An Empirical Investigation into Learning Bug-Fixing Patches in the Wild via Neural Machine Translation

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Massimiliano Di Penta, Martin White, Denys Poshyvanyk

Can you translate
buggy code
into fixed code?

Can you translate buggy code into fixed code?

Google

Translate

Buggy | English | Spanish | Detect language

```
public void addElement ( Element <?> elem) {
     myList.add(elem);
}
```

Fixed | Dutch | Spanish | Translate

```
public void addElement ( Element <?> elem) {
    if (! myList.contains(elem))
         myList.add(elem);
}
```

Why?

Automated Program Repair is (arguably) one of the most exciting research problem in SE.

//TODO - <insert example of bug which costed a lot of money>

//TODO - <sentence about testing and fixing being expensive>

How?

Via Neural Machine Translation by
Learning from past mistakes (historical bug-fixes)

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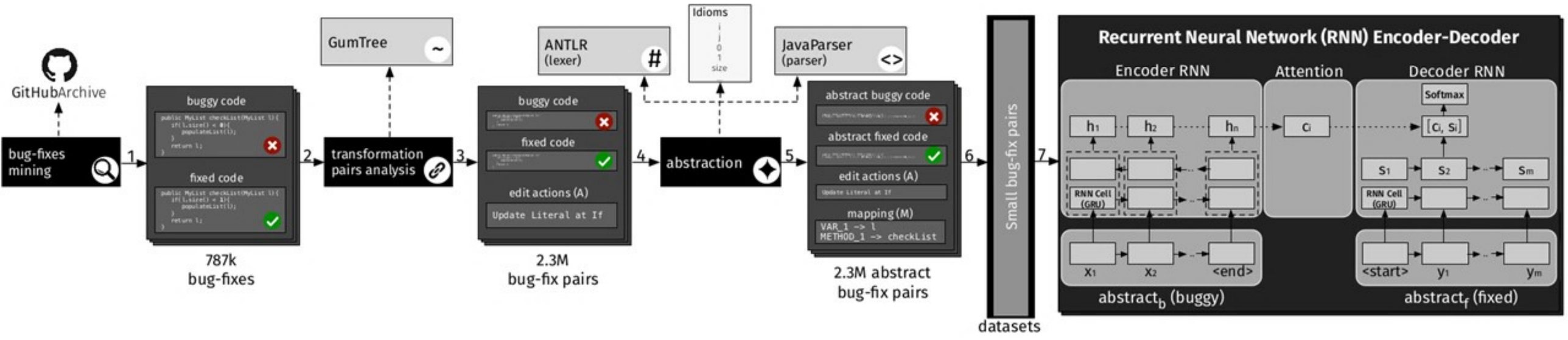
GitHub

