Towards Efficient Comparison of Change-based Models

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lpdp
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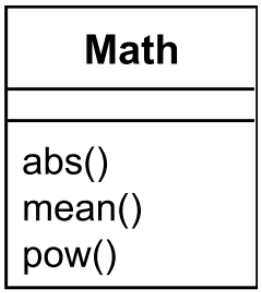
Introduction

- A model can have many versions or variants
- Persisted as snapshots, in state-based format (e.g., XMI)
- Model comparison highlights their differences
- Comparing versions in a state-based format can be computationally expensive
- They need to be loaded in their entirety before their elements can be matched and diffed

Introduction

- **Change-Based Persistence (CBP)** persists the complete history of changes of a model instead of its eventual state.



(a) origin

```
1  <uml:Class id="x" name="Math">
2    <operation id="a" name="abs"/>
3    <operation id="b" name="mean"/>
4    <operation id="c" name="pow"/>
5  </uml:Class>
```

Listing 1 – The simplified XMI of the model in Fig. 1a.

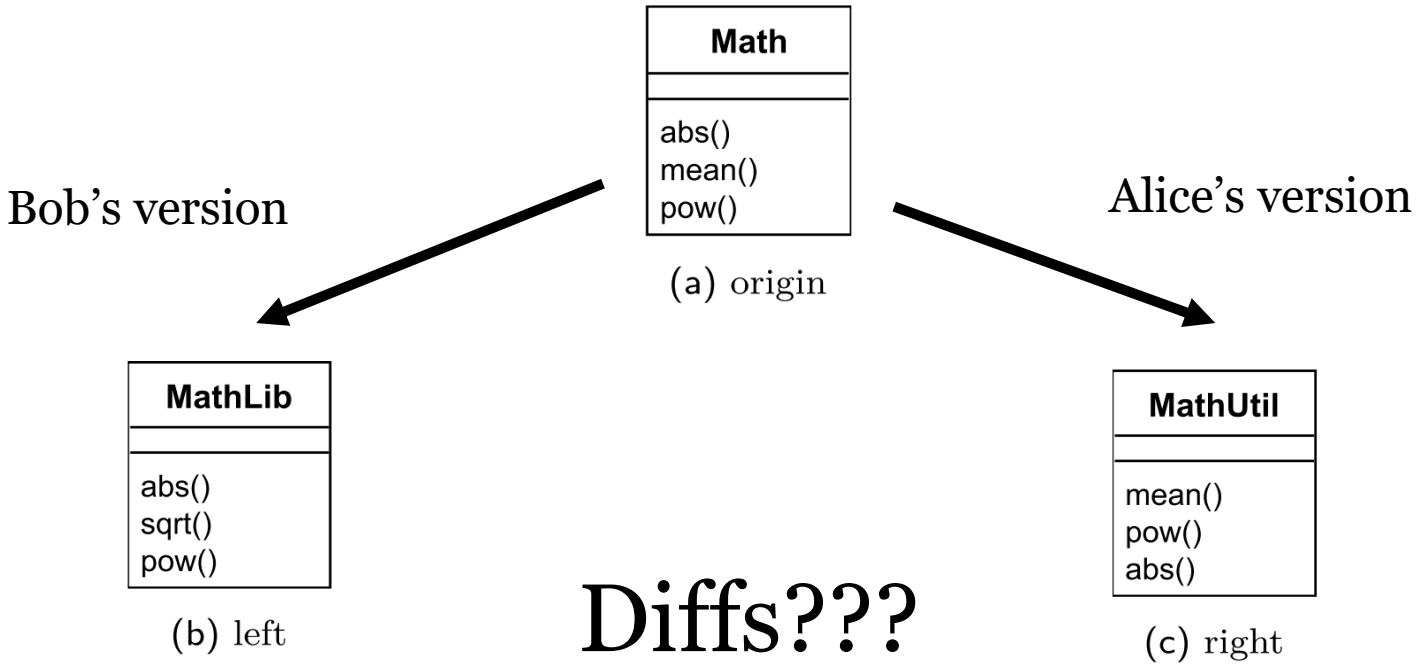
```
1   create x type Class
2   set x.name to "Math"
3   create a type Operation
4   set a.name to "abs"
5   create b type Operation
6   set b.name to "mean"
7   create c type Operation
8   set c.name to "pow"
9   add a to x.operations at 0
10  add b to x.operations at 1
11  add c to x.operations at 2
```

Listing 2 – The pseudo-formatted CBP of the model in Fig. 1a.

Main Goals

- Use the persisted changes to optimise:
  - Incremental model management
  - Model differencing, conflict detection, and merging
- Support Collaborative Modelling
  - Support common text-based Version Control Systems (e.g. Git, SVN) to persist changes
- Facilitate Model Analytics
- **This paper addresses Model Differencing**

Example



Diffs???

State-based Comparison:

1. Load models,
2. Match elements, and
3. Diff

State-based Model Comparison

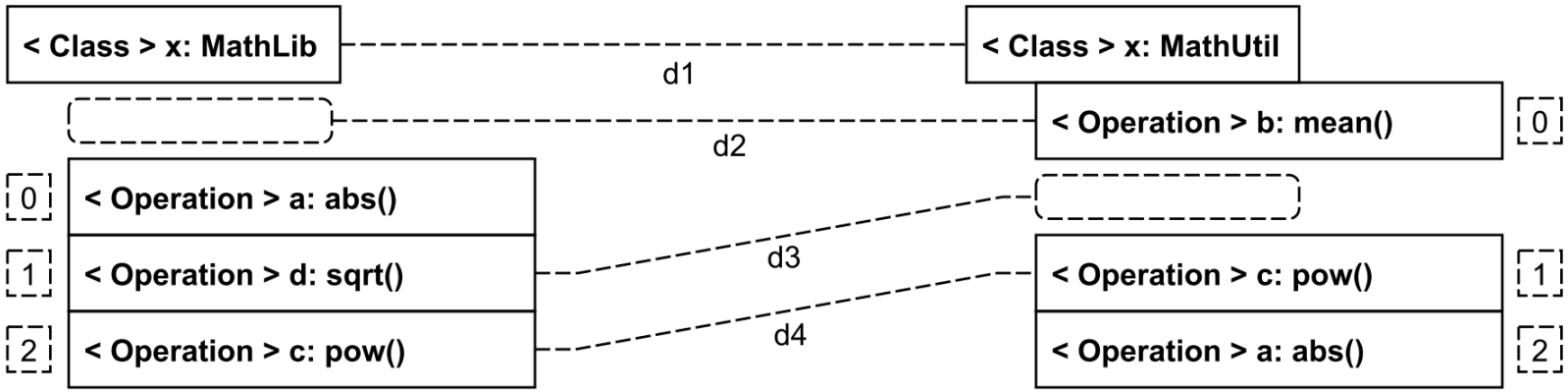


Figure 3 – A model comparison of the left and right models in Listings 3 and 4.

