Evaluating lexical approximation of program dependence

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Journal of Systems and Software

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Naturalness of source code

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- Java

```
127
128   private static final Logger logger = Logger.getLogger(FinalizableReferenceQueue.class.getNa
129
130   private static final String FINALIZER_CLASS_NAME = "com.google.common.base.internal.Finaliz
131
```

```
200       try {
201         ((FinalizableReference) reference).finalizeReferent();
202       } catch (Throwable t) {
203         logger.log(Level.SEVERE, "Error cleaning up after reference.", t);
204       }
```

- Python

```
456         except Exception:
457             if not from_error_handler:
458                 raise
459             self.logger.exception('Request finalizing failed with an ' 'error while handling
460         return response
```

Code lines handing the logging function contains the word ‘log’

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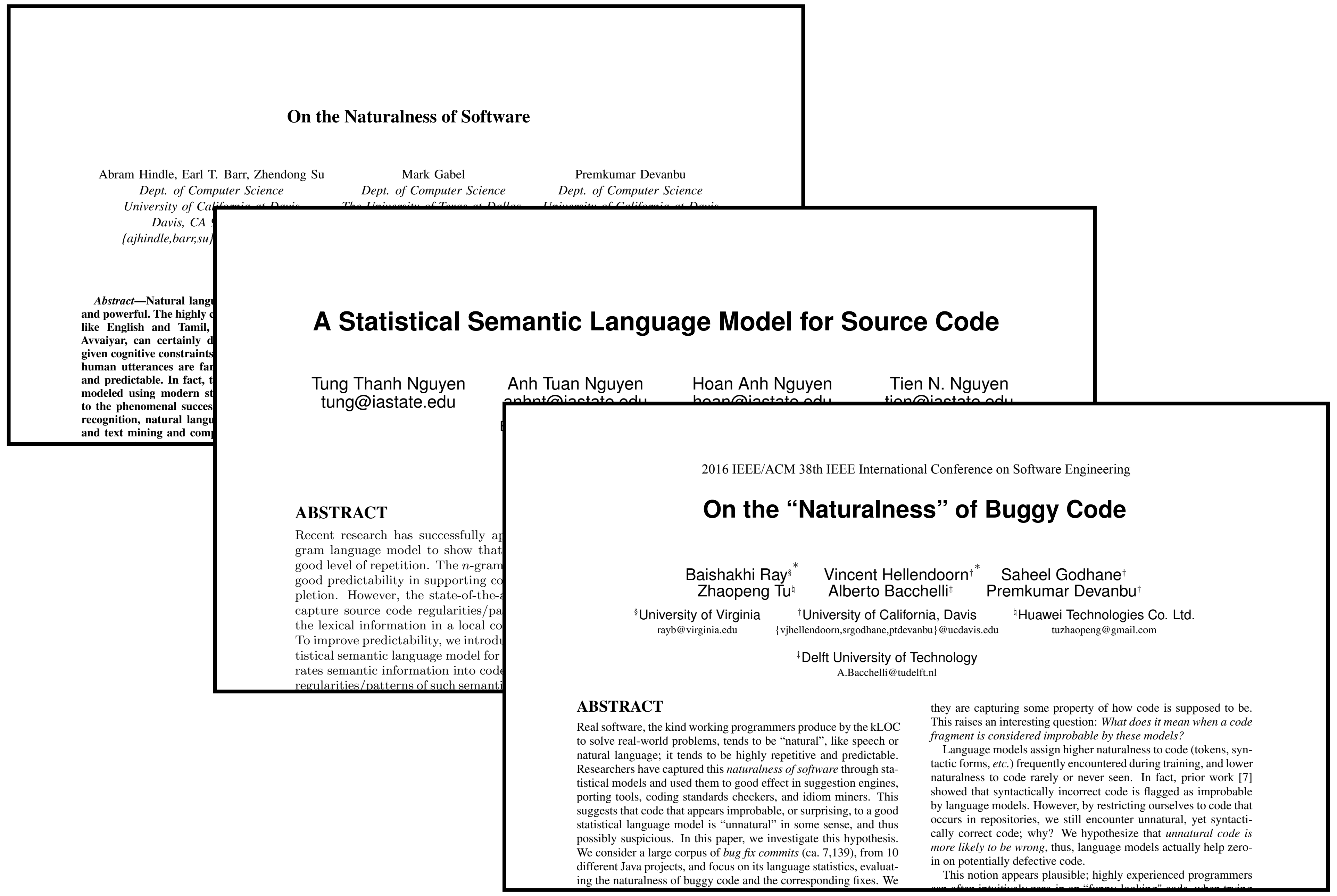

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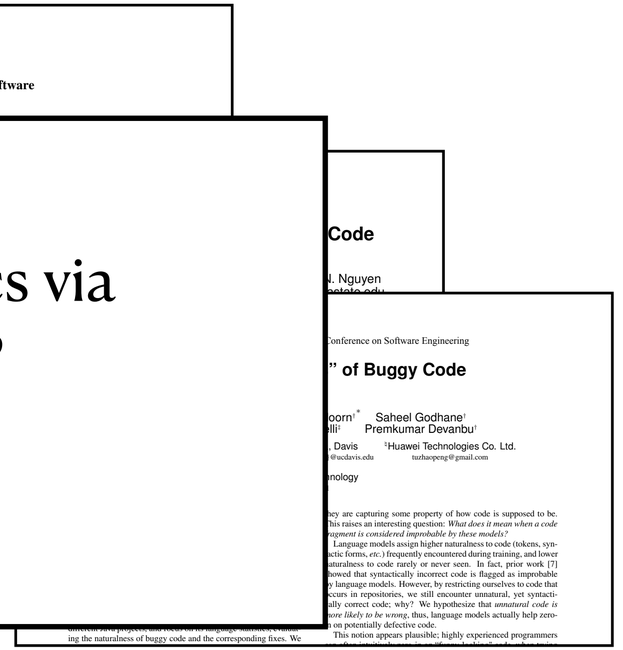

Can we approximate the program semantics via lexical information of the source code?

➡ Program dependency analysis

Code lines handing the logging function contains the word ‘log’

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Observation-Based Slicing (ORBS)

- Purely dynamic program slicing technique
- Use code-level modification & runtime information
- Thus, it can work on
  - multi-lingual programs, or
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    while (i < 11) {
        sum = sum + i;
        i = i + 1;
    }
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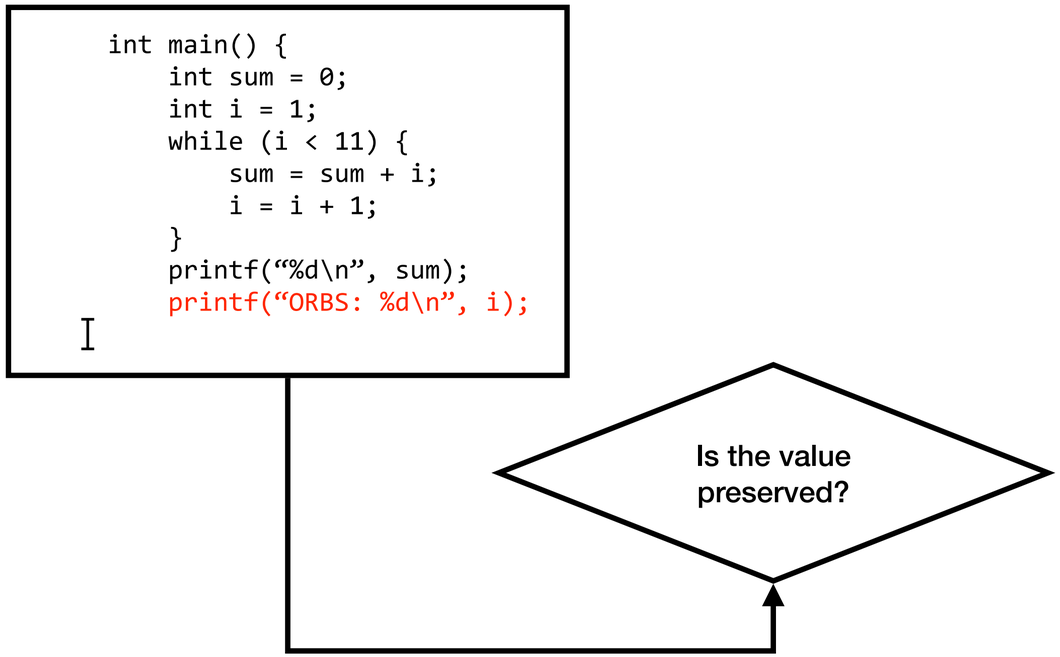

