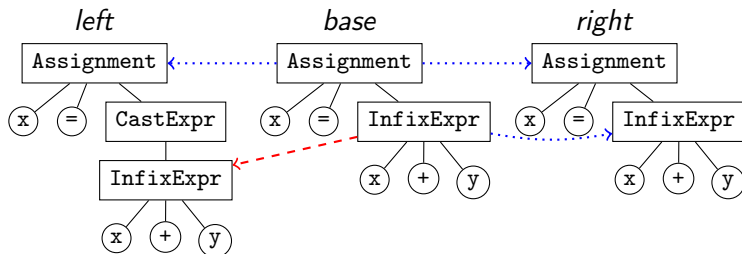
Structured merging recognizes source code as AST (abstract syntax tree), which has higher merge accuracy than unstructured merging.

AST matching



AST matching: When manipulating *base* AST into some variant, the matched two nodes (e.g. Assignments) are recognized as the same one.

Shifted code

`x = (int)(x + y) // left``x = x + y // base`

Definition: Given two mappings (u', v') and (u, v) , if u is a child of u' , whereas v is not a child but a later descendant of v' , then the code fragment corresponding to v is called a **shifted code**.

Challenge: Existing structured merging algorithms visits nodes in a top-down way, so they **cannot handle shifted code**.

Our idea

Problem: how to merge shifted code?

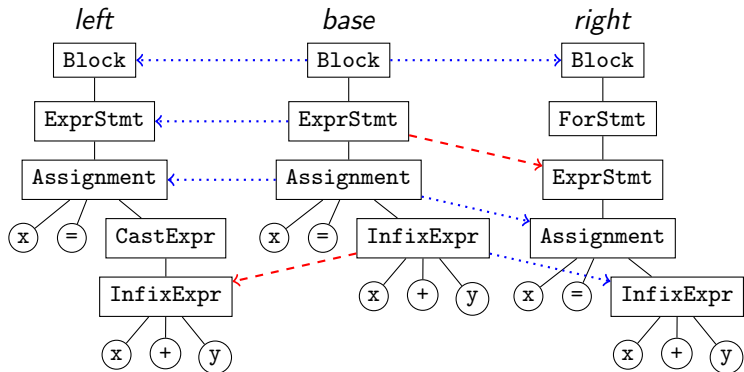
Method: introduce a **bottom-up** merging algorithm.

