Conflict Resolution for Structured Merge via Version Space Algebra*

Fengmin Zhu and Fei He

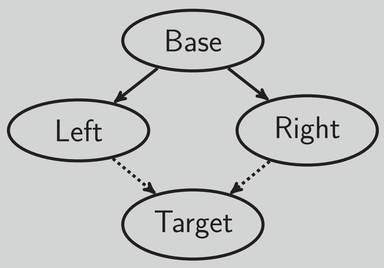
School of Software, Tsinghua University

Introduction

- Conflicts are widely exhibited in real-world software merge scenarios.
- Structured & unstructured approaches cannot resolve conflicts when concurrent changes contradict each other.
- We propose an interactive mechanism to provide the developer with candidate resolutions as recommendations.
- We present an algorithm to form the program space of resolutions and design a problem-specific ranking function for fast convergence.

Table: Three-way merge rules lead to conflicts.

	Type	Base B	Left L	Right R	Target T
1	Node	e	e	e'	e'
2	Node	e	e_L	e_R	conflict
3	List	$e \in B$	$e \in L$	$e \notin R$	$e \notin T$
4	List	$e \notin B$	$e \in L$	$e \notin R$	$e \in T$ or conflict



Objective: find recommended resolutions for conflicting scenarios.

Preliminary: VSA

Version space algebra (VSA) [1] succinctly represents a large set of programs [2].

$$
\begin{aligned}
\text{VSA } \widetilde{N} ::= {} & \{P_1, P_2, \ldots, P_k\} && \text{(explicit)} \\
\mid {} & \widetilde{N_1} \cup \widetilde{N_2} \cup \cdots \cup \widetilde{N_k} && \text{(union)} \\
\mid {} & F_{\bowtie}(\widetilde{N_1}, \widetilde{N_2}, \ldots, \widetilde{N_k}) && \text{(join)} \\
\mid {} & \texttt{List}_{\bowtie}(\widetilde{N_1}, \widetilde{N_2}, \ldots, \widetilde{N_k}) && \text{(list join)}
\end{aligned}
$$

Motivation

```
...                  ...                  ...                  ...
for (...) {          for (...) {          for (...) {          for (...) {
  try {                s3;                  try {                s3;
    s1;                if (...) {             s1;                if (...) {
  } catch {              try {                } catch {            try {
    // empty             s4;                  s2;                  s4;
  }                    } catch {            }                    } catch {
}                        // empty           }                      s2;
...                    }                   ...                    }
                     }                                          }
                   }                                          }
                   ...                                        ...
```

(a) *base* (b) *left* (c) *right* (d) *expected*

Figure: A conflicting merge scenario. Changes are highlighted.

"Combine" some of the changes and represent them as a VSA.

Methods

1. Conflict Detection
2. Program Space Representation with VSA
3. Resolution Ranking
4. User interaction

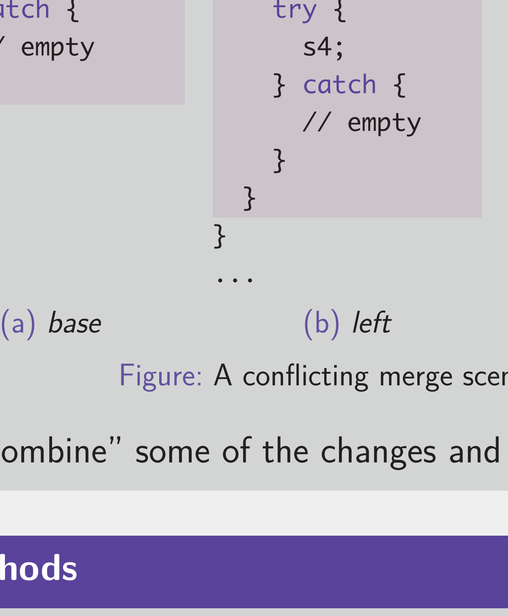


Figure: VSA representation for candidates.