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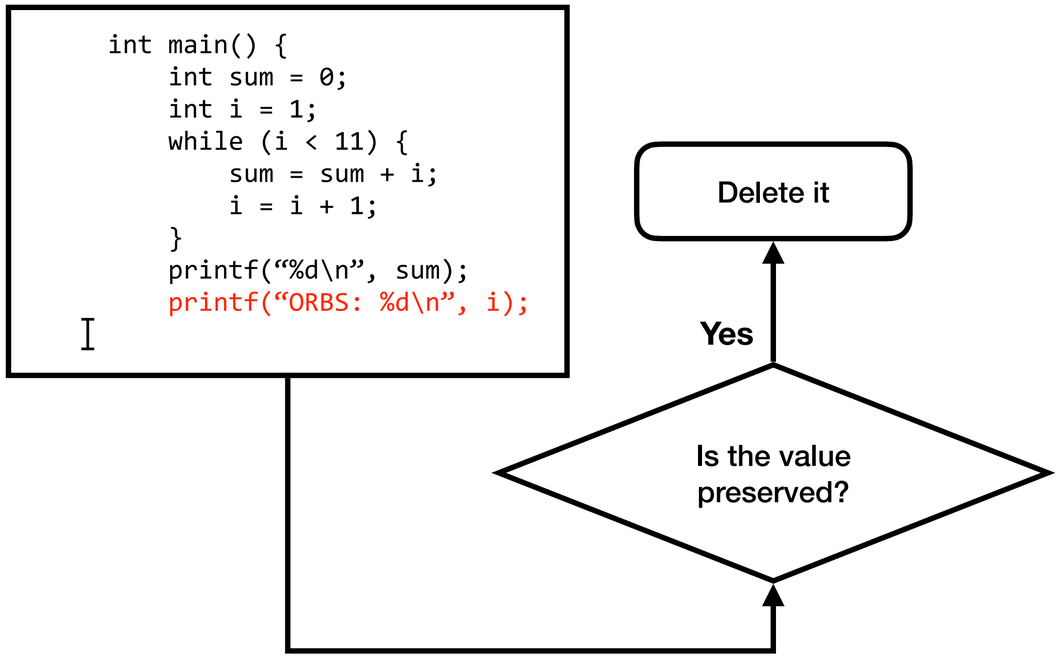

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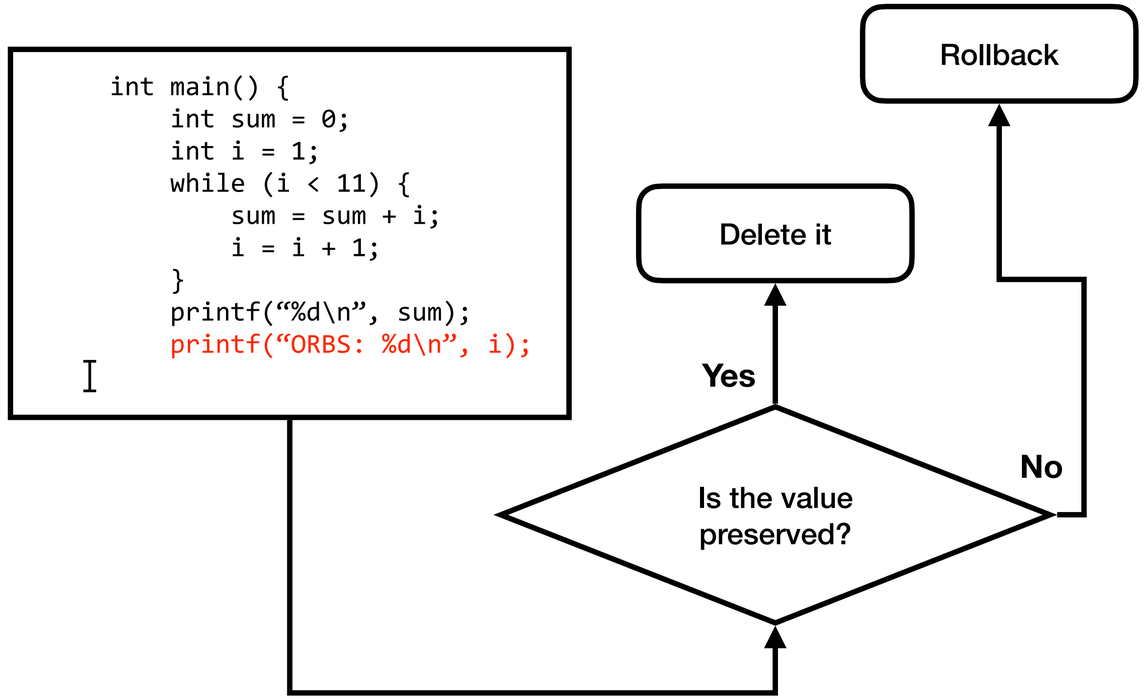

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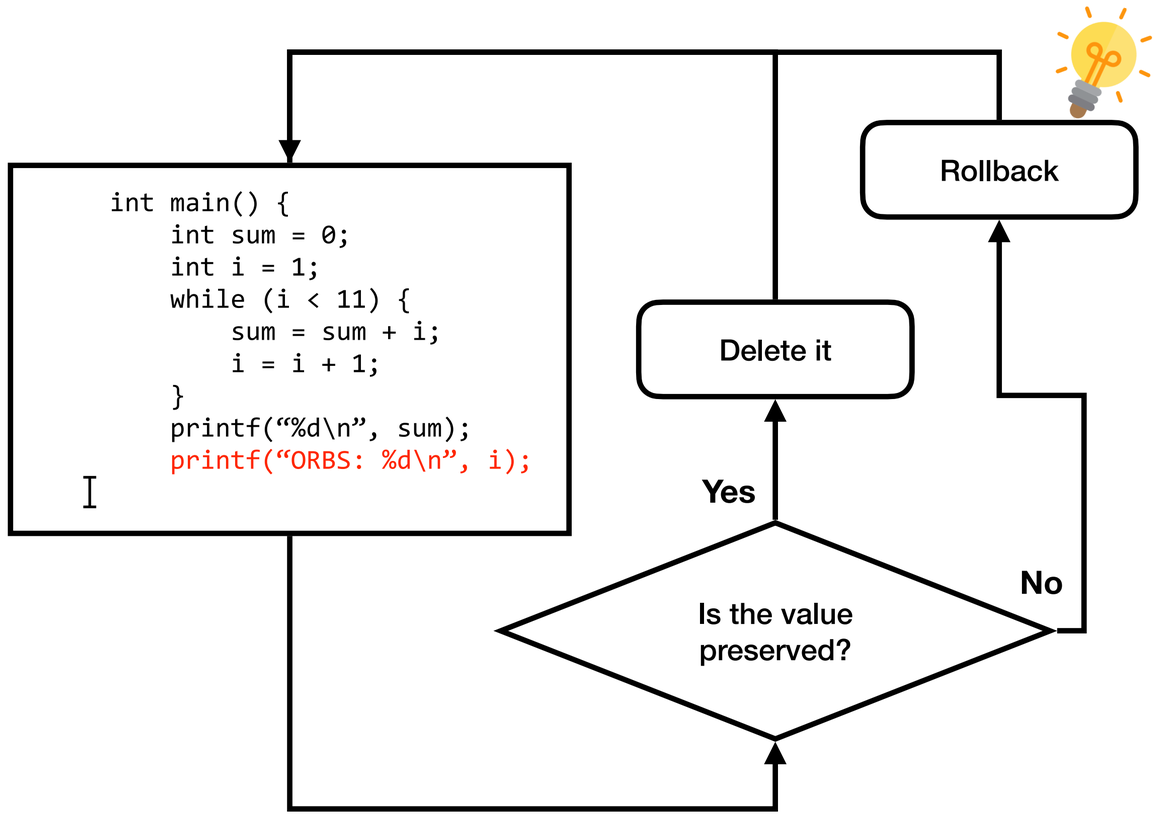

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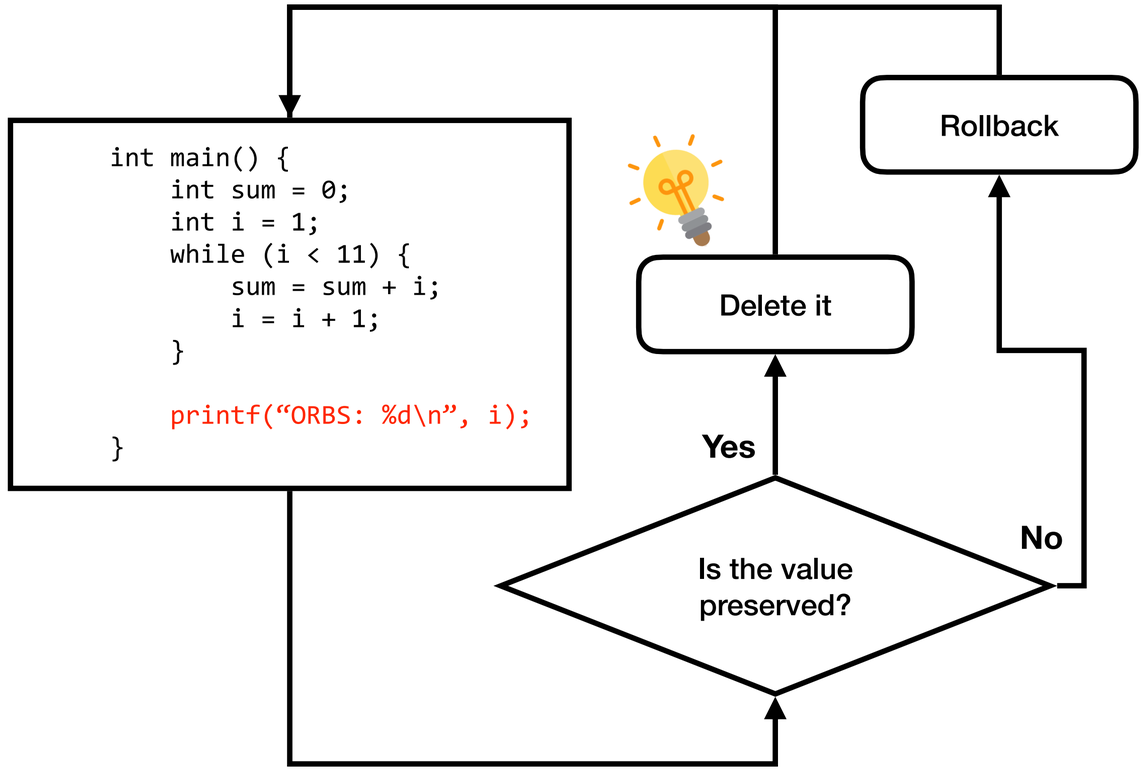