① Introduction

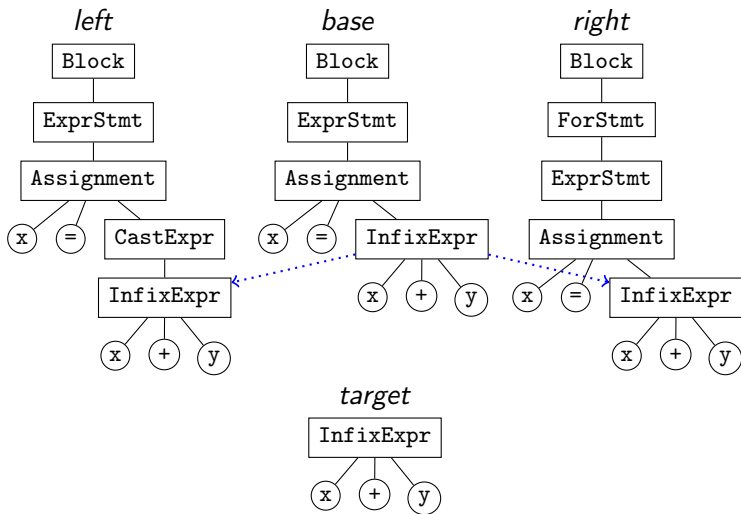
② Algorithm

③ Evaluation

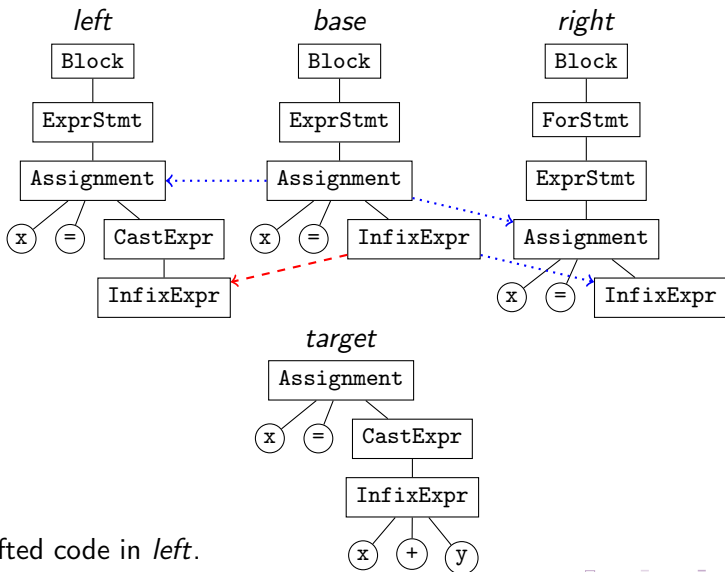
A motivating example



Four merge scenarios of inner nodes.



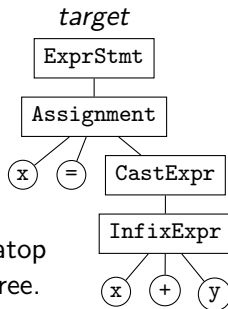
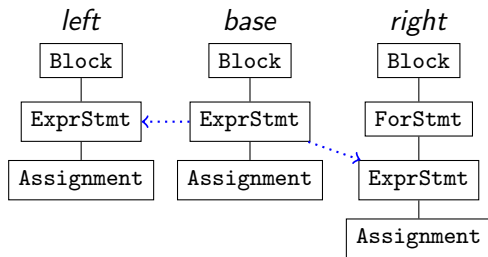
Three subtrees of `InfixExpr` are equal, so their merging is trivial.



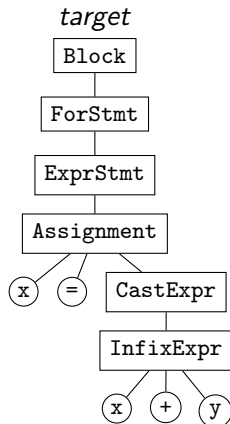
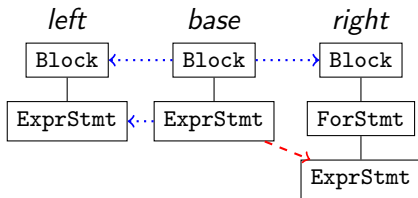
Shifted code in *left*.

Relevant

If there exists a descendant w of v such that u matches w , we say that u is **relevant** to v .



Just put an ExprStmt atop
the computed merged tree.



Shifted code in *right*: copy the subtree of `ForStmt`, and replace its child subtree (`ExprStmt`) with computed merged result.

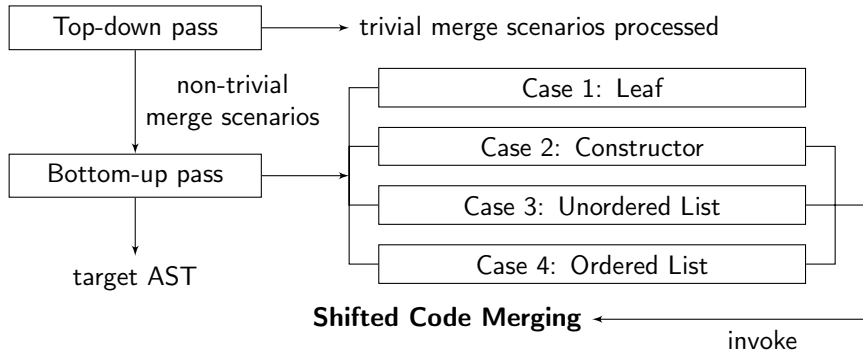
Pseudocode

Algorithm: Shifted Code Merging

```
1 Function IssueShifted(b: Node, l: Node, r: Node):  
2   let  $l', r'$  be nodes s.t.  $(b, l') \in \mathcal{M}_L, (b, r') \in \mathcal{M}_R$ ;  
3   if  $l' = l \wedge r' = r$  then return  $\mathcal{R}(b)$ ;  
4   if  $l' \neq l \wedge r' = r$  then return  $l[\mathcal{R}(b)/l']$ ;  
5   if  $r' \neq r \wedge l' = l$  then return  $r[\mathcal{R}(b)/r']$ ;  
6   if  $l[\mathcal{R}(b)/l'] = r[\mathcal{R}(b)/r']$  then return  $l[\mathcal{R}(b)/l']$ ;  
7   return Conflict(l, r);
```

