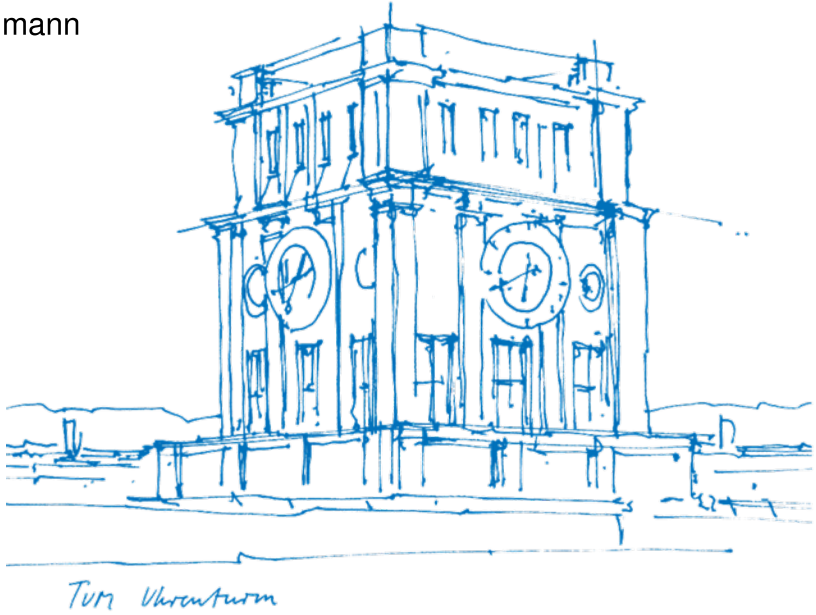
Chair III: Database Systems
Chair XXV: Data Science and Engineering
Department of Informatics
Technical University of Munich

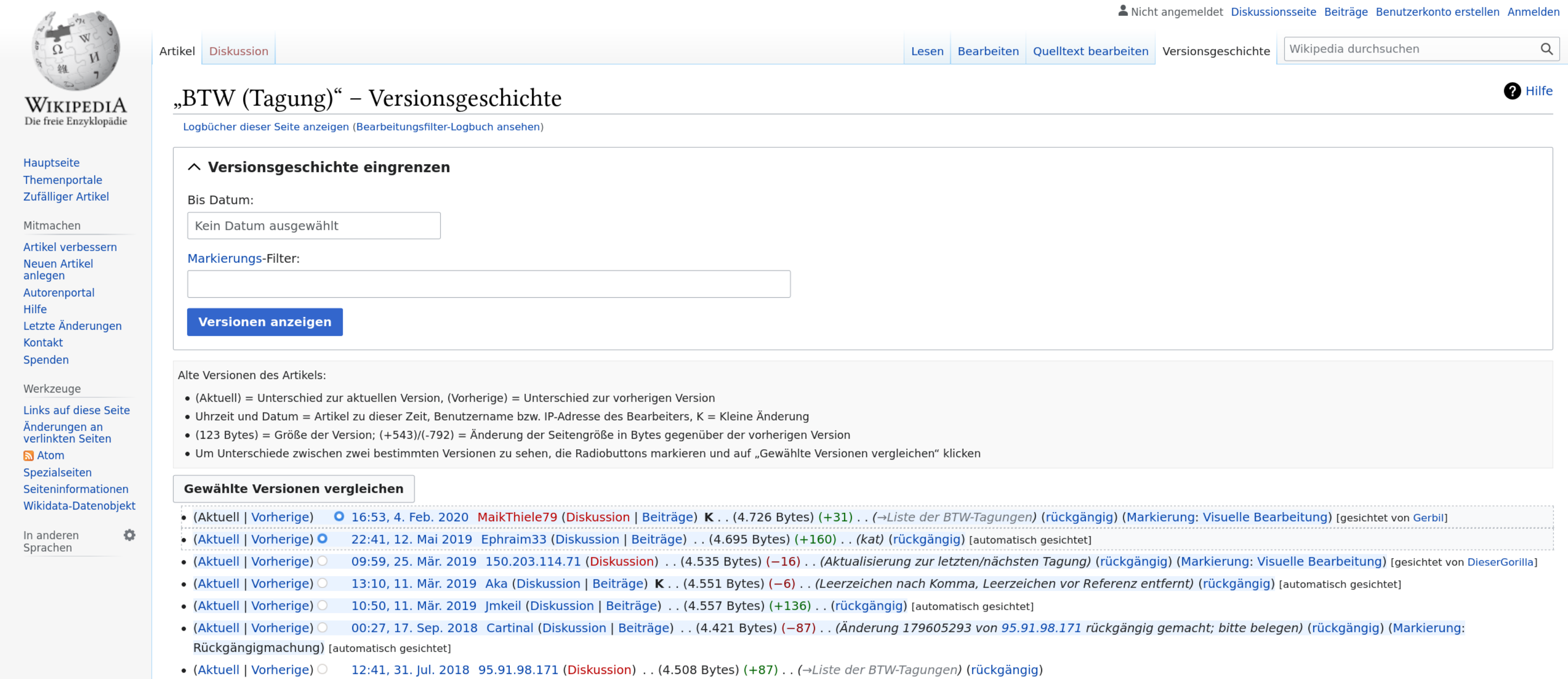
Umbra as a Time Machine: Adding a Versioning Type to SQL

