Genetic Improvement on GSON using Gin

Team 9

Task

2019 SSBSE Challenge Track

- GSON[5]
  - convert Java Objects into JSON
  - Huge Open Source Project

Improve GSON using a tool called Gin[1,2]

Gin

Genetic Improvement Tool for JAVA

- Mutation
- Test framework
- Fitness
  - Execution Time Analysis
  - CPU Time Analysis
  - Number of test cases passed
- (https://github.com/gintool/gin)

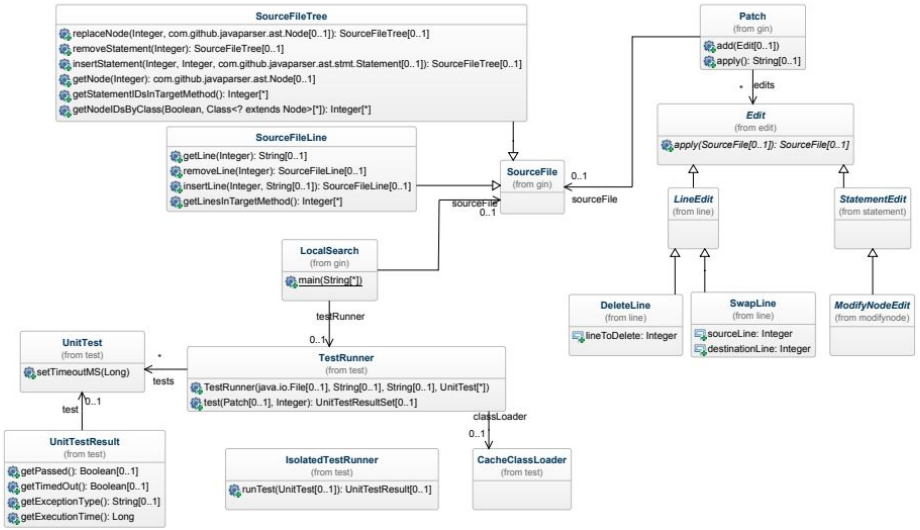


Figure 2: Gin core classes. Attributes are omitted and only a subset of method signatures are shown for simplicity. Also note that several Edit implementations and supporting utility classes are omitted.

Previous Study[3]

- 1-Point Crossover
  - takes two parents and creates two children: one comprising the first half of edits of parent 1 and the second half of edits of parent 2; the second child containing the remaining edits.
- Mutation
  - delete, copy, swap and replace operations
  - binary operator
    - e.g. == with !=
  - unary operator
    - e.g. ++ with --
- Tested with runtime & 3 single injected bugs on GsonBuilder.java

```
List<TypeAdapterFactory> factories = new ArrayList<TypeAdapterFactory>(
this.factories.size()+ this.hierarchyFactories.size()+ 3);
```

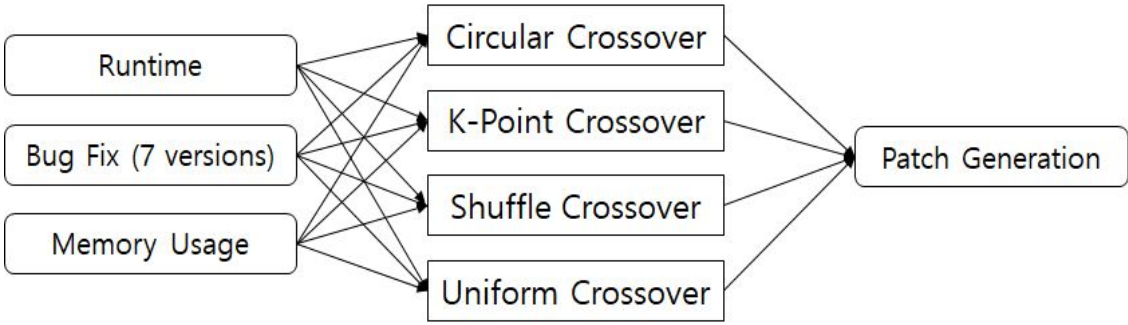
The mutant looked like this:

```
List<TypeAdapterFactory> factories = new ArrayList<TypeAdapterFactory>(
this.factories.size()+ this.hierarchyFactories.size()- 3);
```