EMF Compare applies a Longest Common Subsequence (LCS) algorithm to identify these differences:

d_{S1}: **change** x.name **from** "MathLib" **to** "MathUtil"
d_{S2}: **delete** b
d_{S3}: **add** d **to** name.operations **at** 1
d_{S4}: **move** c **in** name.operations **from** 1 **to** 2

Change-based Model Differencing (1)

```
1  <uml:Class id="x" name="Math">
2    <operation id="a" name="abs"/>
3    <operation id="b" name="mean"/>
4    <operation id="c" name="pow"/>
5  </uml:Class>
```

Listing 1 – The simplified XMI of the model in Fig. 1a.

```
12  set x.name from "Math" to "MathLib"
13  create d type Operation
14  set d.name to "sqrt"
15  add d to x.operations at 1
16  remove b in x.operations at 2
17  delete b
```

Listing 5 – The appended changes made by Bob to produce the model in Fig. 1b (left version).

```
12  move a in x.operations from 0 to 2
13  set x.name from "Math" to "MathUtil"
```

Listing 6 – The appended changes made by Alice to produce the model in Fig. 1c (right version).

```
1  <uml:Class id="x" name="MathLib">
2    <operation id="a" name="abs/>
3    <operation id="d" name="sqrt"/>
4    <operation id="c" name="pow"/>
5  </uml:Class>
```

Listing 3 – The simplified XMI of the left model in Fig. 1b.

```
1  <uml:Class id="x" name="MathUtil">
2    <operation id="b" name="mean"/>
3    <operation id="c" name="pow"/>
4    <operation id="a" name="abs"/>
5  </uml:Class>
```

Listing 4 – The simplified XMI of the right model in Fig. 1c.

Change-based Model Differencing (2)

- Steps:
  1. Change Event Loading
  2. Element Tree Construction
  3. Diff Computation

- Change Event Loading
  1. Load events from files into memory

```
12  set x.name from "Math" to "MathLib"
13  create d type Operation
14  set d.name to "sqrt"
15  add d to x.operations at 1
16  remove b in x.operations at 2
17  delete b
```

Listing 5 – The appended changes made by Bob to produce the model in Fig. 1b (left version).

```
12  move a in x.operations from 0 to 2
13  set x.name from "Math" to "MathUtil"
```

Listing 6 – The appended changes made by Alice to produce the model in Fig. 1c (right version).

Change-based Model Differencing (3)

- Element Tree Construction
- Left

```
12  set x.name from "Math" to "MathLib"
13  create d type Operation
14  set d.name to "sqrt"
15  add d to x.operations at 1
16  remove b in x.operations at 2
17  delete b
```

Listing 5 – The appended changes made by Bob to produce the model in Fig. 1b (left version).

```
1  <uml:Class id="x" name="MathLib">
2    <operation id="a" name="abs/>
3    <operation id="d" name="sqrt"/>
4    <operation id="c" name="pow"/>
5  </uml:Class>
```

Listing 3 – The simplified XMI of the left model in Fig. 1b.

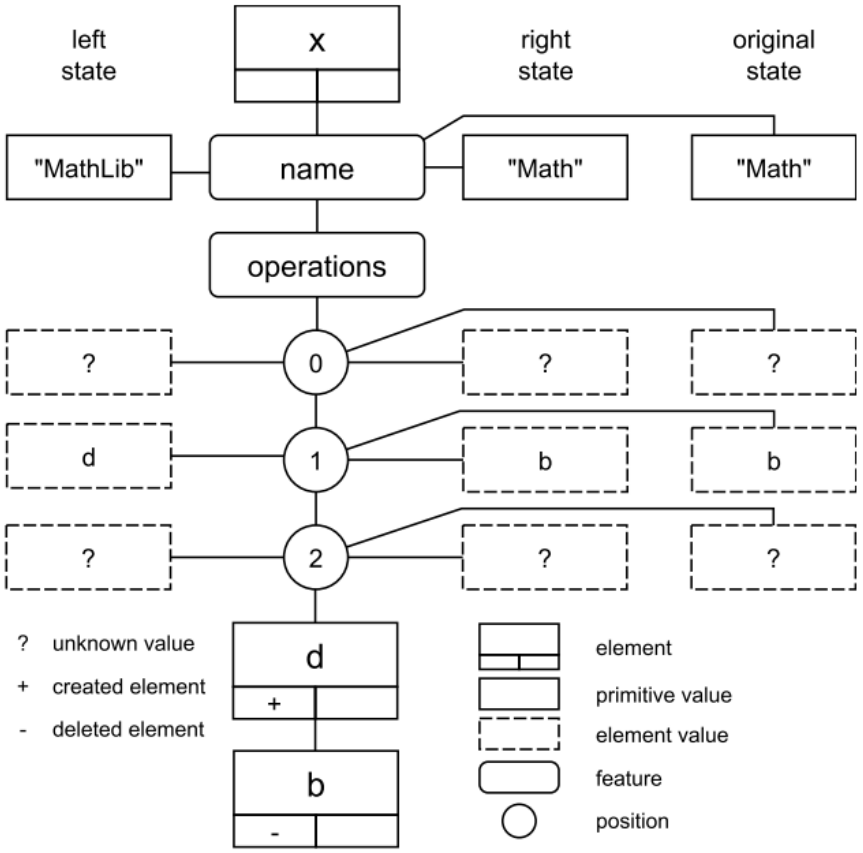


Figure 5 – The elementTree after processing all left change events.