March 2011 - October 2017

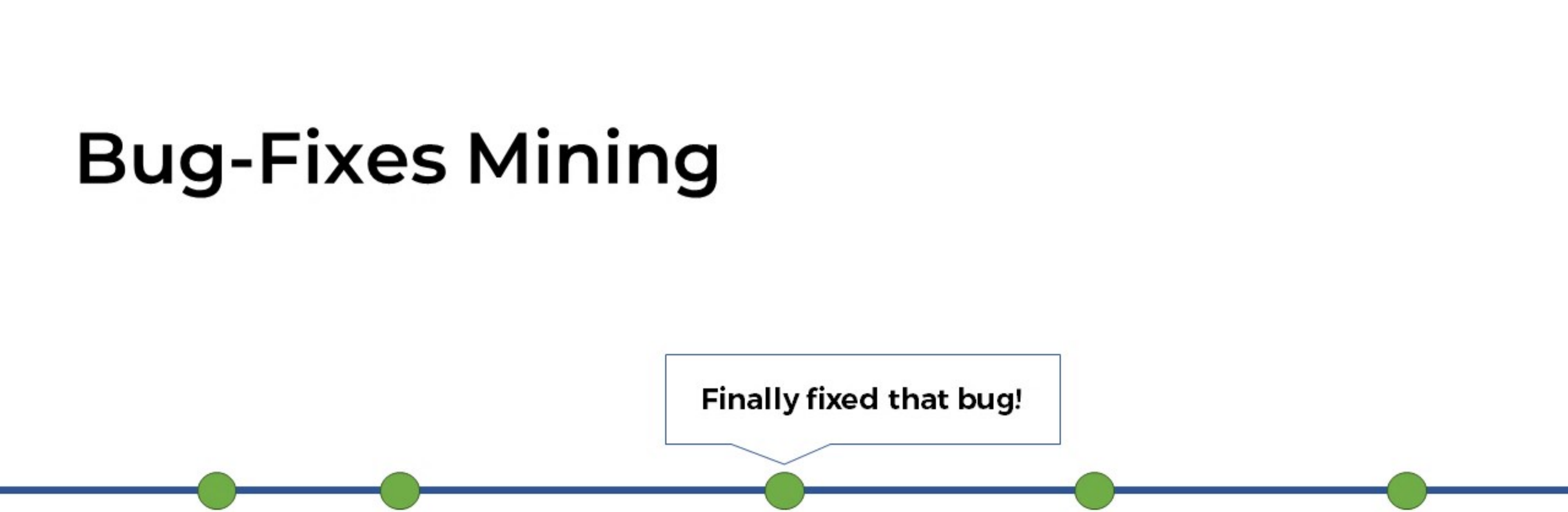
$\sim 10M$illion Bug-fixing commits

Overview

1. Bug-fixes mining
2. Transformation Pairs extraction
3. Code Abstraction
4. NMT (Encoder-Decoder) training



Bug-Fixes Mining

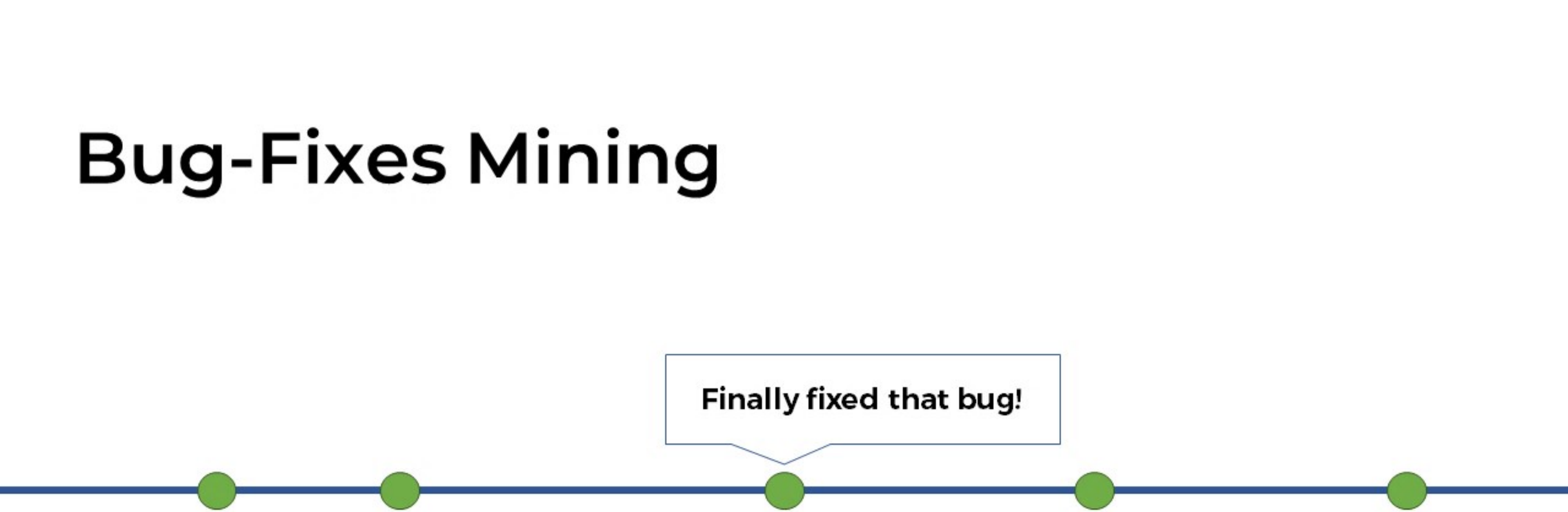


Archive

Regex for Comments

```
(“fix” or “solve” ) AND
(“bug” or “issue” or “problem” or “error” )
```

Bug-Fixes Mining



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Total Commits

10,056,052

Bug-Fixes Mining

Finally fixed that bug!

Archive

Regex for Comments

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(“bug” or “issue” or “problem” or “error” )
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Total Commits