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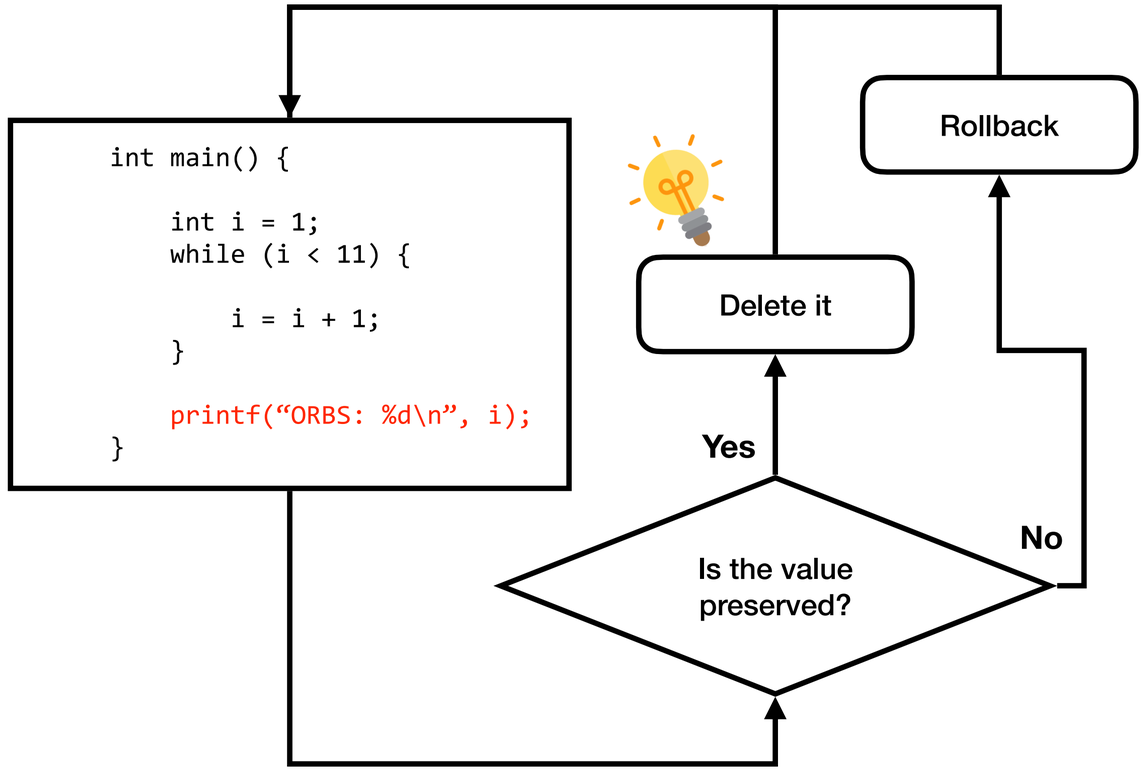

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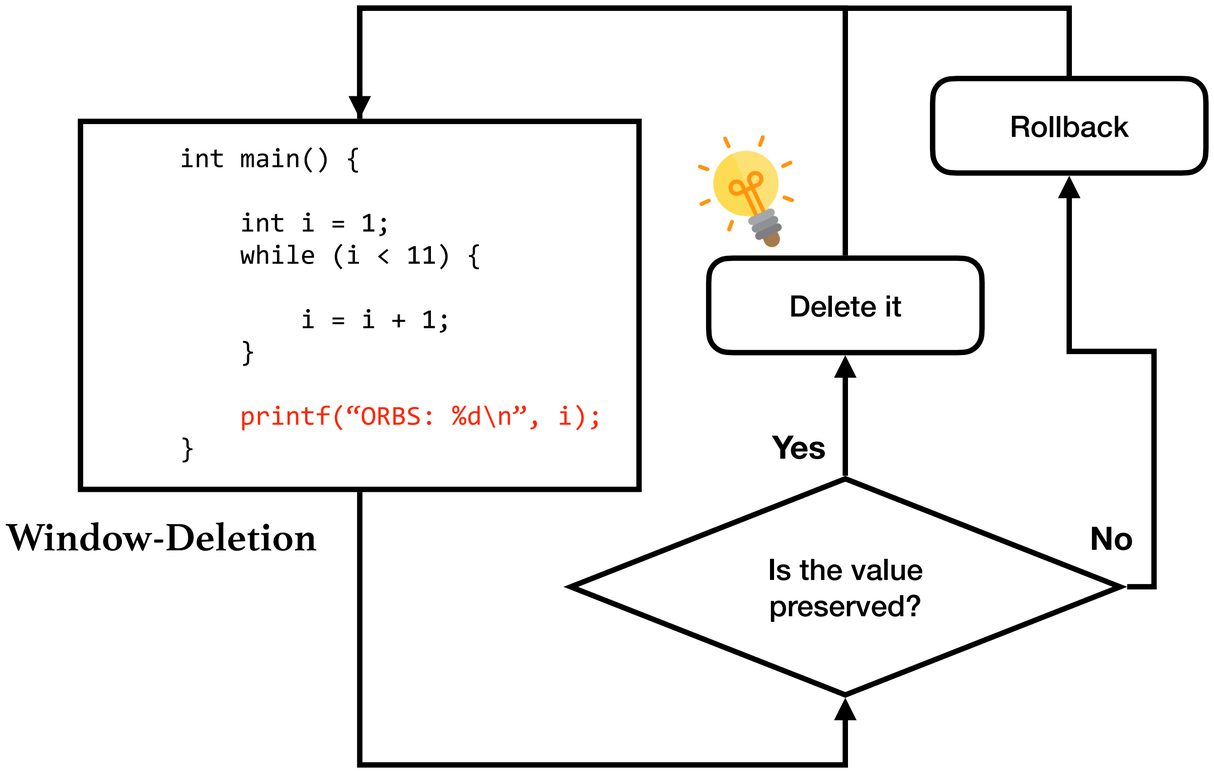

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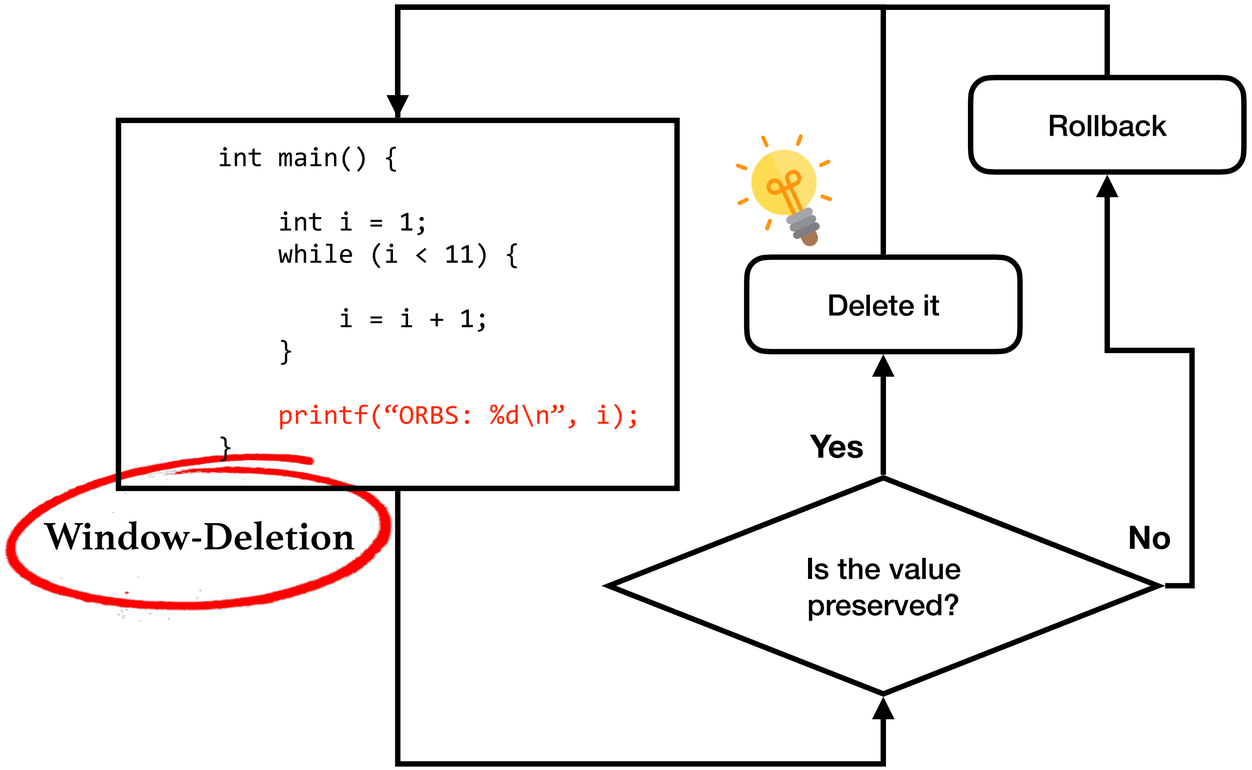
- Scalability issue 
  - Takes around 7,200 seconds to delete 220 lines.
    ⇒ **0.03 del/s = 32.7 s/del**
    (* ‘escape’ package in Guava)