b is required to be relevant to *l* and *r*.

Framework



The technical details could be found in our paper.

① Introduction

② Algorithm

③ Evaluation

Dataset

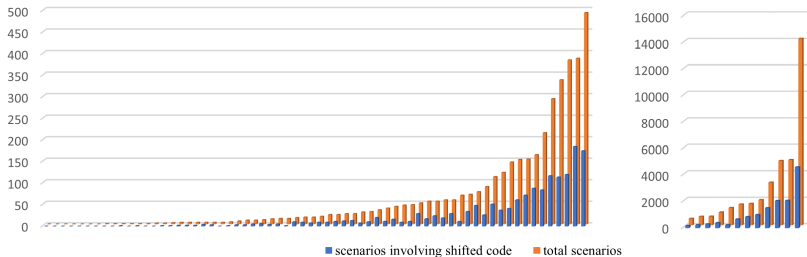
We seek the top-100 most popular open-source Java projects on GitHub¹; exclude any non-software-project (e.g., tutorials).
On the remaining 78 projects, we extract **40,533** merge scenarios via an analysis of their commit histories.

¹According to the following list, until July 12, 2021:

github.com/EvanLi/Github-Ranking/blob/master/Top100/Java.md

Frequency of shifted code

38.54% among 40,533 merge scenarios

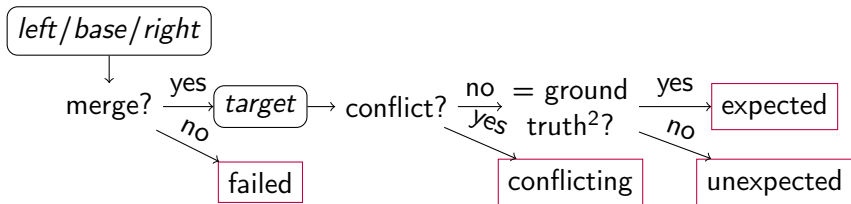


Baseline tools

We compare Mastery with four state-of-the-art merge tools:

- JDime: structured;
- jFSTMerge: semistructured, tree-based;
- IntelliMerge: semistructured, graph-based, refactoring-aware;
- GitMerge: unstructured, the default merging tool in Git.

Taxonomy of results



²We use code merged by developer as ground truth.

Distribution of results

Tool	Expected (Accuracy)	Unexpected	Conflicting	Failed
Mastery	82.26%	8.64%	9.09%	0.00%
JDime	80.89%	6.03%	11.37%	1.70%
jFSTMerge	74.17%	9.47%	16.35%	0.01%
IntelliMerge	24.11%	60.58%	8.49%	6.81%
GitMerge	75.60%	1.95%	22.45%	0.00%

Shifted-aware merging is effective

- Among the 1,398 scenarios where Mastery's results are expected whereas JDime's are not, 48.78% (+10.25%) involves shifted code.
- Among the 1,650 scenarios where JDime's results are conflicting whereas Mastery's are not, 51.82% (+13.28%) involves shifted code.

Runtime performance

Tool	Mastery	JDime	jFSTMerge	IntelliMerge
Sort	structured		semi-structured	
Avg Time	10.33 s	24.06 s	13.21 s	4.34 s

Mastery is 2.4x as fast as JDime, and 1.3x as fast as jFSTMerge.

Recap

Problem: how to merge scenarios containing shifted code in structured merging?

Method: merging in both top-down and **bottom-up** way.

Evaluation: improve overall efficiency and effectiveness.

Tool: <https://github.com/thufv/mastery>

Thanks!