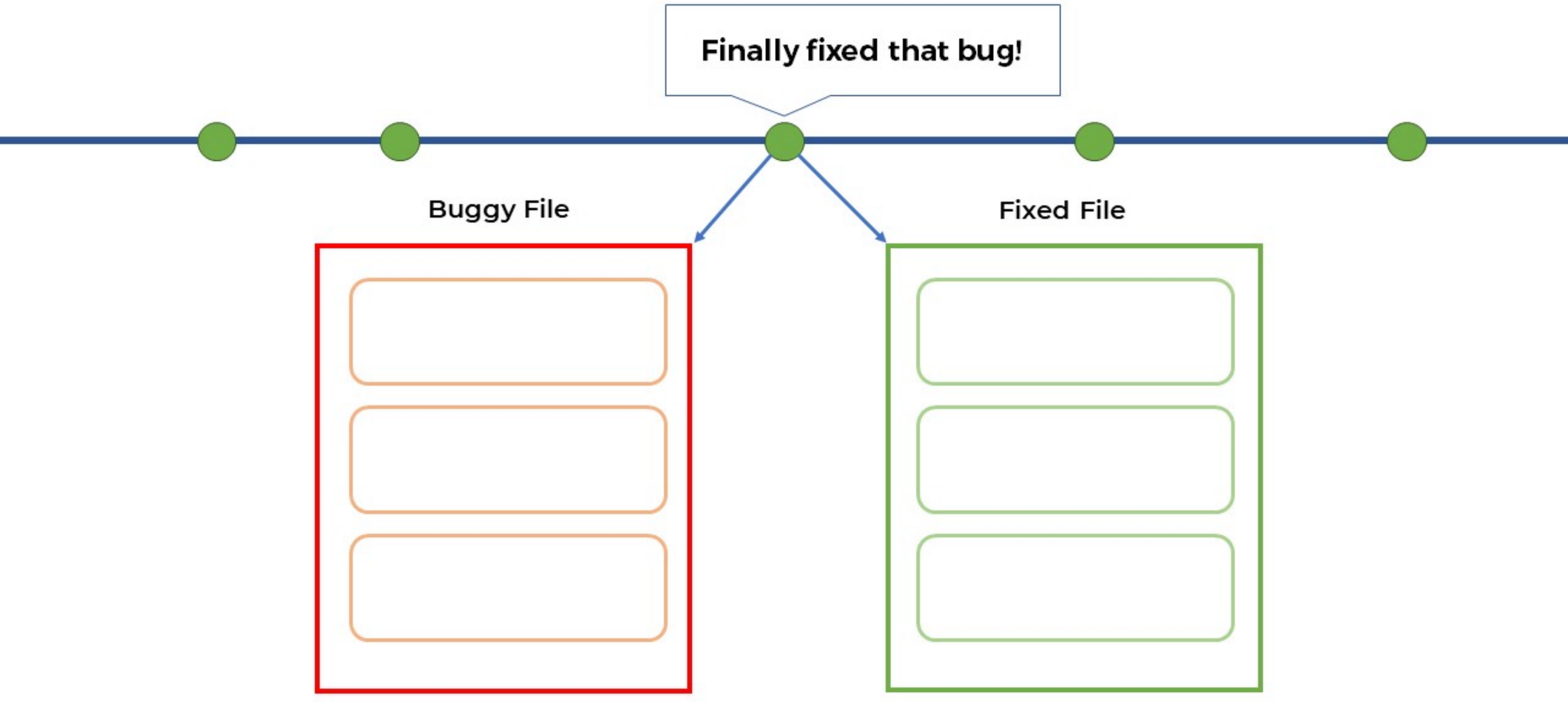
10,056,052

Java Commits

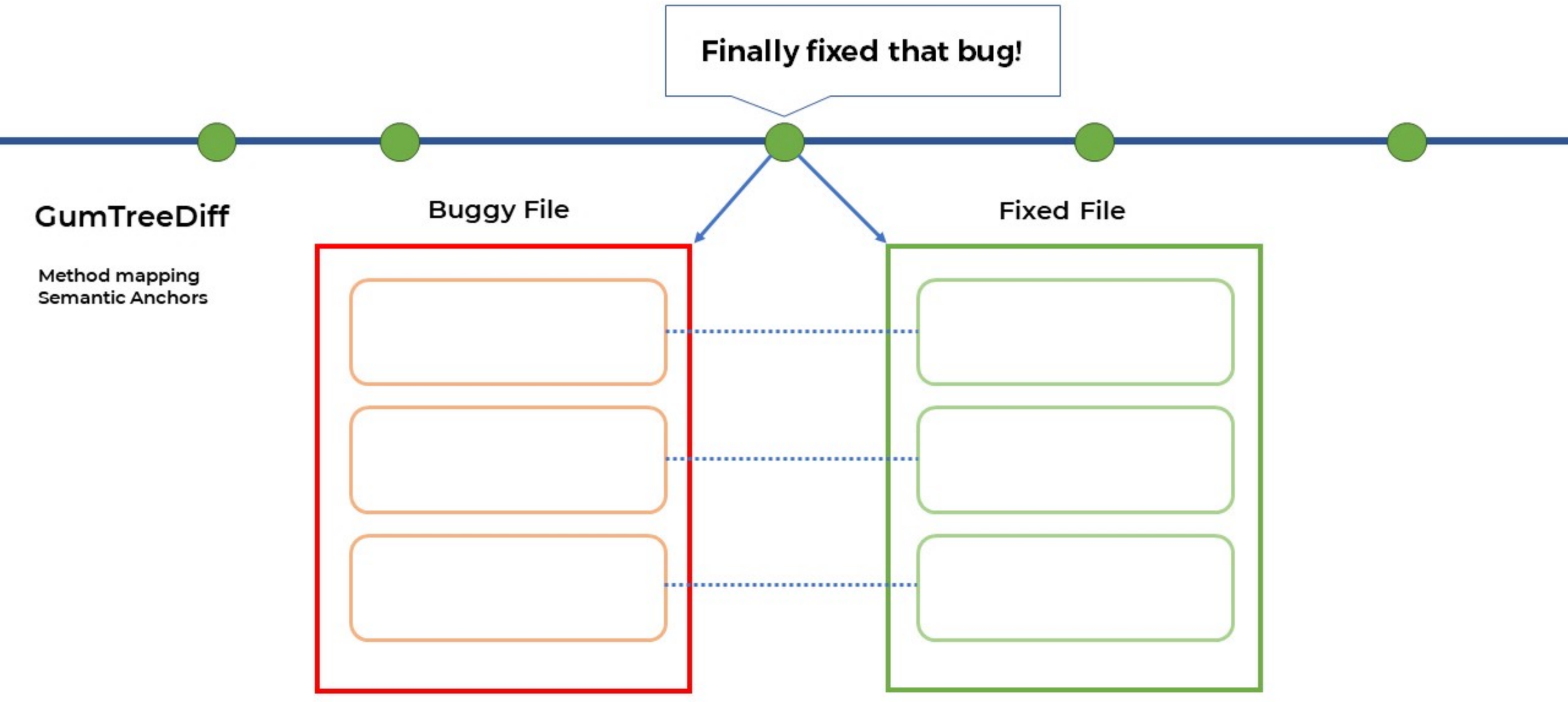
No more than 5 files

787,178

Pair Extraction



Pair Extraction