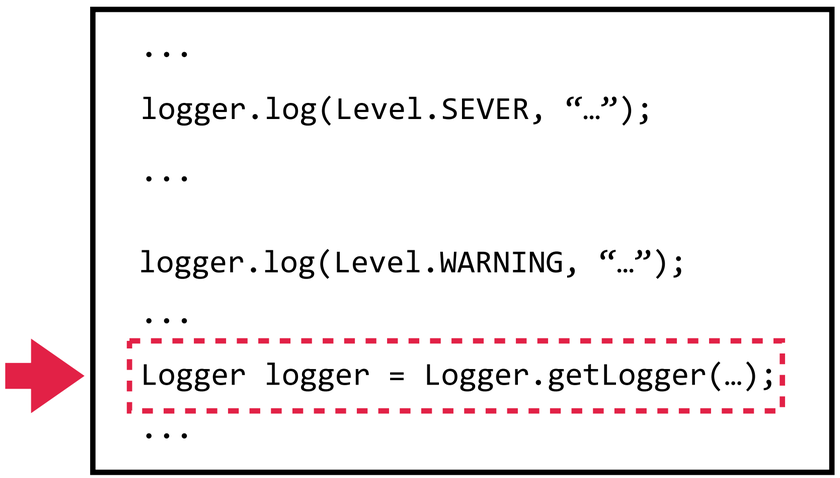


Lexical deletion operator

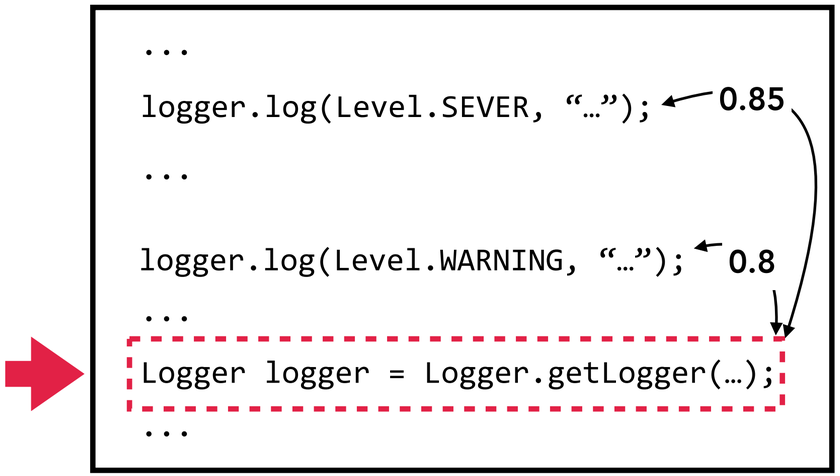
```
...
logger.log(Level.SEVER, “…”);
...

logger.log(Level.WARNING, “…”);
...
Logger logger = Logger.getLogger(…);
...
```

Lexical deletion operator



Lexical deletion operator



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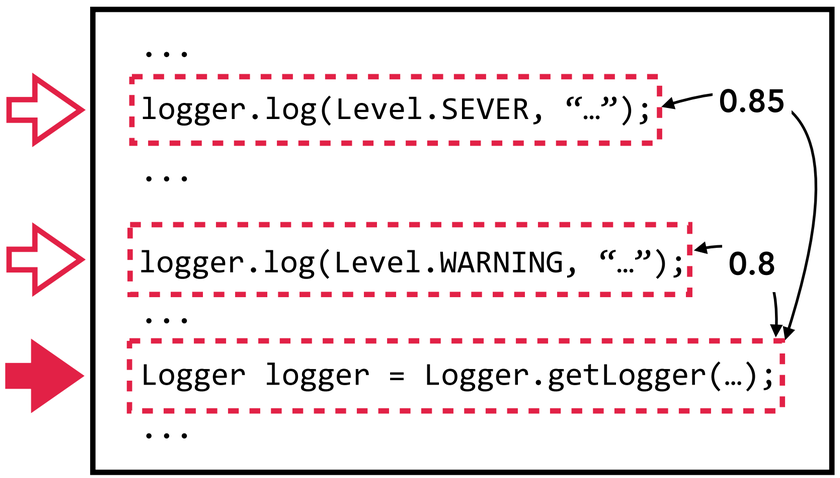
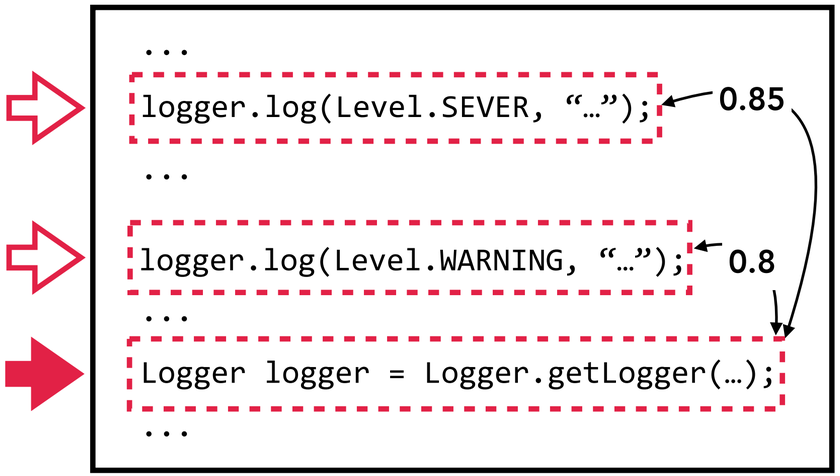


Lexical deletion operator

Shares the functionality



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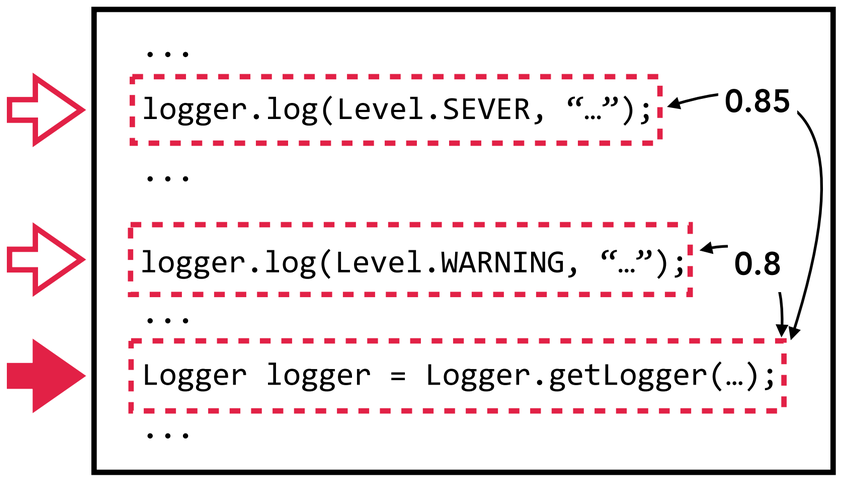


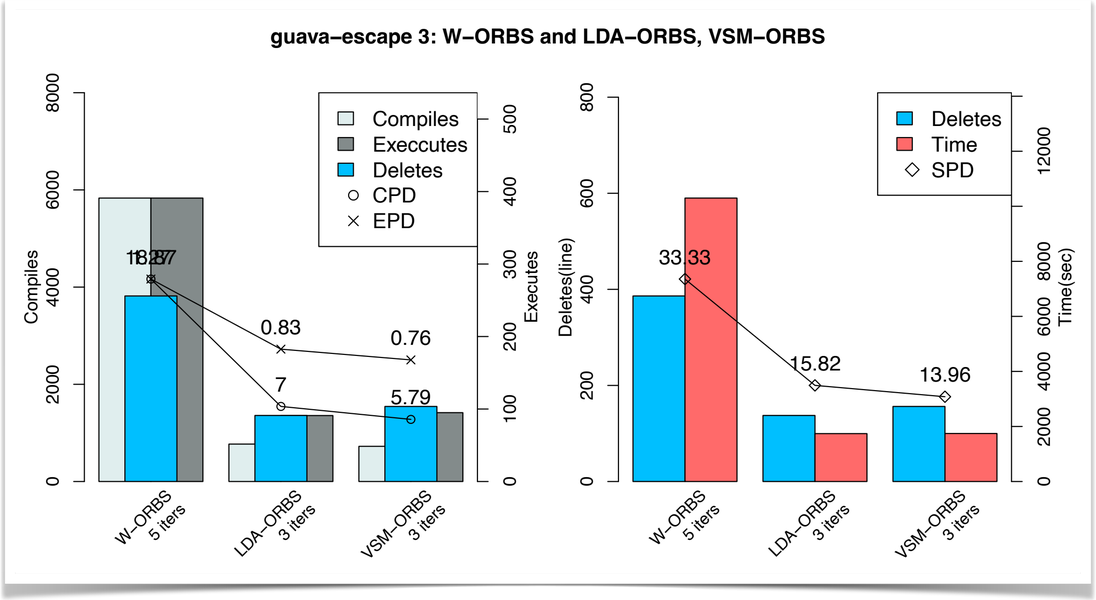
- Two language model to calculate the similarity
  - Vector Space Model (VSM)
  - Latent Dirichlet Allocation (LDA)