Change-based Model Differencing (4)

- Element Tree Construction
- Right

```
12  move a in x.operations from 0 to 2
13  set x.name from "Math" to "MathUtil"
```

Listing 6 – The appended changes made by Alice to produce the model in Fig. 1c (right version).

```
1  <uml:Class id="x" name="MathUtil">
2    <operation id="b" name="mean"/>
3    <operation id="c" name="pow"/>
4    <operation id="a" name="abs"/>
5  </uml:Class>
```

Listing 4 – The simplified XMI of the right model in Fig. 1c.

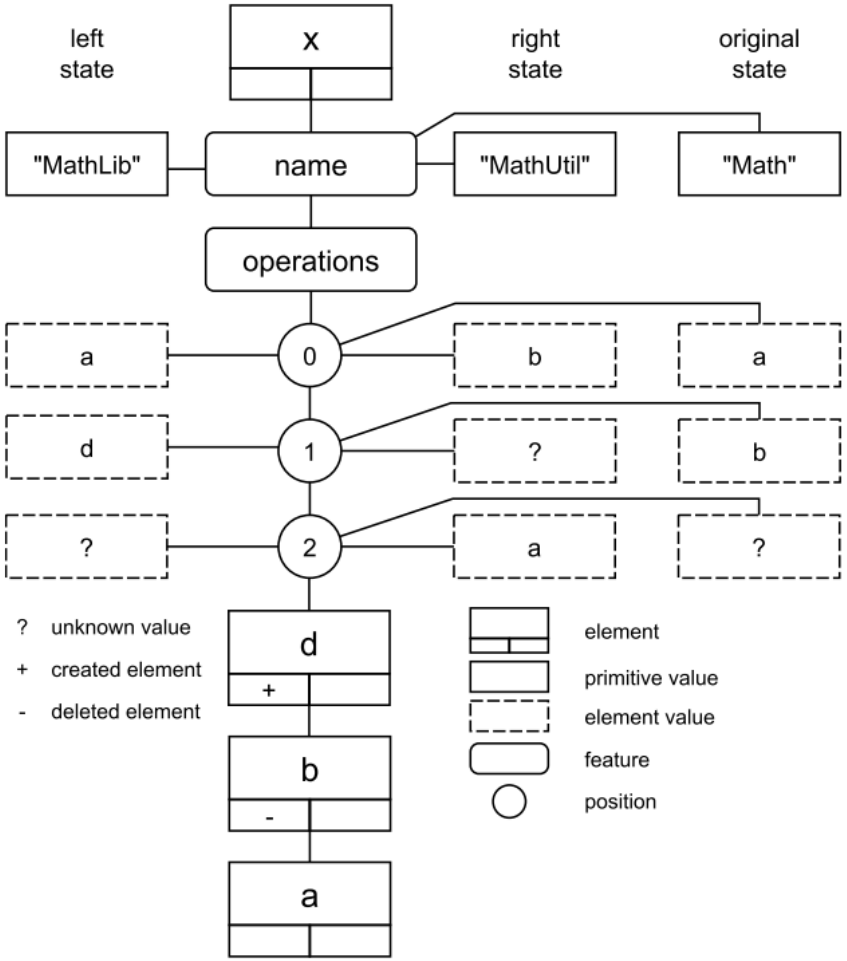


Figure 6 – The elementTree after processing all left and right change events.

Change-based Model Differencing (5)

Diff Computation

Diffs = a set of operations to make right side equal to left side

- D_{C1}: **change** x.name **from** “MathLib” **to** “MathUtil”
- D_{C2}: **delete** b
- D_{C3}: **add** d **to** name.operations **at** 1
- D_{C4}: **move** a **in** name.operations **from** 2 **to** 1

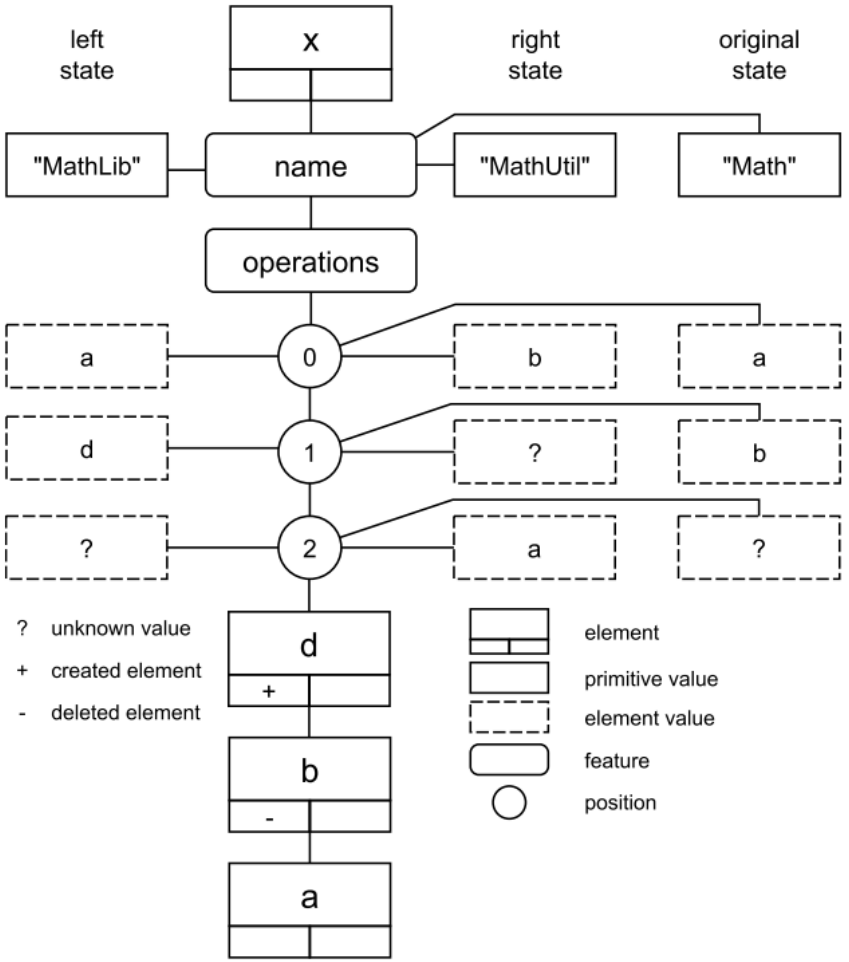


Figure 6 – The elementTree after processing all left and right change events.