What did we do

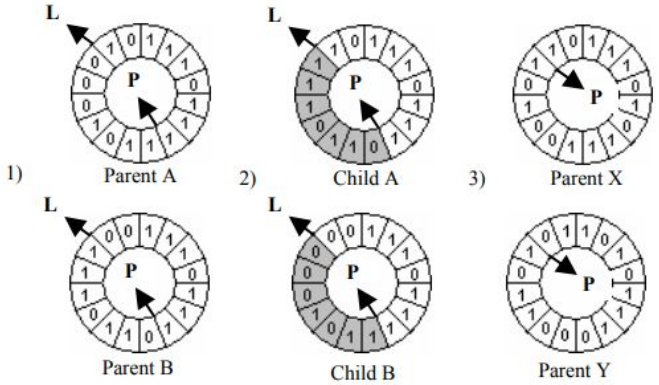
Improve former study by adding

- Implement Memory usage Analysis in Gin
- 4 new crossover operators
  - Circular crossover
  - K-point crossover
  - Shuffle crossover
  - Uniform crossover
- New mutation operator
- Generated 7 bugs to test bug fix on



Circular Crossover

- Make gene in circular form
- P : any point, L (length) : random positive number (L <= len(chromosome))
- interchange two respective segments
- the next bit after the segment of the last crossover becomes new starting point



A Hybrid Fuzzy-Genetic Algorithm DOI: 10.1007/11816157_63

K-Point Crossover

- Total of k cut points (0 <k <n).
- Cut points divide the gene into k + 1 subsets.
- Child is recombined by alternatively selecting subsets of the genes of two parents.

Parent1:	1 | 0 1 | 1 1 | 0 0 1 0 | 1
Parent2:	1 | 1 0 | 0 1 | 1 0 0 1 | 0
Offspring1:	1 | 1 0 | 1 1 | 1 0 0 1 | 1
Offspring2:	1 | 0 1 | 0 1 | 0 0 1 0 | 0

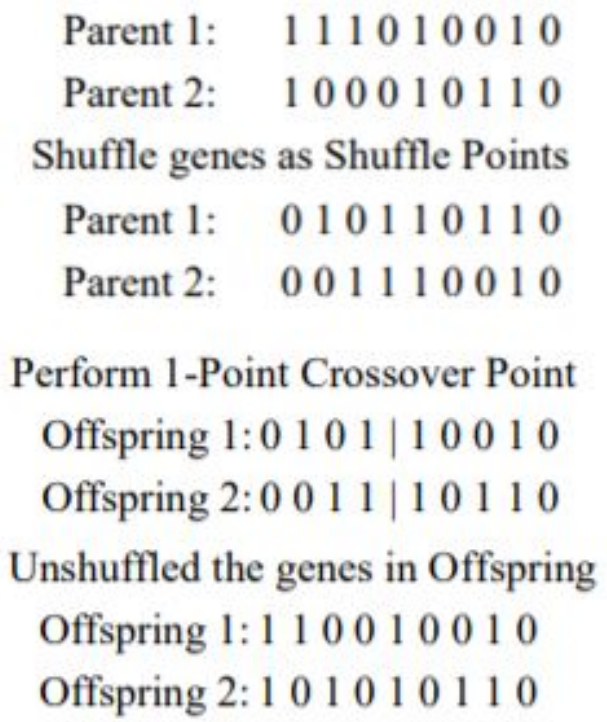
Uniform Crossover

- Make a random real number between 0 and 1 for each iteration .
- The random real number determines whether the child chooses first or second parent as the i-th gene.
- The rest of the child will choose the remaining parent's i-th gene.

Parent1:	1 0 1 1 1 0 0 1 0 1
Parent2:	1 1 0 0 1 1 0 0 1 0
Offspring1:	1 0 0 1 1 1 0 0 1 0
Offspring2:	1 1 1 0 1 0 0 1 0 1

Shuffle Crossover

- Apply the same shuffle on both parents.
- Then apply 1-point crossover.
- Reverse and swap unshuffled genes.



Mutation

- Previous Study
  - addRandomEdit
    - add a random edit to a random location of the patch
  - patch(chromosome) length grow at every iteration
- Ours
  - Replace a random edit instead of just adding one
  - We joined these two methods, letting the operator add a random edit for a certain probability p, and replace a random node with a random edit (without changing the other nodes) for probability 1-p.

Injected Bugs

- PI Test[6]
  - mutation testing system
  - gives fault that test suite can detect
- We use 7 bugs
  - 1 ~ 5 : operator change
  - 6 : statement order change
  - 7 : inject new method


```
# 1
587
    List<TypeAdapterFactory> factories = new ArrayList<TypeAdapterFactory>(this.factories.size() + this.hierarchyFactories.size() + 3);
    List<TypeAdapterFactory> factories = new ArrayList<TypeAdapterFactory>(this.factories.size() + this.hierarchyFactories.size() - 3);

# 2
611
    if (datePattern != null && !"".equals(datePattern.trim()))
    if (!datePattern == null && !"".equals(datePattern.trim()))

# 3
611
    if (datePattern != null && !"".equals(datePattern.trim()))
    if (datePattern != null && "".equals(datePattern.trim()))

# 4
615
    else if (dateStyle != DateFormat.DEFAULT && timeStyle != DateFormat.DEFAULT)
    else if (dateStyle == DateFormat.DEFAULT && timeStyle != DateFormat.DEFAULT)

# 5
615
    else if (dateStyle != DateFormat.DEFAULT && timeStyle != DateFormat.DEFAULT)
    else if (dateStyle != DateFormat.DEFAULT && timeStyle == DateFormat.DEFAULT)
```