- Advantage of the lexical deletion operators:
  - Can delete an ***arbitrary number*** of similar lines in a single deletion
  - Can delete ***non-consecutive lines***
  - Still, language agnostic

Lexical deletion operator

ORBS vs. LS-ORBS

- Benchmarks: 18 slicing criteria from Java and C programs
  - Java: apache commons csv, cli, and guava library
  - C: Siemens suite



LS-ORBS achieves / uses

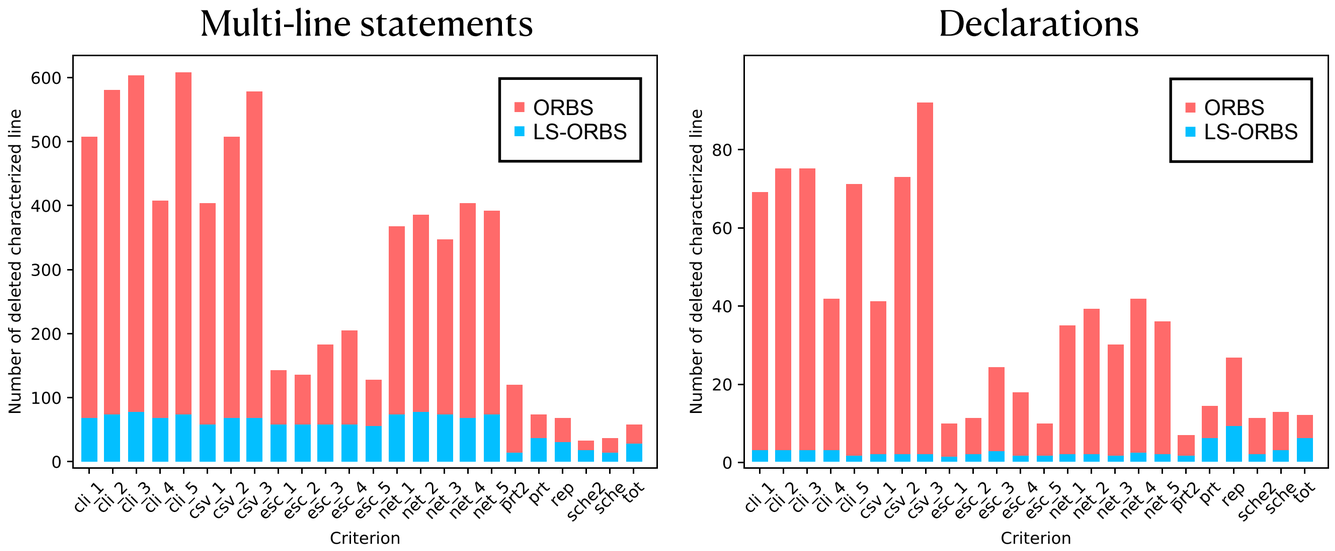
👍 **45%** # of compilations,

👍 **70%** # of executions,

👎 **38%** # of deleted lines,

👍 **64%** time taken per deleted line compared to ORBS.

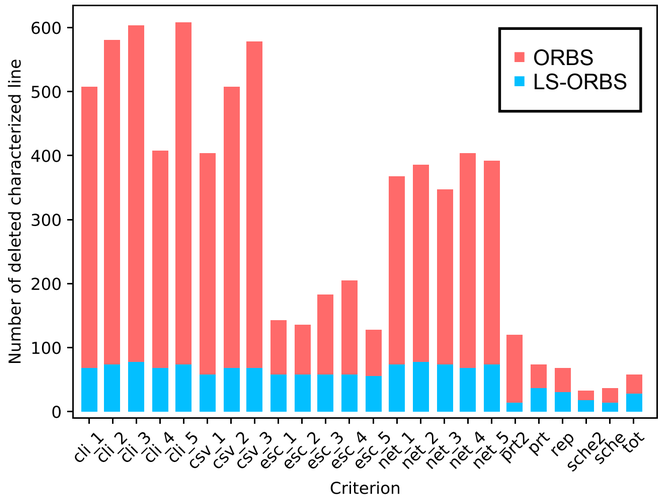
When are lexical deletion operators effective / ineffective?



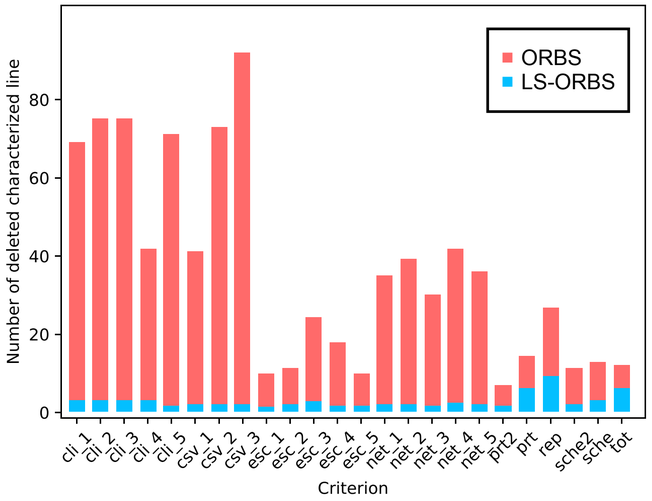
Syntactic structures in source code is challenging to the lexical deletion operators

When are lexical deletion operators effective / ineffective?

Multi-line statements

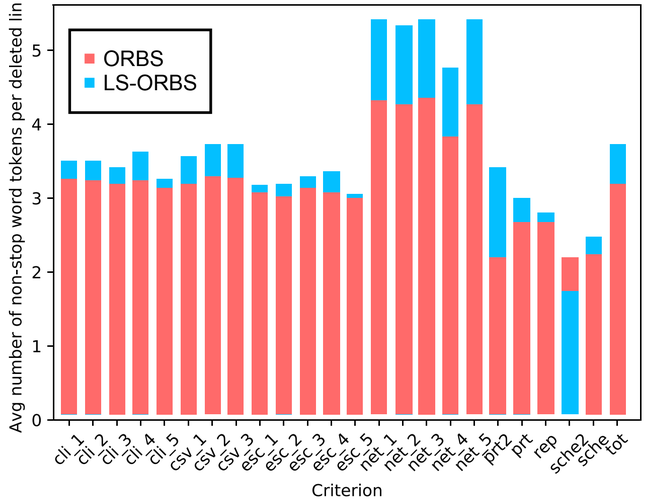


Declarations



Syntactic structures in source code is challenging to the lexical deletion operators

Non-stop words in deleted lines



Lexical deletion operators are effective in the statements with non-stop words.

When are lexical deletion operators effective / ineffective?

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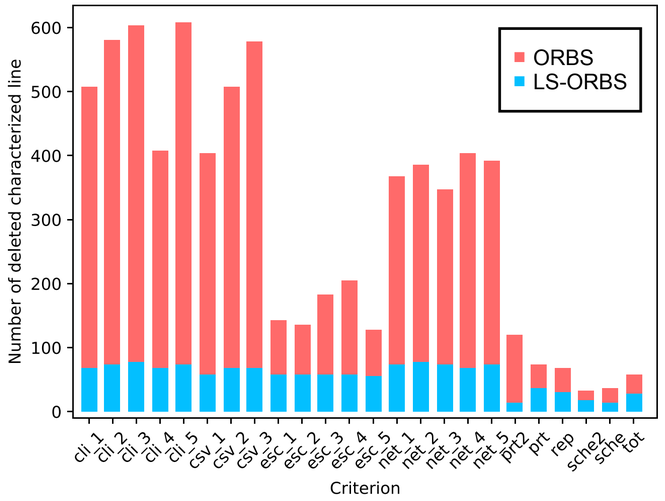

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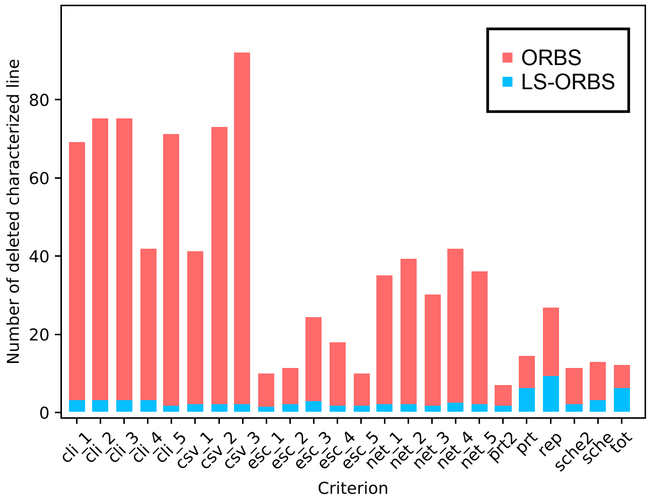

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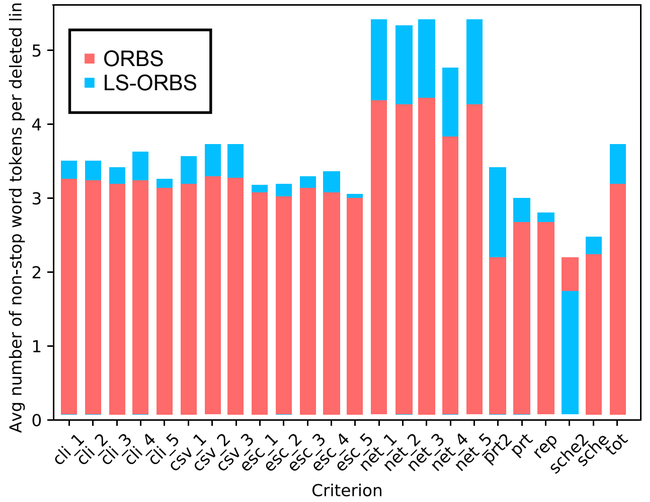

Lexical deletion operators are effective in the statements with non-stop words.