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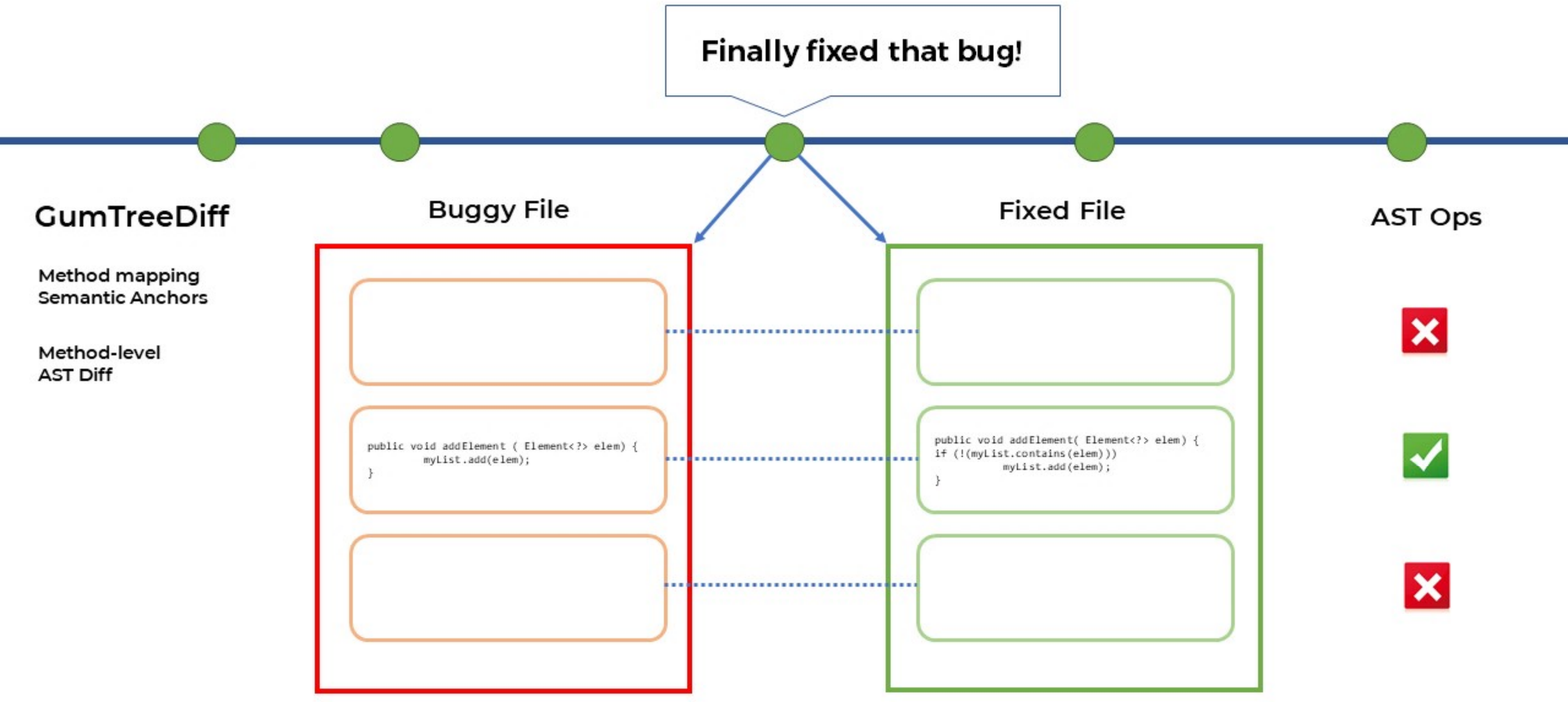

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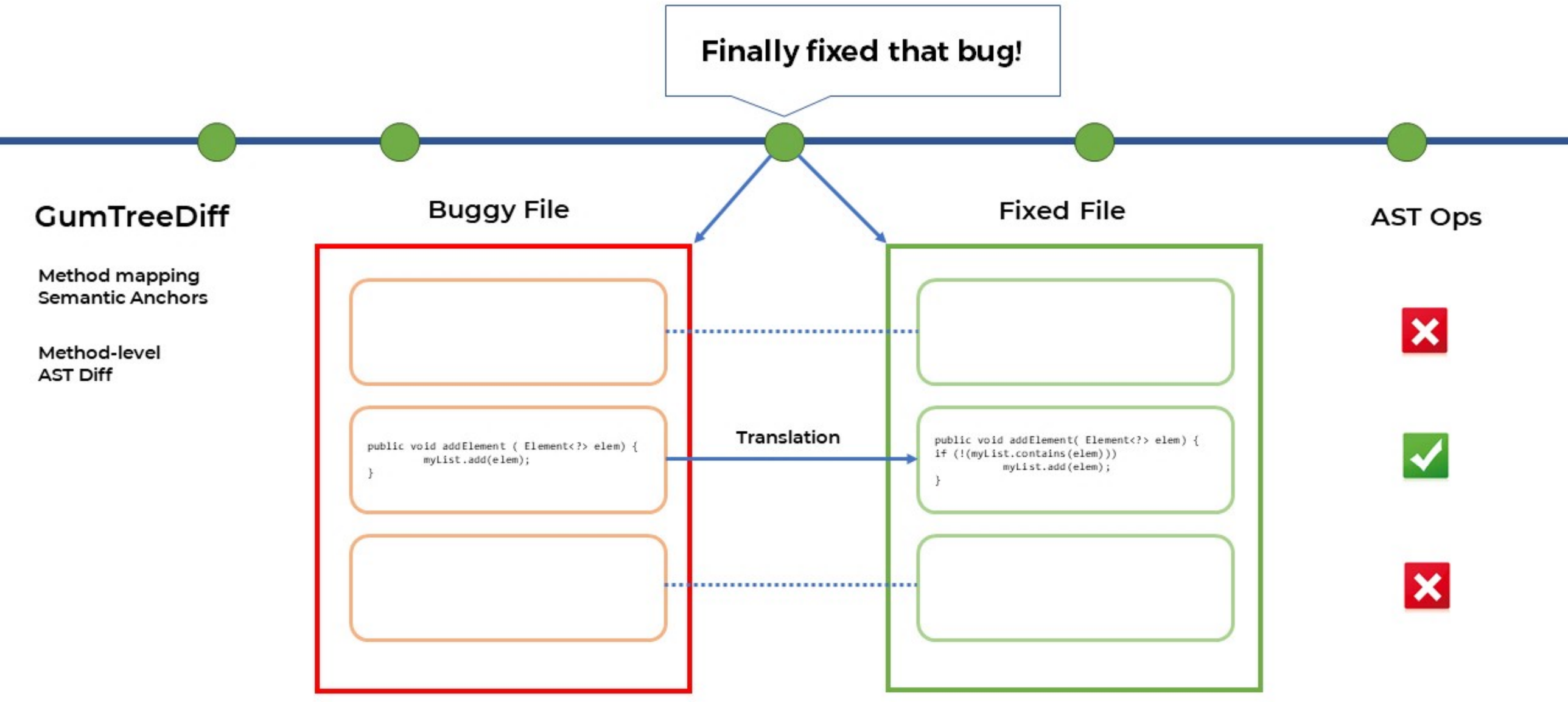