Change-based Model Differencing (6)

- Change-based:

d_{C1}: **change** x.name **from** “MathLib” **to** “MathUtil”
d_{C2}: **delete** b
d_{C3}: **add** d **to** name.operations **at** 1
d_{C4}: **move** a **in** name.operations **from** 2 **to** 1

- State-based:

d_{S1}: **change** x.name **from** “MathLib” **to** “MathUtil”
d_{S2}: **delete** b
d_{S3}: **add** d **to** name.operations **at** 1
d_{S4}: **move** c **in** name.operations **from** 1 **to** 2

Performance Evaluation:
Mixed Operations

- Original model
  - 1.6 million elements
  - 224 MBs (XMI file)
- Two original models were randomly modified
  - 1.1 million changes to each model
  - set, move, add, delete types of changes
  - 1 change can produce more than 1 events
- Ratio
  - set : move : add : delete = 40 : 20 : 1 : 1

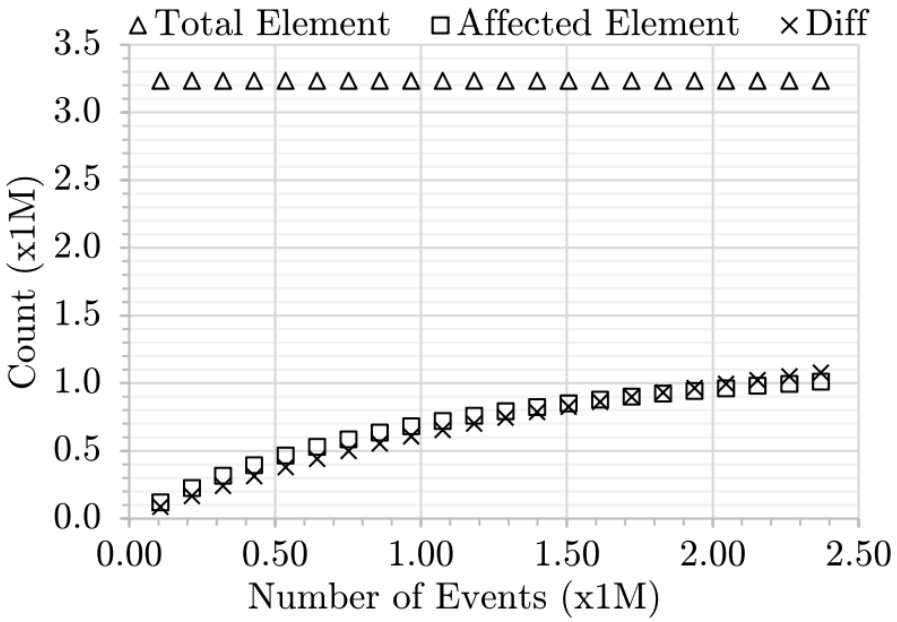
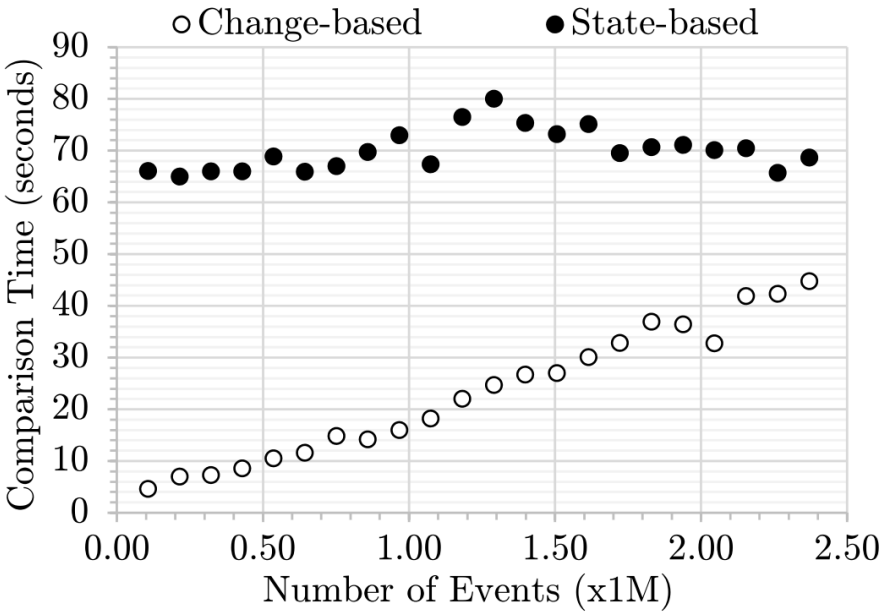