Injected Bugs

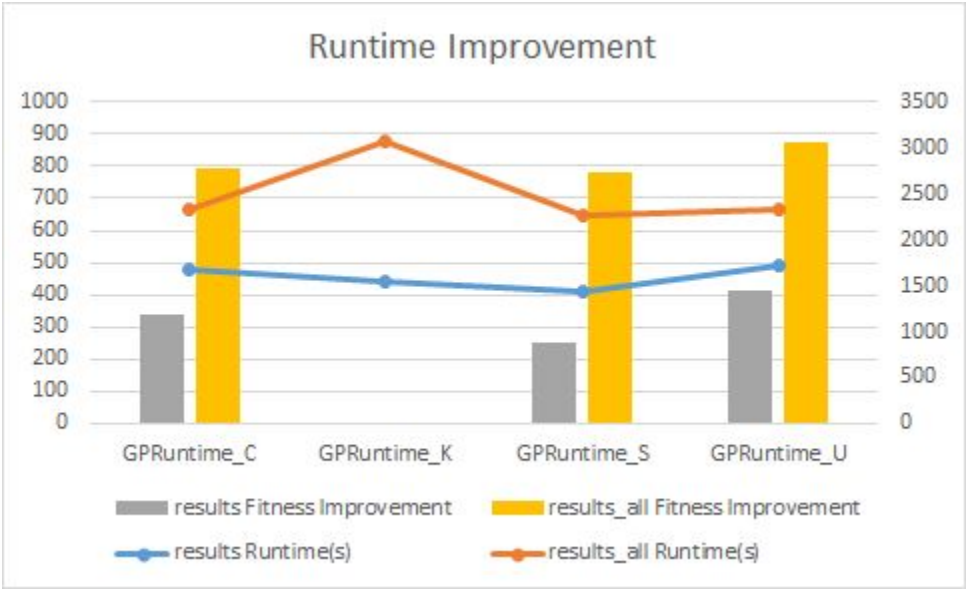
- PI Test[6]
  - mutation testing system
  - gives fault that test suite can detect
- We use 7 bugs
  - 1 ~ 5 : operator change
  - 6 : statement order change
  - 7 : inject new method


```
# 6
588
        # delete
        factories.addAll(this.factories);
599
        # insert
        factories.addAll(this.factories);

# 7
590
        # insert
        Collections.reverse(factories);
```