There is a complementary relation between window deletion and lexical deletion.

MOBS: Multi-operator ORBS

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obs_matrix_dict = OrderedDict()
for obs_dir in obs_dir_list:
    itv_state_idx = get_itv_state_idx(work_dir, obs_dir)
    cmp_dict = get_cmp_dict(obs_dir)
    for testname, obs_dict in cmp_dict.items():
        obs_row = get_obs_row(itv_state_idx, obs_dict)
        if is_stdout:
            oracle_stdout_path = os.path.join(work_dir, "oracle", "test", testname)
            obs_stdout_path = os.path.join(obs_dir, "test", testname)
            obs_row = np.append(
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            if obs_row[itv_matrix_idx] == 0:
                if not np.array_equal(obs_row[1:], [0] * (len(obs_row) - 1)):
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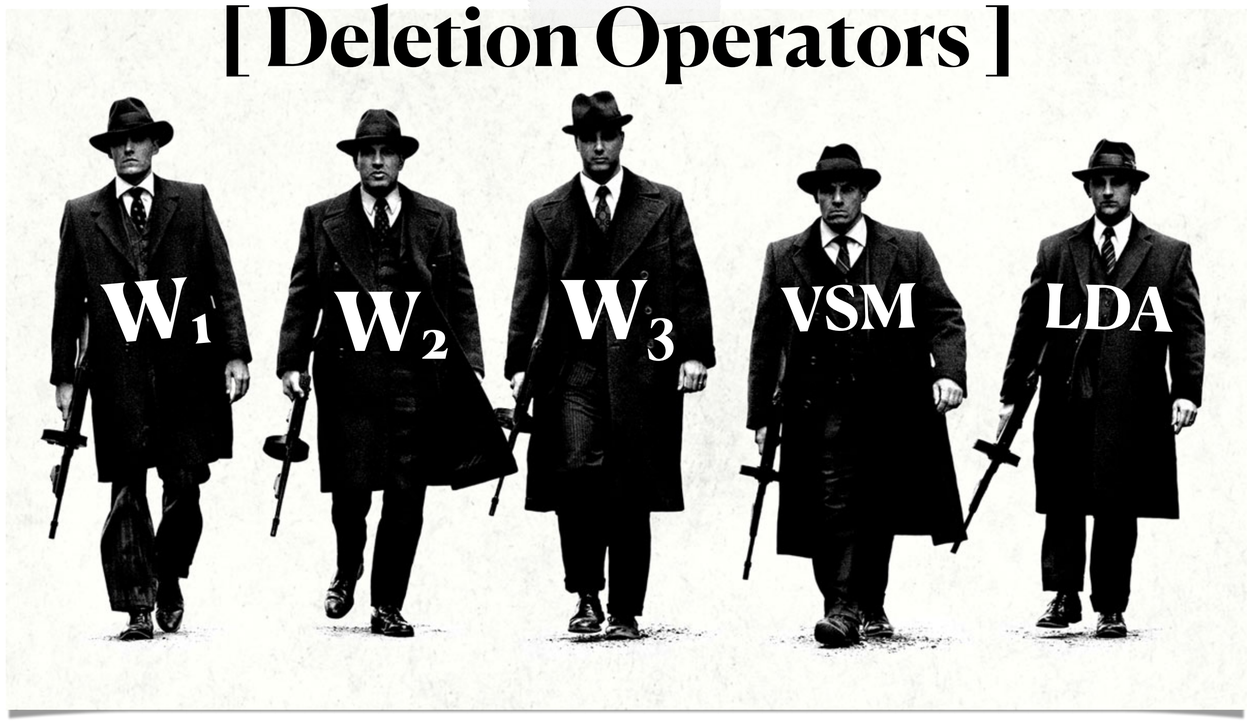

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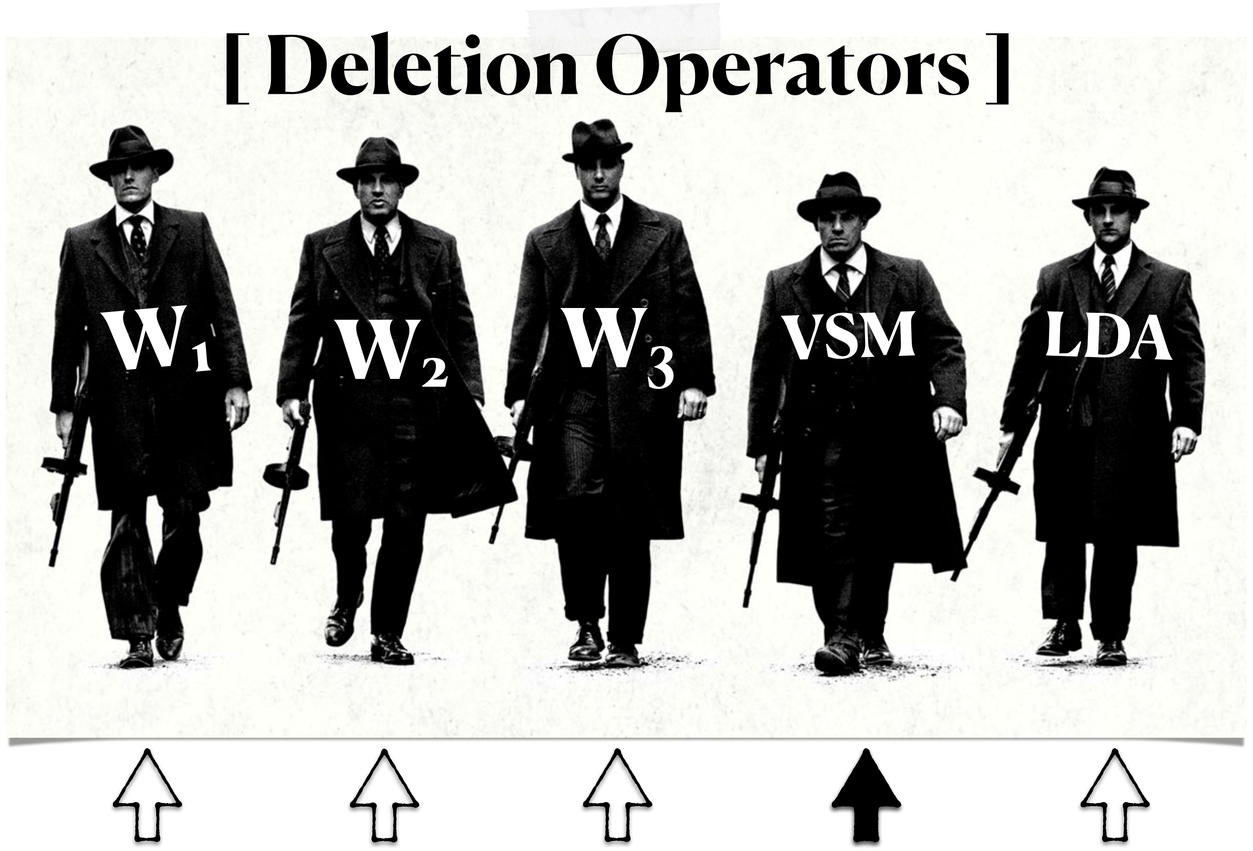