Figure 8 – total elements, affected elements, and diffs

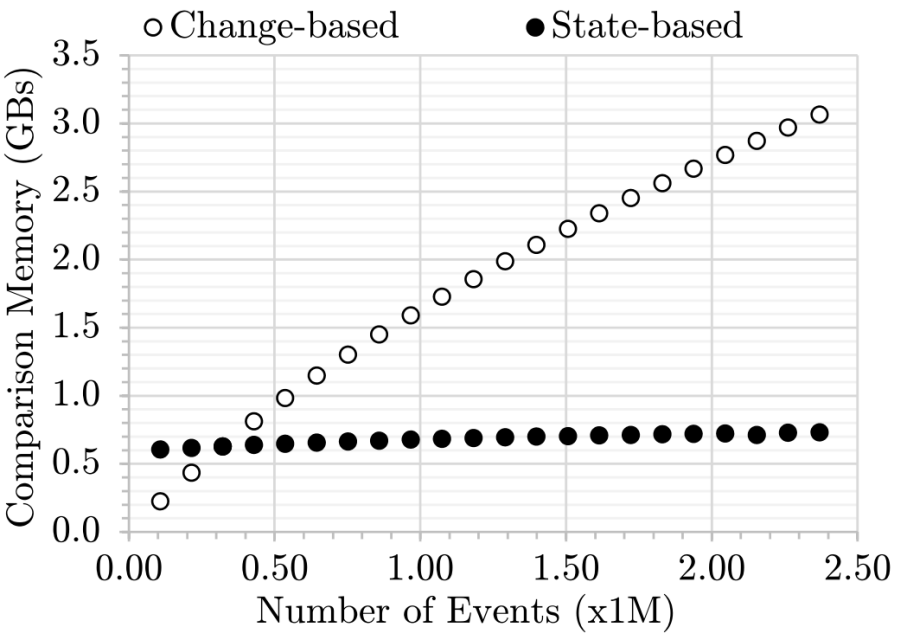
Performance Evaluation:
Mixed Operations