Code Abstraction

Goal: reduce Vocabulary

Source Code

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public void addElement ( Element <?> elem) { if ( myList.size() > 0) { myList.add(elem); } }
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Abstracted code

```
public void        (       <?>      ) { if (           () >  ) {          (     ); } }
```

- Java Keywords and separators

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- Java Keywords and separators
- Idioms: frequent identifiers and literals (e.g. size, add, 0)

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public void METHOD_1 ( TYPE_1 <?> VAR_1) { if ( VAR_2.size() > 0) { VAR_2.add(VAR_1); } }
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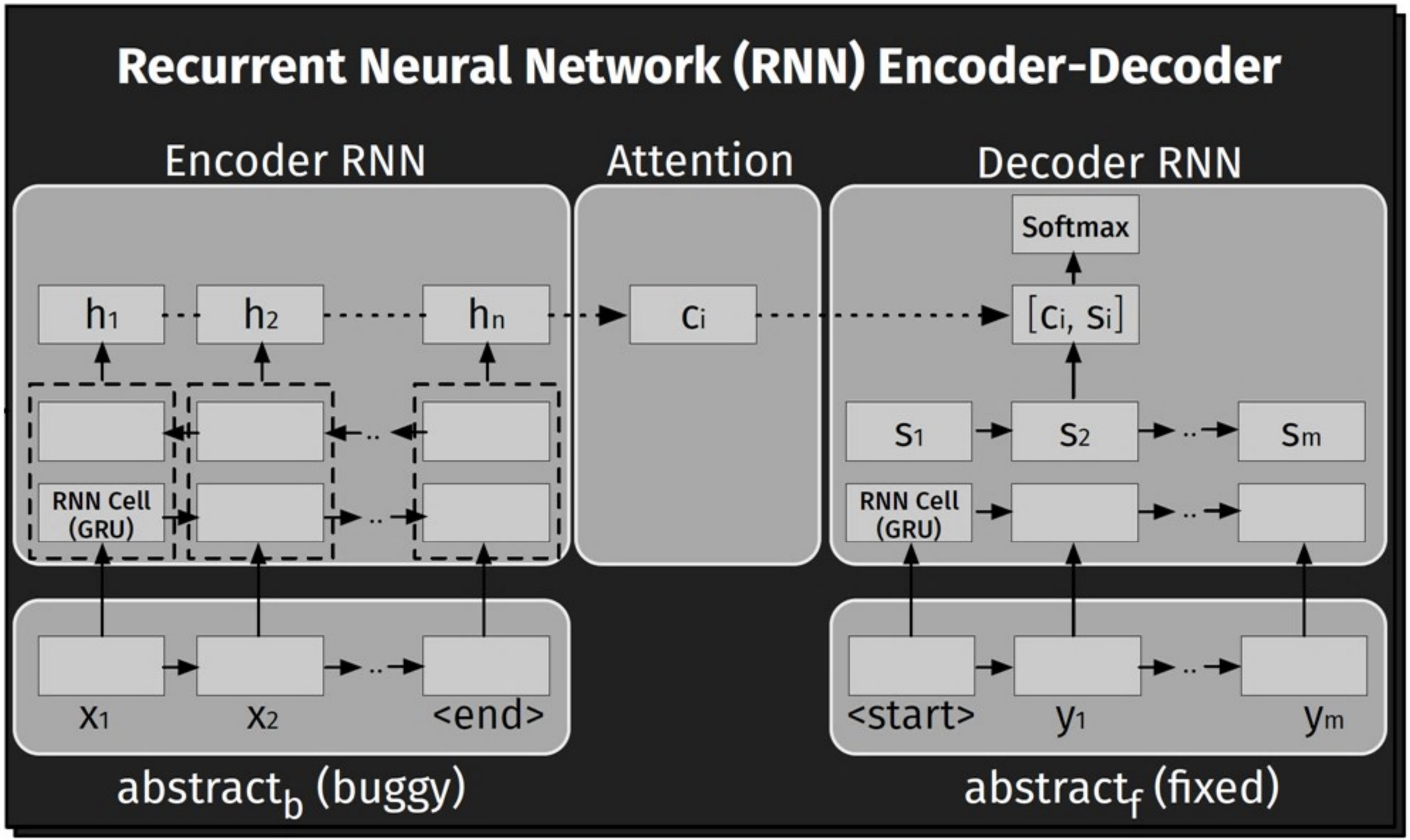
- Java Keywords and separators
- Idioms: frequent identifiers and literals (e.g. size, add, 0)
- IDs : replace identifiers and literals with typified IDs (e.g., METHOD, TYPE, VAR, INT, STRING, etc.)