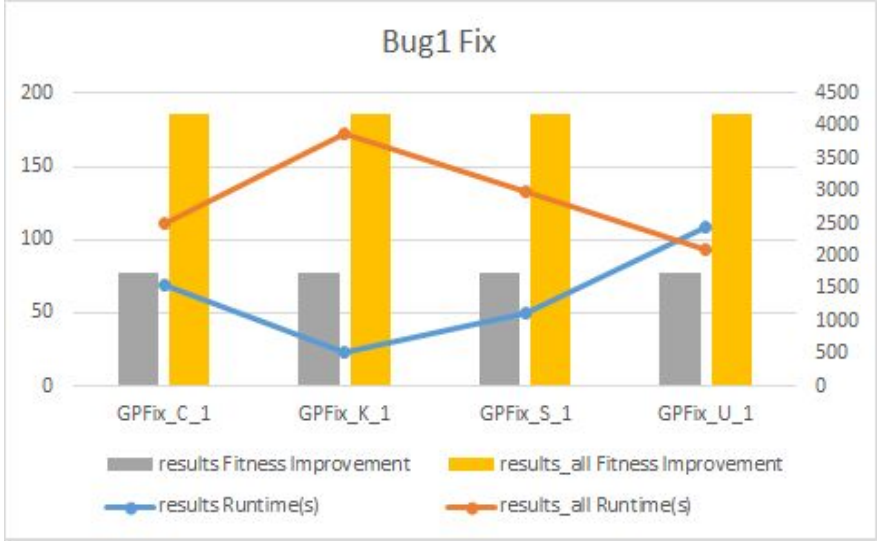
Result - Runtime Improvement

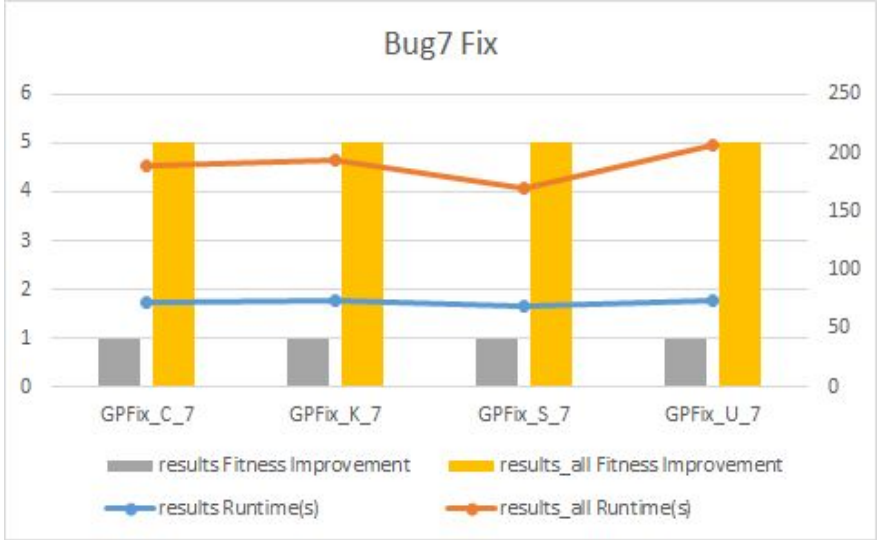
- Only k-point crossover couldn't improve runtime of GSON.
- The others show similar performance, but uniform crossover shows slightly better fitness improvement.



Result - Bug Fix

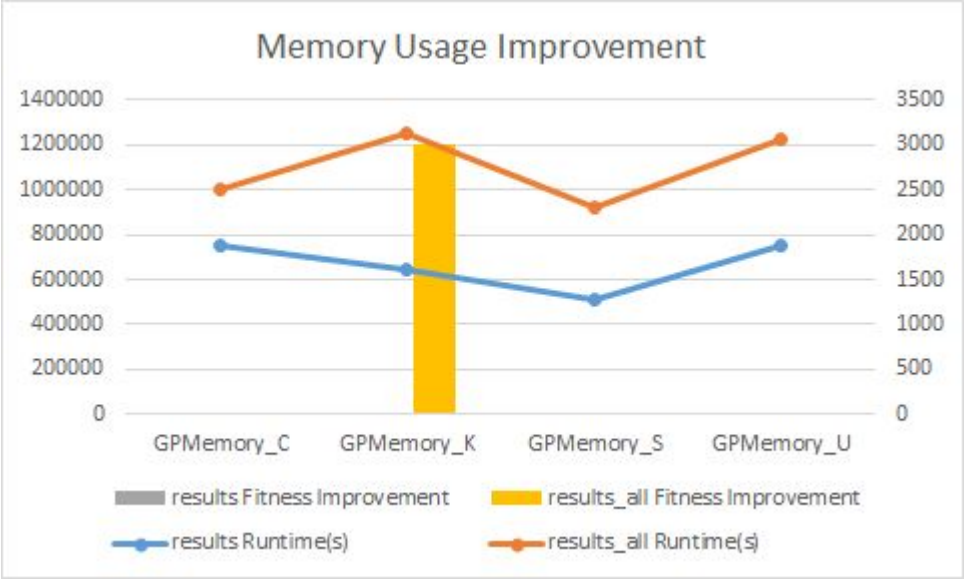
- Only bug 1 and bug 7 were fixed.
- Shows exactly same increment in number of test cases passed between different crossover operators.
- Different crossover operators result in different runtime in fixing bug 1, as opposed to bug 7.





Result - Memory Usage Improvement

- Different from runtime improvement, only k-point crossover improve memory usage of GSON.
- Since k-point found only single patch that improves memory usage while others do not, we cannot confirm that k-point crossover is certainly better than other crossover.



Analysis

- Overall, 4 crossover operators shows similar performance and ability.
- Memory usage was harder to improve than runtime, since simply deleting, copying, swapping statement or changing operator cannot definitely decrease the current memory usage.
- If fault is hardly affected by other parts of codes, the probability of locating the fault significantly decreases.
  - Fault related to *variable a* → fix fault by other part that access or affect *variable a*
  - *a* == *b* to *a* != *b* → fix fault only by changing != operator to ==
- Patch bloat : the size of patch increases as generation number increases → not suitable for fixing small bugs, limit the size of patch
- It would have been better if more data or experiment cases were provided.

Conclusion

- Applied genetic improvement to GSON using Gin
  - with 4 kinds of crossover
  - on 3 domains
- Negligible performance difference between crossover operators
- Successfully improved runtime and memory usage, fixed 2 bugs.
- Problems to be solved:
  - patch bloat
  - fault localization for fixing bugs

Bibliography

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