- Change-based vs. State-based Model Differencing

Comparison Time

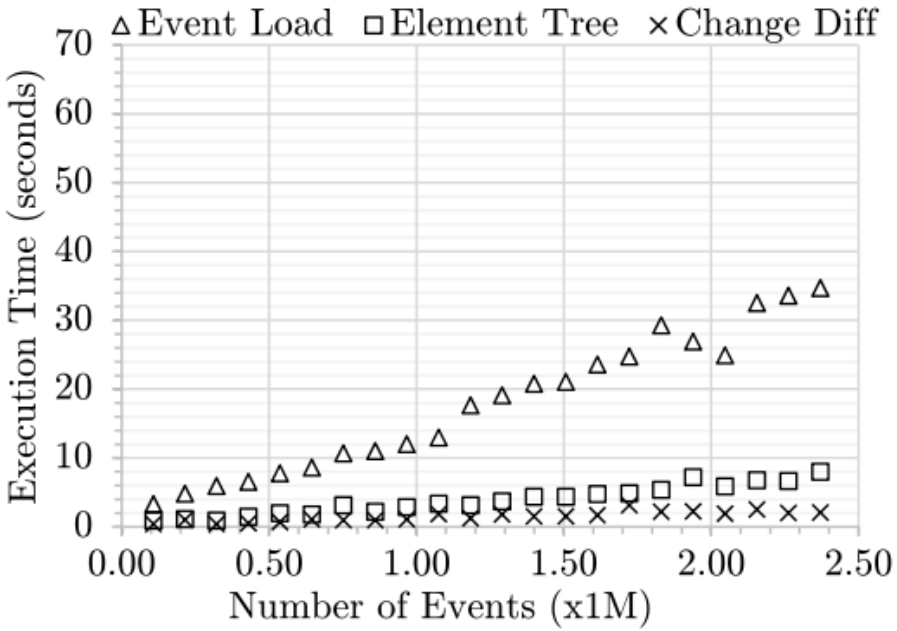


Memory Footprint

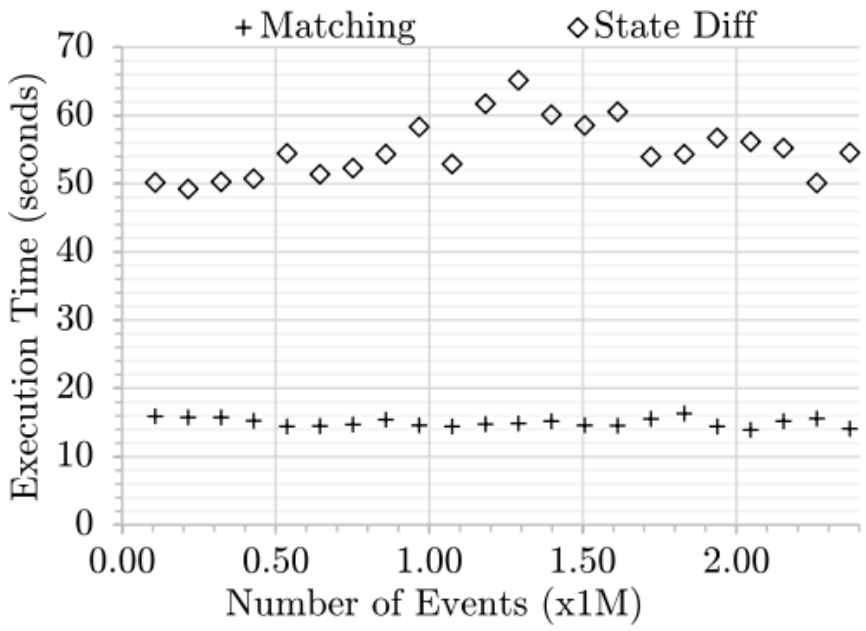


Performance Evaluation:
Mixed Operations

- Breakdown view of comparison time



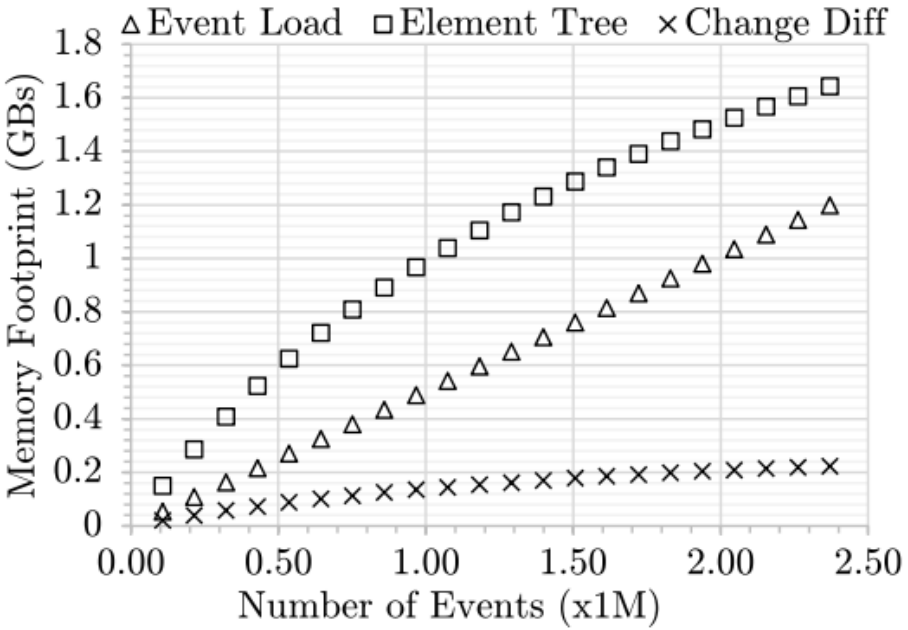
(a) change-based comparison time



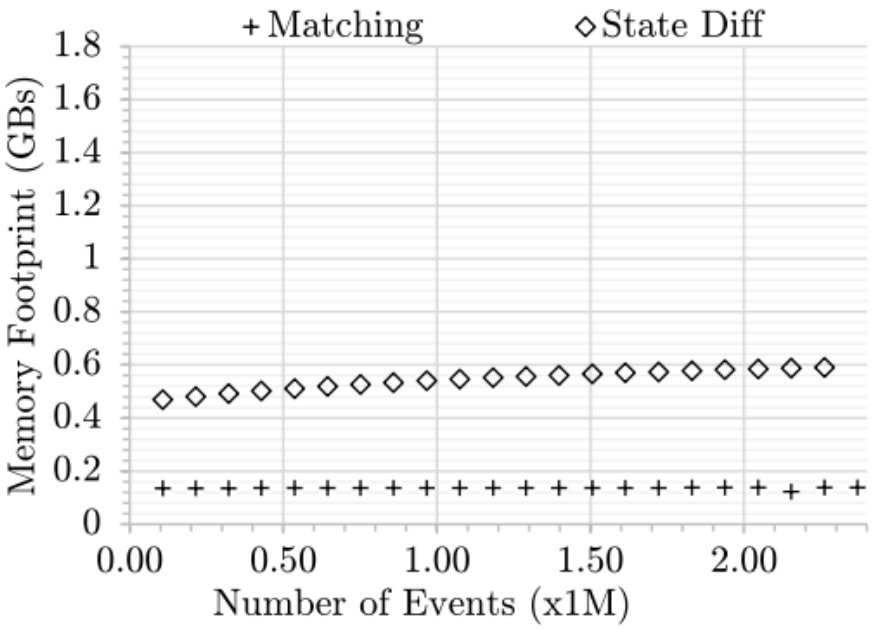
(b) state-based comparison time

Performance Evaluation:
Mixed Operations

- Breakdown view of memory footprint

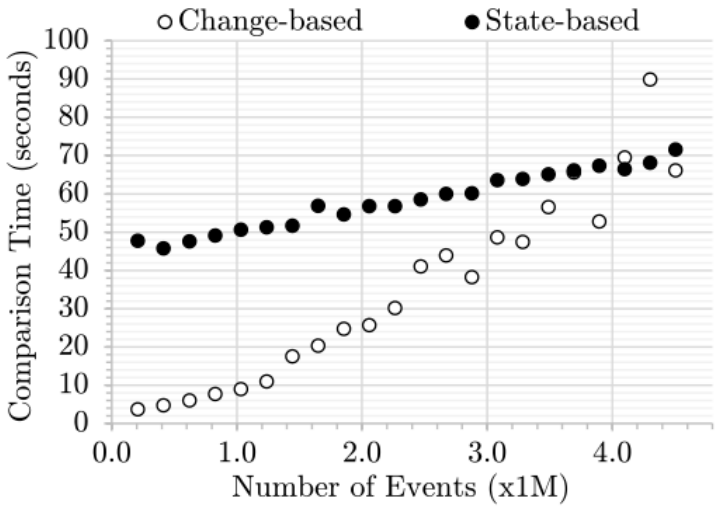


(c) change-based memory footprint

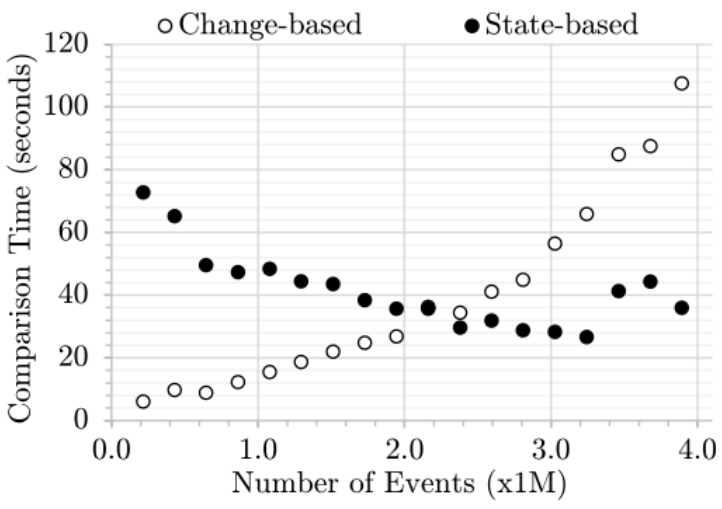


(d) state-based memory footprint

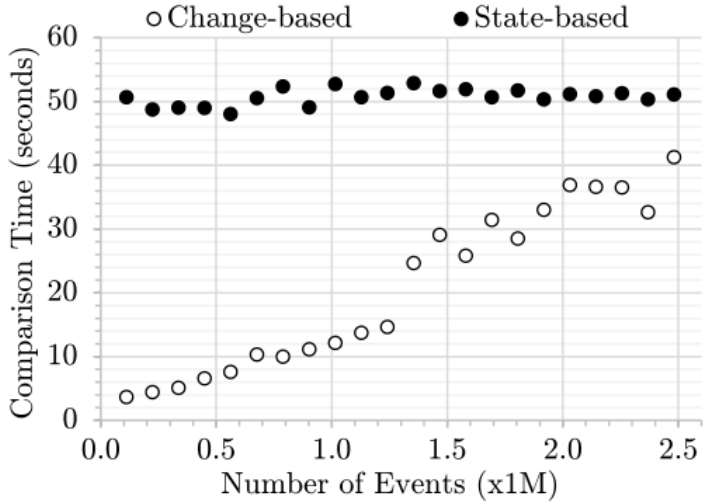
Performance Evaluation on Comparison Time:
Homogenous Operations