Learning Fixes



Learning Fixes

Hyperparameters

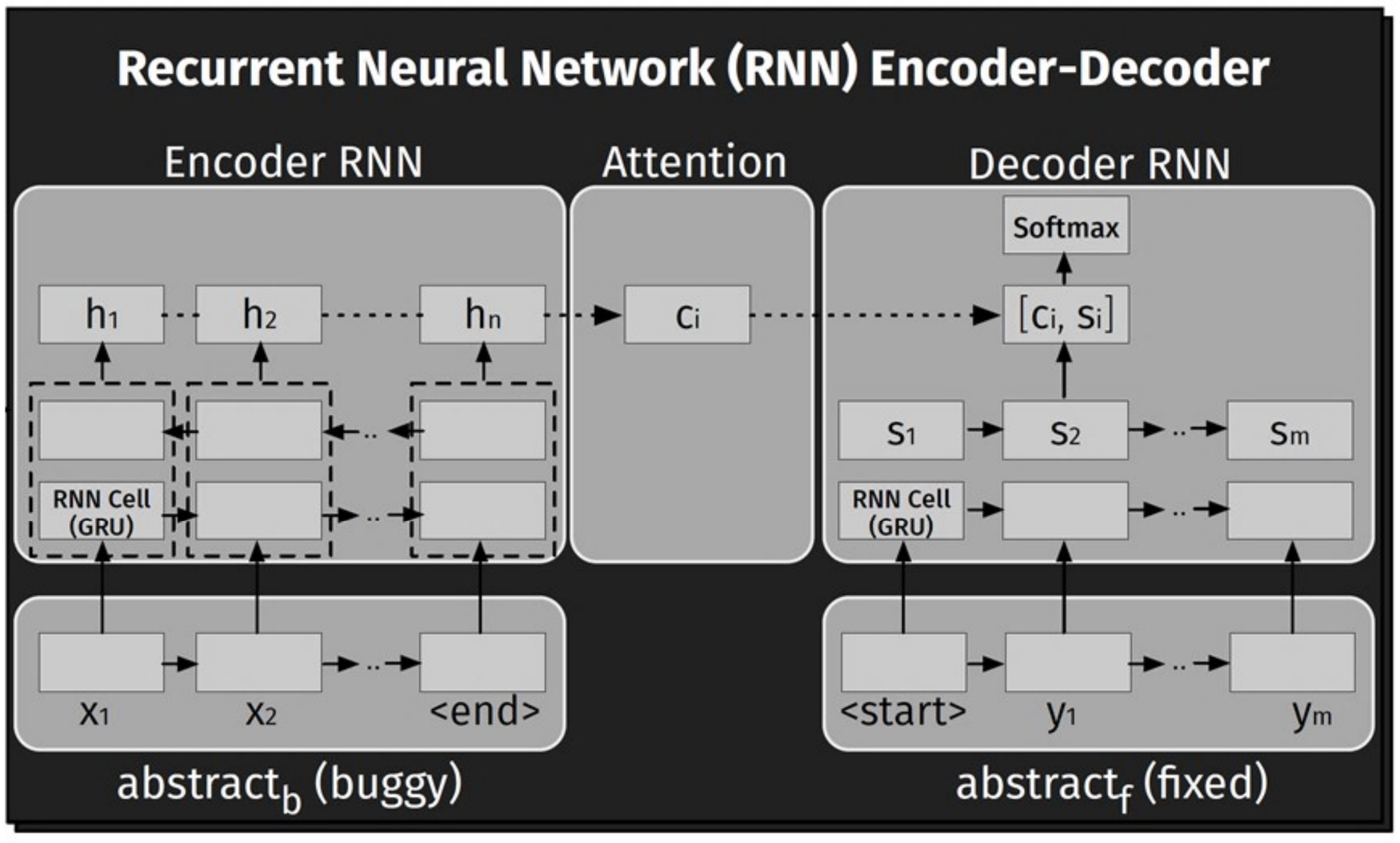
10 configurations

RNN Cells
- LSMT
- GRU

Layers
- 1
- 2
- 4

Units
- 256
- 512

Embedding Size
- 256
- 512



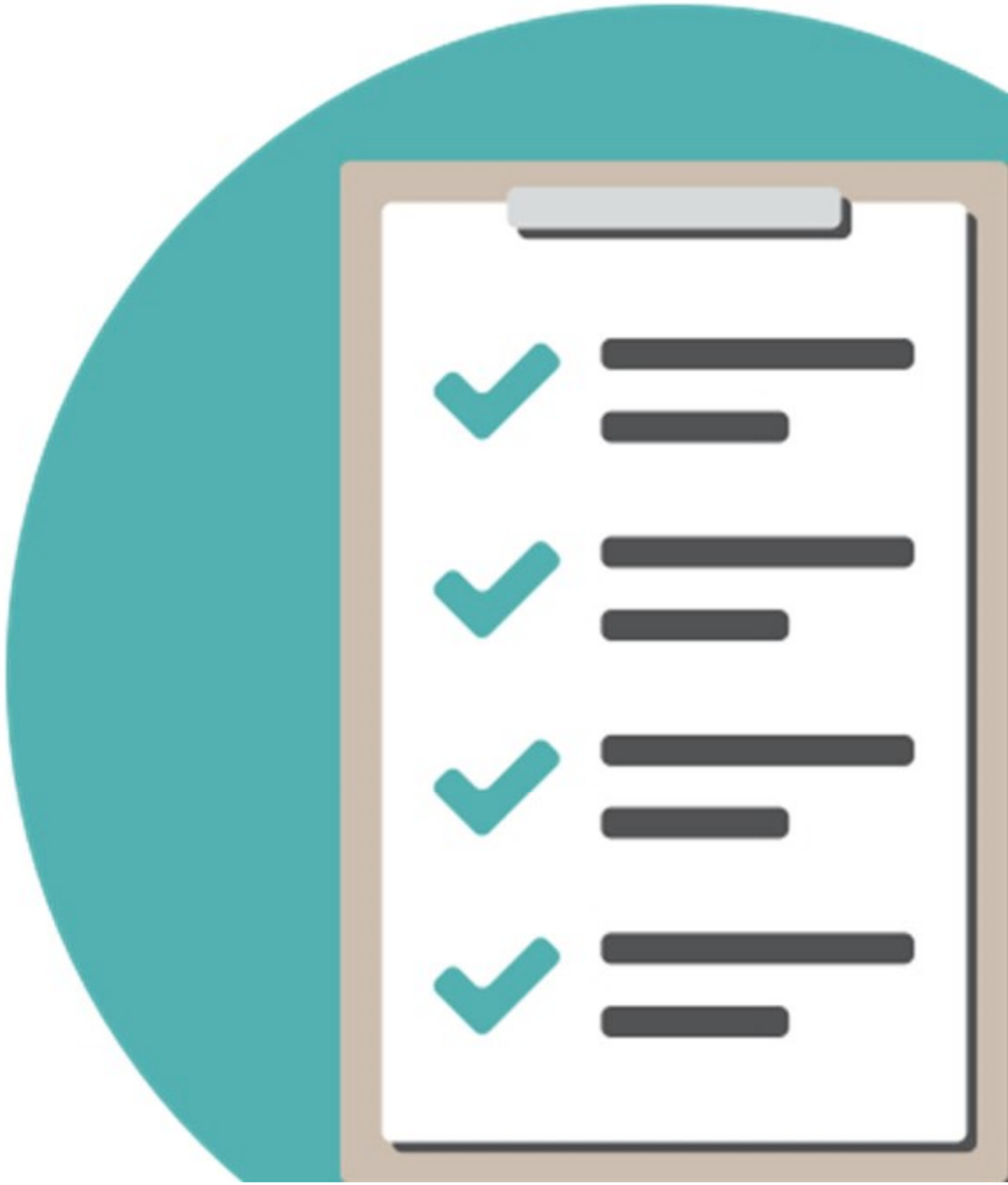
Evaluation

Small Methods
No longer than 50 tokens

Dataset: 58,350 methods

- 80% Training
- 10% Validation
- 10% Test

No duplicates