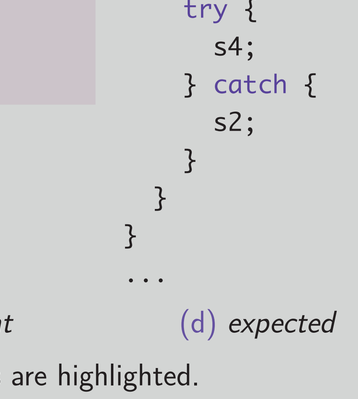


Figure: AST of the expected program. Node color represents from which version it is derived: blue for *left*, green for *right*, and purple for both.

System Architecture

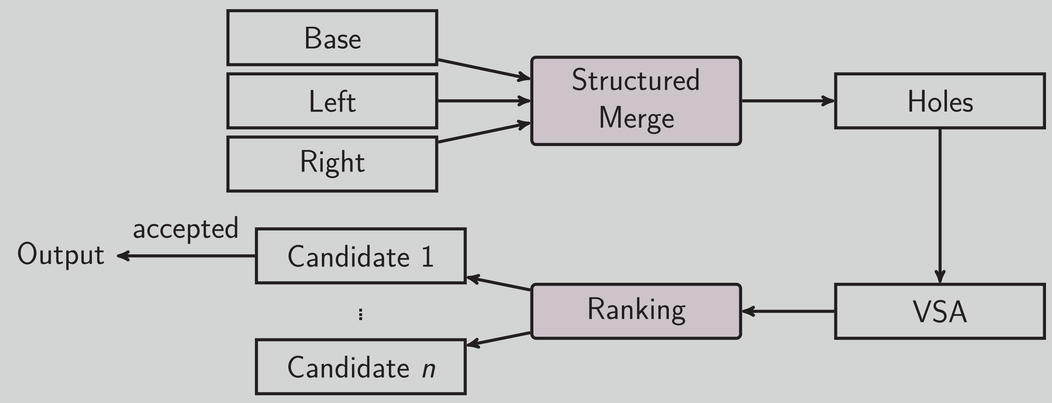


Figure: System architecture of `AutoMerge`, built on the top of `JDime` [3].

Evaluation Results

Table: Evaluation results on conflict resolution. Conf. files: number of conflicting files. k: interaction rounds. P.S.: size of program space per hole. Time: execution time of conflict resolution (excluding merge) per hole.

Project	Conf. files	Holes	Resolved holes	Max. k	Avg. k	P.S.	Time (ms)
auto	4	11	10 (90.9%)	2	1.18	191.1	94.72
drjava	2	2	2 (100%)	2	1.50	515	297.50
error-prone	8	13	8 (61.5%)	13	4.62	6.31	146.46
fastjson	8	19	19 (100%)	18	2.37	8.37	119.16
freecol	22	57	57 (100%)	2	1.81	23.9	87.91
itextpdf	47	47	47 (100%)	1	1.00	6	231.94
jsoup	2	2	2 (100%)	1	1.00	6	116
junit4	33	51	45 (88.2%)	13	1.78	133	126.73
RxJava	1	1	1 (100%)	2	2.00	6	1
vert.x	11	41	41 (100%)	4	1.78	7.24	63.22
Overall	138	244	232 (**95.1%**)	18	**1.79**	48.88	127.10

- High resolution rate by constructing expressive VSAs.
- Efficient implementation with restricted VSA construction.
- Few interaction rounds with the ranking mechanism.

Contributions

- We propose an interactive approach for resolving merge conflicts. To the best of our knowledge, this is the first attempt on conflict resolution of structured merge.
- We identify the expressiveness and efficiency of version space algebra, and elaborate an algorithm to automatically construct the VSA representation.
- We design a simple but effective mechanism for ranking resolutions.
- We prototype our approach as `AutoMerge`, and conduct experiments on real-world software projects. Results show great practicality of our approach.

References

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Contact Information

- Website: `https://thufv.github.io/automerge`
- Email: `zfm17@mails.tsinghua.edu.cn`, `hefei@tsinghua.edu.cn`

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