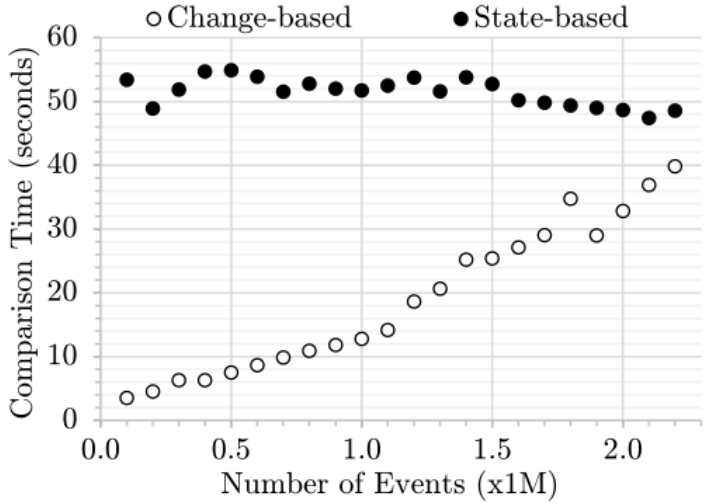
(a) add-only



(b) delete-only

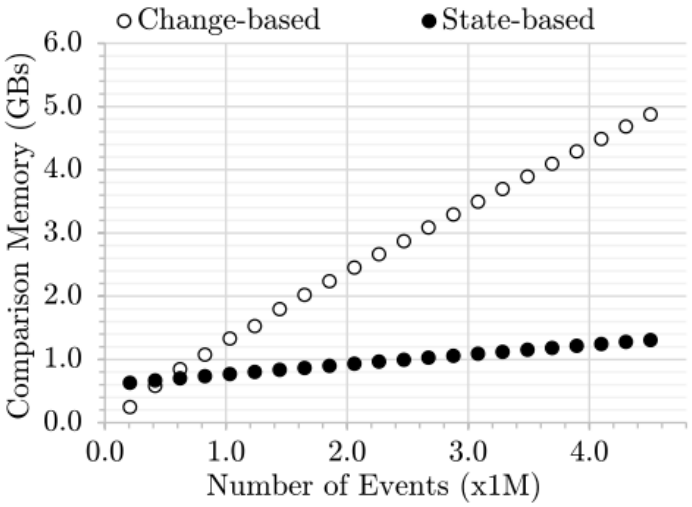


(c) move-only

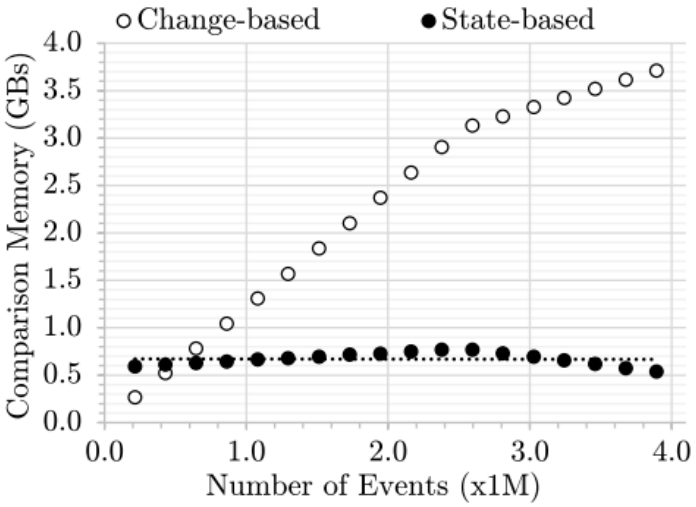


(d) change-only

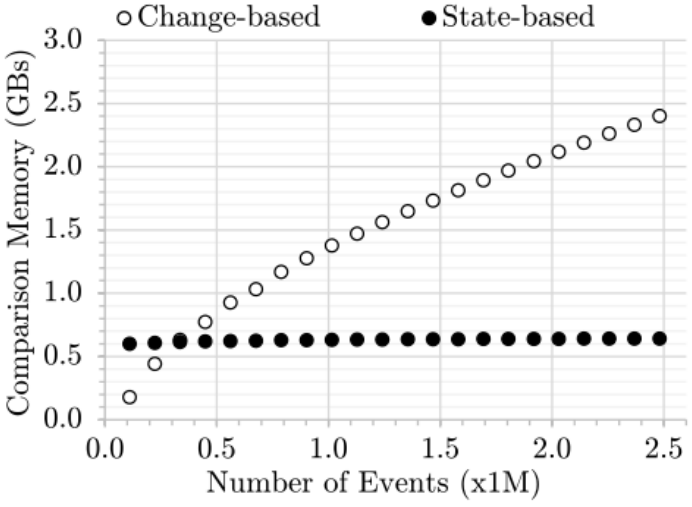
Performance Evaluation on Memory Footprint:
Homogenous Operations