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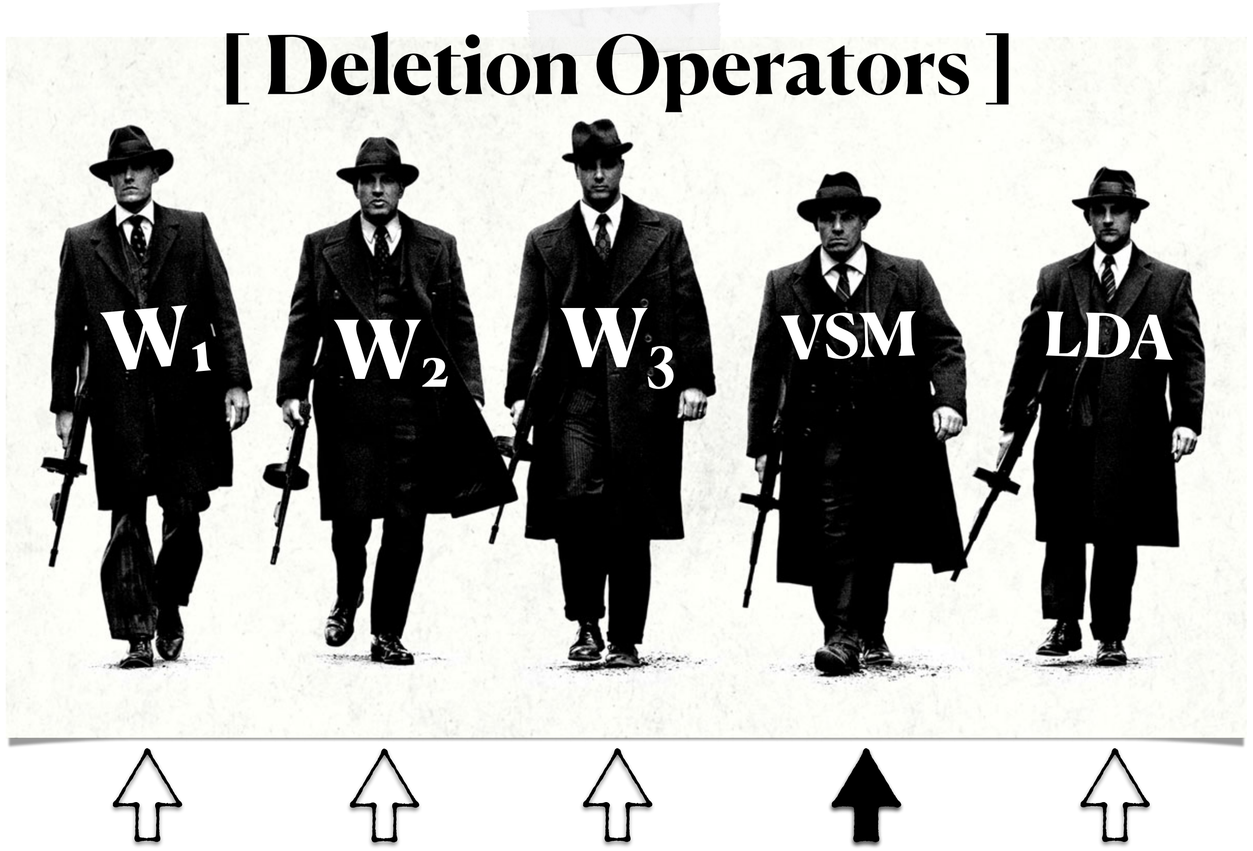

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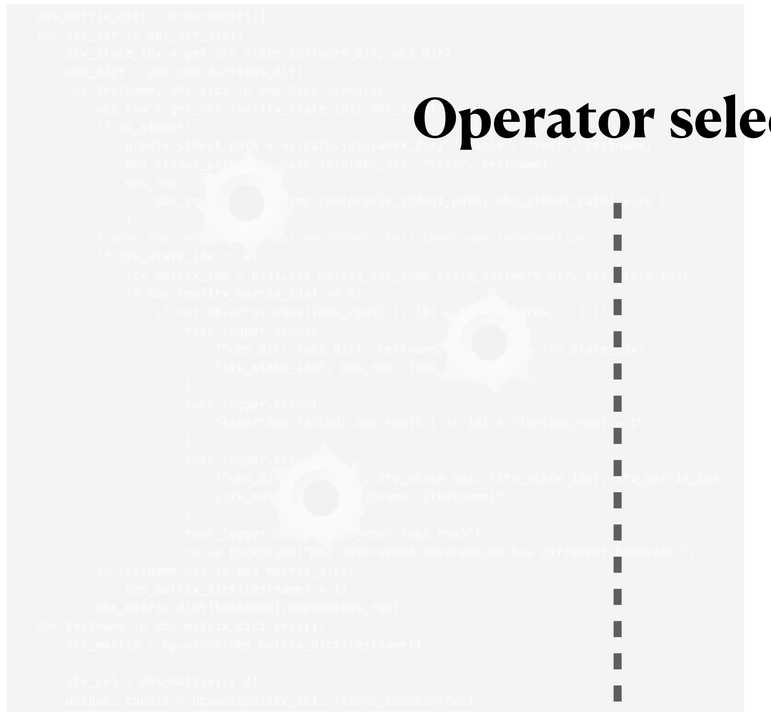
Operator selection using probability distribution



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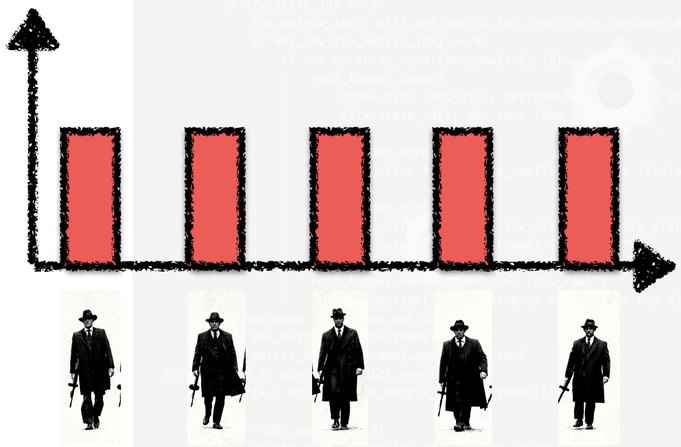

Uniform distribution

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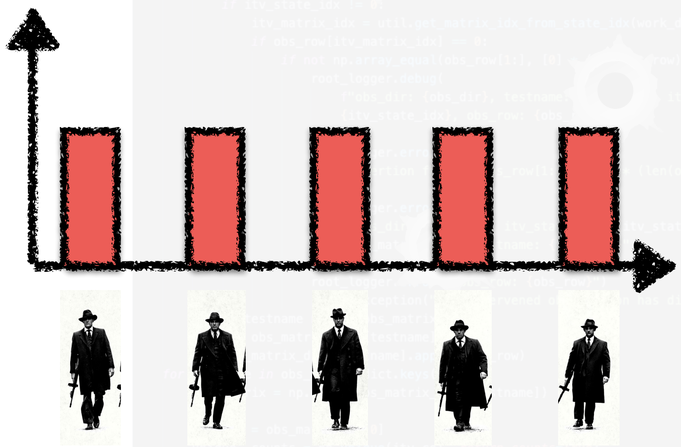

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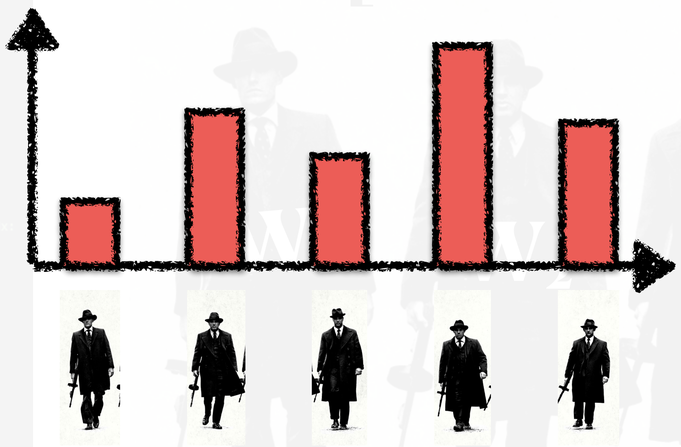

Fixed distribution based on applicability / effect of D.O

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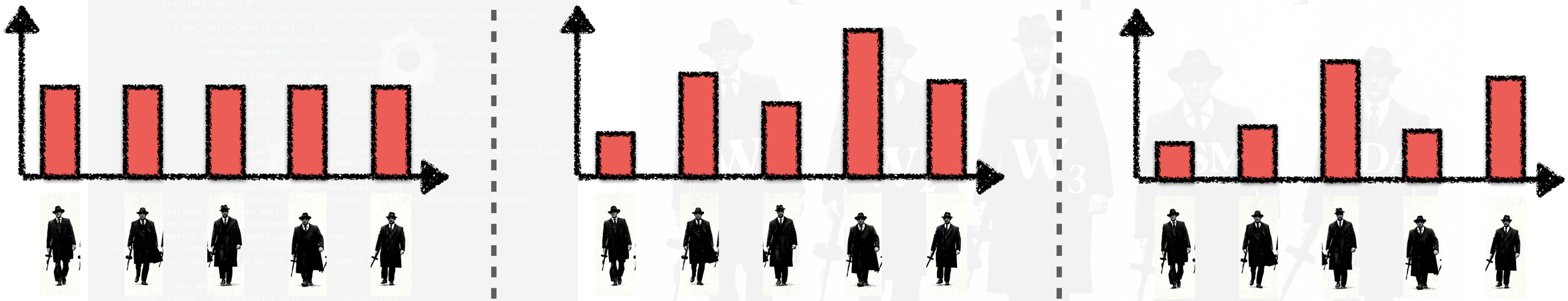

Uniform distribution

Fixed distribution based on applicability / effect of D.O

Adaptive distribution

Result

Table 2: Statistics on Number of Deleted Lines (μ_{del}), Execution Time (μ_{time}), Seconds per Deletion (μ_{spd}), and Speed Up ratio w.r.t W-ORBS by W-ORBS and MOBS