Unique at source and abstracted code level



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ID	Value
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TYPE_1	Element
VAR_1	elem
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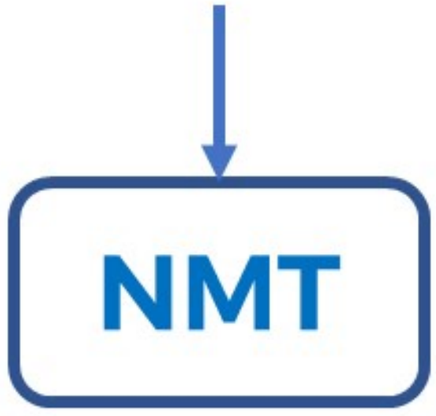
Neural Machine Translation



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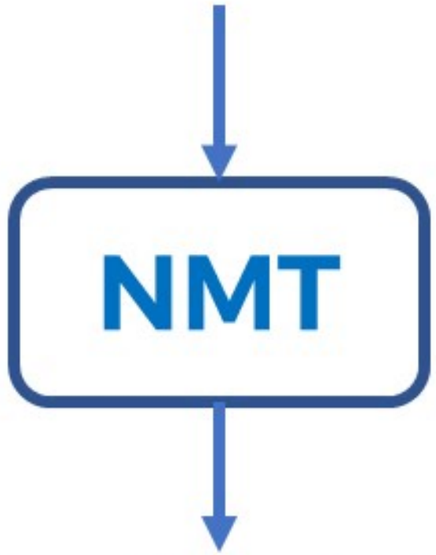