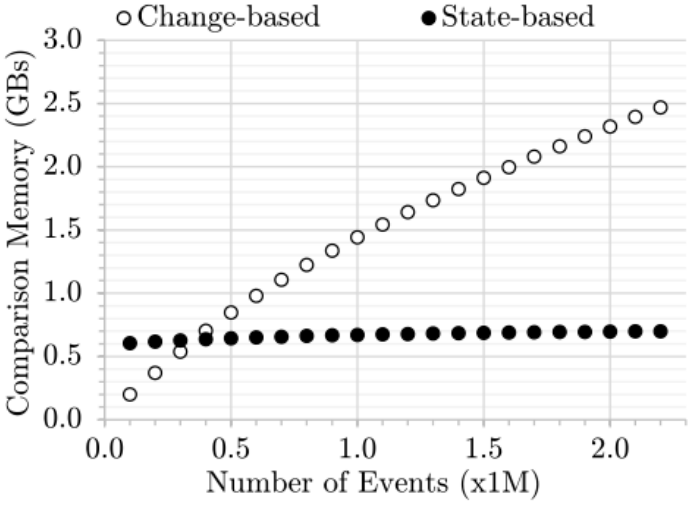
(a) add-only



(b) delete-only



(c) move-only



(d) change-only

Conclusions and Future Work

- **Conclusions**
  - Proposed change-based model comparison
  - It exploits the nature of change-based persistence; only compare the last set of changes between two versions
  - It can compare models faster than state-based model comparison
  - **Drawback**: It needs to load change events; may requires more memory than state-based approach
  - Arguably, diff and merge operations are usually performed on smaller deltas
- **Future Work**
  - Conflict detection and merging of change-based models

- Prototype: https://github.com/epsilonlabs/emf-cbp

```
12  set x.name from "Math" to "MathLib"
13  create d type Operation
14  set d.name to "sqrt"
15  add d to x.operations at 1
16  remove b in x.operations at 2
17  delete b
```

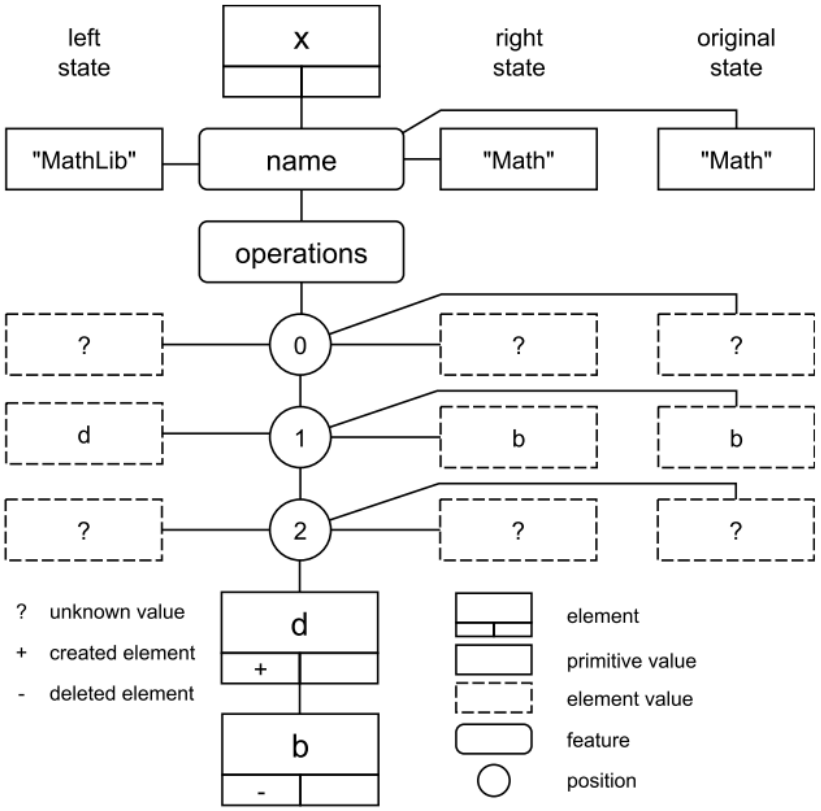


Figure 5 – The elementTree after processing all left change events.

```
12  move a in x.operations from 0 to 2
13  set x.name from "Math" to "MathUtil"
```

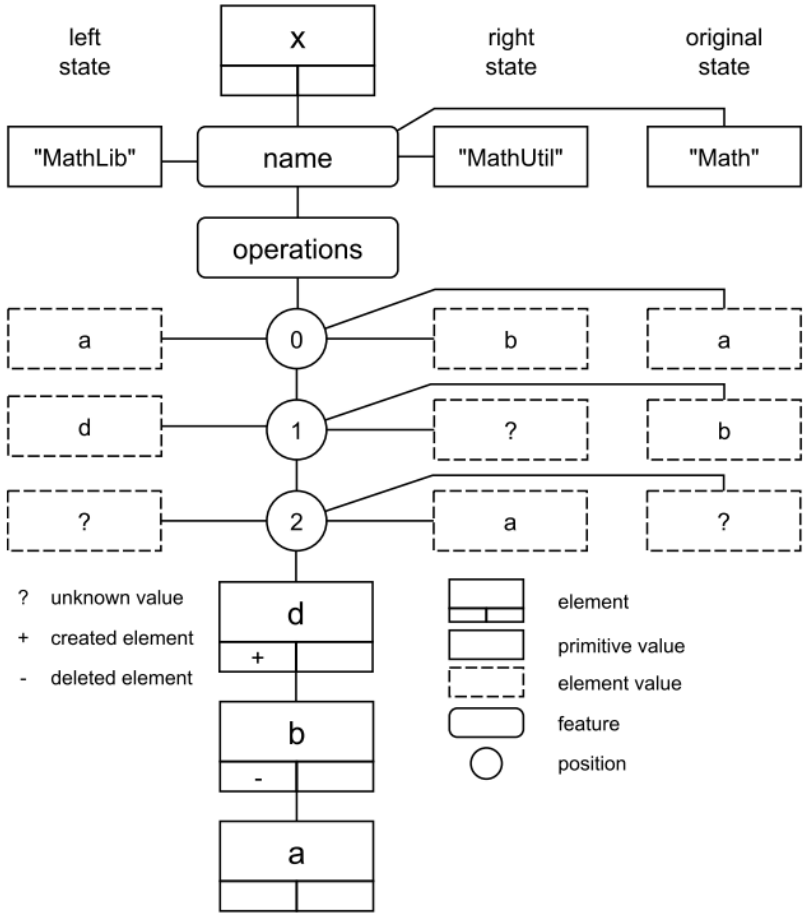


Figure 6 – The elementTree after processing all left and right change events.