Criteria	Strategy	μ_{del}	μ_{time}	μ_{spd}	Speedup
commons-cli	ROS-MOBS	1051	20533	19.89	2.76
	FOS-app-MOBS	957	23697	25.32	2.40
	FOS-aff-MOBS	969	21690	22.89	2.62
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	W-ORBS	1255	56897	46.01	1.00
commons-csv	ROS-MOBS	665	12850	19.86	3.61
	FOS-app-MOBS	618	14862	24.55	3.11
	FOS-aff-MOBS	625	14103	22.97	3.26
	FOS-uni-MOBS	606	13531	22.68	3.39
	W-ORBS	797	46008	58.78	1.00
guava-escape	ROS-MOBS	213	5172	24.75	3.17
	FOS-app-MOBS	195	5146	26.64	3.21
	FOS-aff-MOBS	201	5213	26.55	3.11
	FOS-uni-MOBS	210	5143	24.89	3.17
	W-ORBS	264	16249	63.01	1.00
guava-net	ROS-MOBS	788	11854	15.17	2.67
	FOS-app-MOBS	724	11725	16.23	2.73
	FOS-aff-MOBS	738	12362	16.88	2.55
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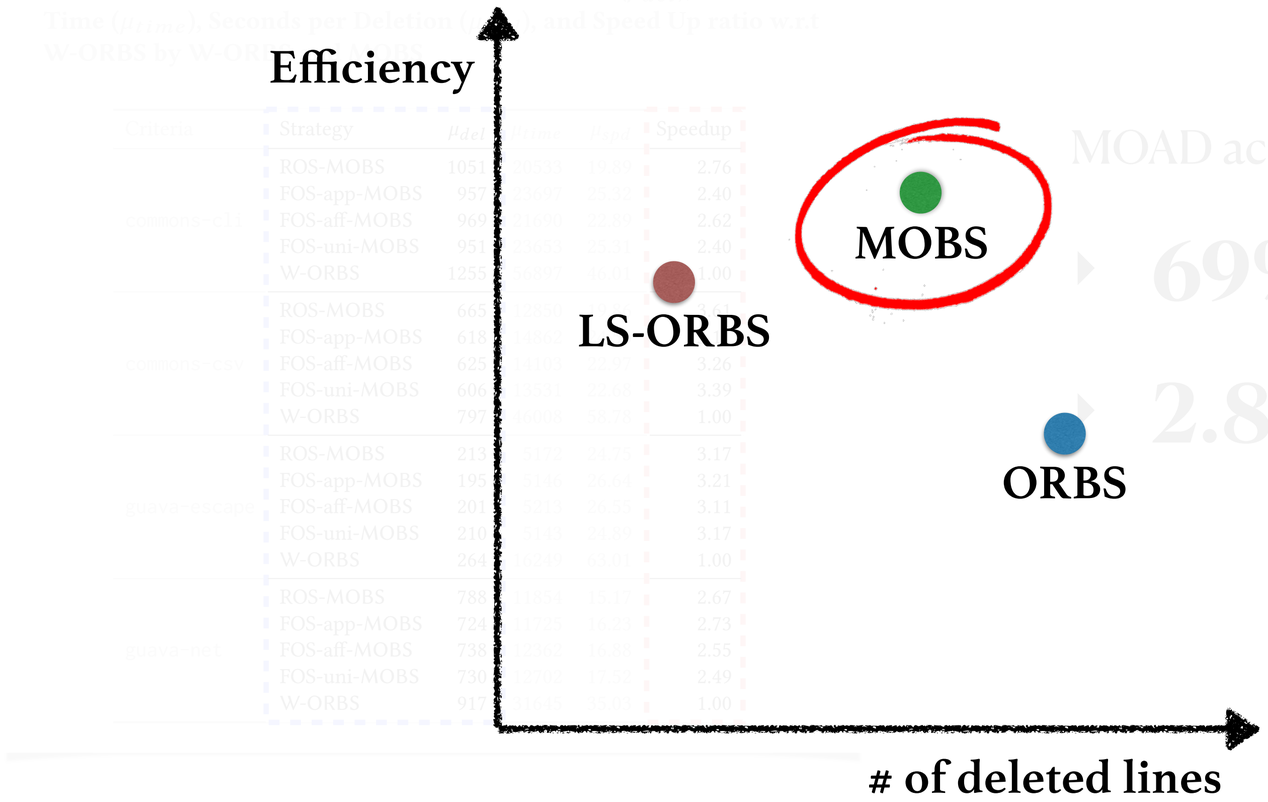
MOAD achieves / uses

- **69%** # of deleted lines,
- **2.8X** faster

  compared to ORBS.

Result



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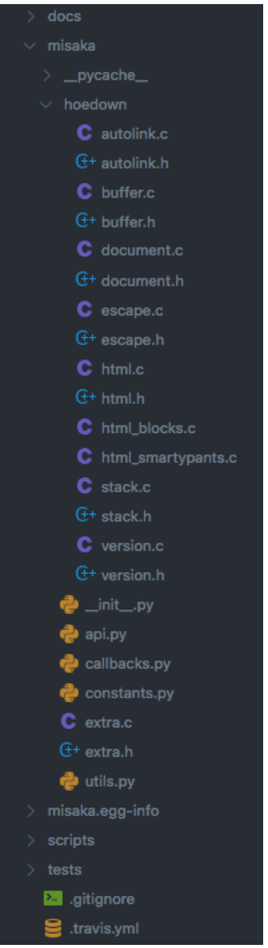
Example. Multi-lingual deletion



- Misaka(http://misaka.61924.nl)
  - A Python binding for Hoedown, a markdown parsing C library.
  - Programming language: C, Python

	NCLOC	FILES	TC
C	4360	10	
Python	473	5	
Total	4833	15	92

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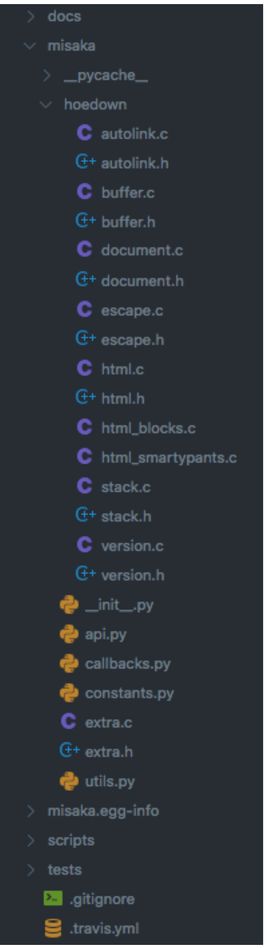

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- VSM Deletion operator

```
┌ callbacks.py      (97)  > elif align_bit == TABLE_ALIGN_LEFT:
| callbacks.py      (98)  >     align = 'left'
└ hoedown/html.c    (393) > case HOEDOWN_TABLE_ALIGN_LEFT:
```

- LDA Deletion operator

```
┌ api.py                  (29)   > lib.hoedown_buffer_puts(ib, text.encode('utf-8'))
| hoedown/document.c      (2490) > hoedown_buffer_free(text);
└ hoedown/html_smartypants.c (195) > hoedown_buffer_putc(ob, text[0]);
```

- Both LDA and VSM Deletion operator

```
┌ callbacks.py      (125) > result = renderer.blockhtml(text)
└ hoedown/html.c    (635) > renderer->blockhtml = NULL;
```

Naturalness of source code

- Java
- Python

Can we approximate the program semantics via lexical information of the source code?

➡ Program dependency analysis

Code lines handing the logging function contains the word 'log'

Like a natural language, a source code is also repetitive and predictable.

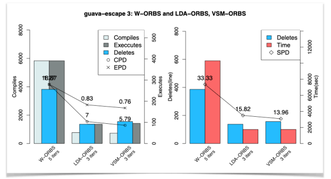
Lexical deletion operator

```
...
logger.log(Level.SEVER, "…");   ← 0.85
...
logger.log(Level.WARNING, "…");  ← 0.8
...
Logger logger = Logger.getLogger(…);
...
```

- Two language model to calculate the similarity
  - Vector Space Model (VSM)
  - Latent Dirichlet Allocation (LDA)
- Advantage of the lexical deletion operators:
  - Can delete an ***arbitrary number*** of similar lines in a single deletion
  - Can delete ***non-consecutive lines***
  - Still, language agnostic

ORBS vs. LS-ORBS

- Benchmarks: 18 slicing criteria from Java and C programs
  - Java: apache commons csv, cli, and guava library
  - C: Siemens suite



LS-ORBS achieves / uses

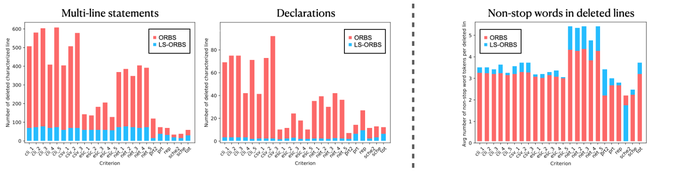
👍 **45%** # of compilations,

👍 **70%** # of executions,

👎 **38%** # of deleted lines,

👍 **64%** time taken per deleted line compared to ORBS.

When are lexical deletion operators effective / ineffective?



Syntactic structures in source code is challenging to the lexical deletion operators

Lexical deletion operators are effective in the statements with non-stop words.

There is a complementary relation between window deletion and lexical deletion.

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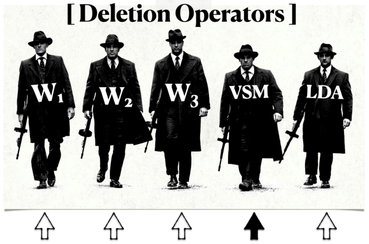

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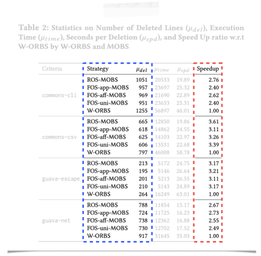

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Thank you.