Abstracted Fixed Code

```
public void METHOD_1 ( TYPE_1 <?> VAR_1) { if (! VAR_2.contains(VAR_1)) VAR_2.add(VAR_1); }
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Neural Machine Translation

NMT

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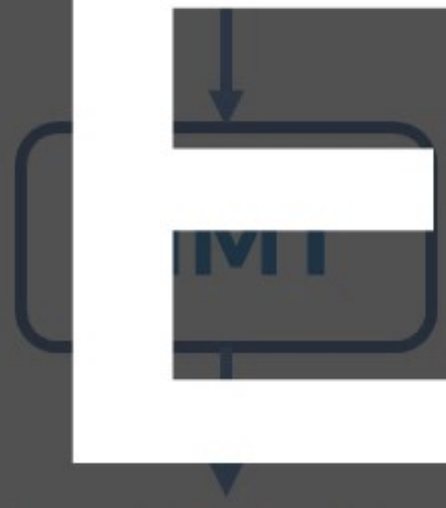

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Mapping

ID	Value
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VAR_1	elem
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YES!

Enlarged font for Reviewers

Buggy Code

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public void addElement ( Element <?> elem) { myList.add(elem); }
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Abstracted Buggy Code

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public void METHOD_1 ( TYPE_1 <?> VAR_1) { VAR_2.add(VAR_1); }
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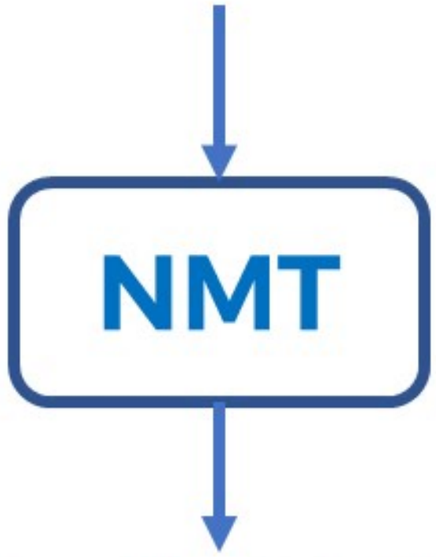

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public void METHOD_1 ( TYPE_1 <?> VAR_1) { if (! VAR_2.contains(VAR_1)) VAR_2.add(VAR_1); }
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Fixed Code

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Mapping

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Results

538 bug-fixes*

9.22% test set

*Unique at source and abstract code level.
*Never seen in training nor validation set.

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1 One Single Patch Attempt per bug

Can you generate multiple candidate patches?

50 different translations?

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With more candidates...
can you fix 30-50% of the bugs?

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What type of AST operations?

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Longer methods?

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Can you generate multiple candidate patches?

DATA!!

Code?

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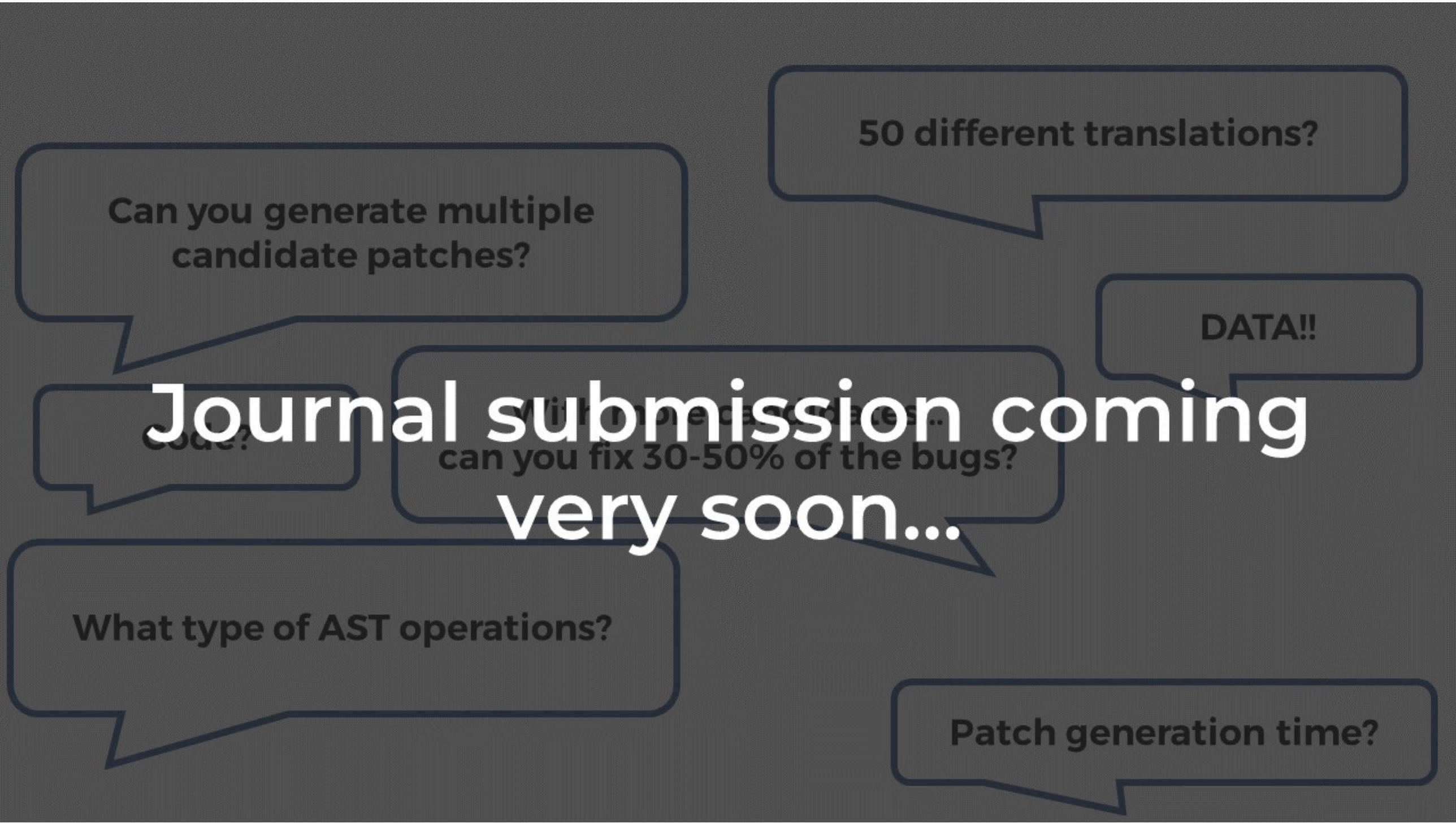
What type of AST operations?

Generation time?

Longer methods?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DATA!!
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What type of AST operations?
Patch generation time?
Journal submission coming very soon...

Thanks!

Questions?

Michele Tufano

@tufanomichele

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