Lukas Karnowski, Maximilian E. Schüle, Alfons Kemper, Thomas Neumann

Dresden, Germany, May 10, 2021



Wikipedia: Version Control with Meta Tables



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Gewählte Versionen vergleichen

- (Aktuell | Vorherige) 16:53, 4. Feb. 2020 MaikThiele79 (Diskussion | Beiträge) **K** . . (4.726 Bytes) (+31) . . *(→Liste der BTW-Tagungen)* (rückgängig) (Markierung: Visuelle Bearbeitung) [gesichtet von Gerbil]
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- (Aktuell | Vorherige) 00:27, 17. Sep. 2018 Cartinal (Diskussion | Beiträge) . . (4.421 Bytes) (−87) . . *(Änderung 179605293 von 95.91.98.171 rückgängig gemacht; bitte belegen)* (rückgängig) (Markierung: Rückgängigmachung) [automatisch gesichtet]
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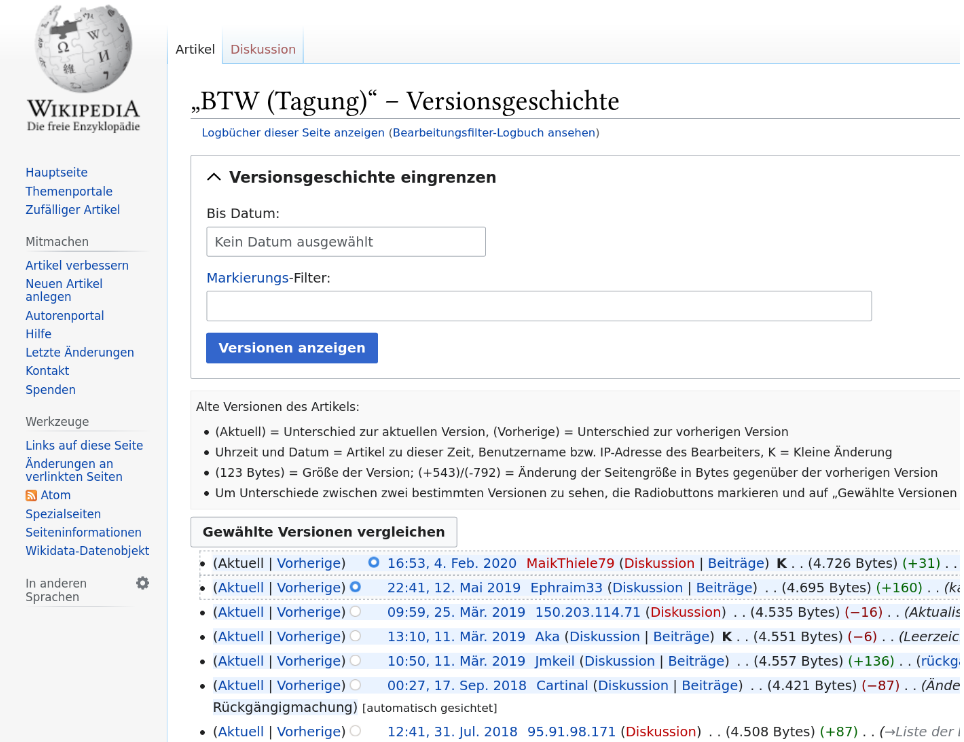
Wikipedia: Version Control with Meta Tables




```sql
CREATE TABLE page (
  page_id INT PRIMARY KEY,
  page_title TEXT,
  page_latest INT REFERENCES pagecontent (old_id)
);
CREATE TABLE revision (
  rev_id INT PRIMARY KEY,
  rev_page INT REFERENCES page (page_id),
  rev_text_id INT REFERENCES pagecontent (old_id),
  rev_parent_id INT,
  rev_timestamp TIMESTAMP
);
CREATE TABLE pagecontent (
  old_id INT PRIMARY KEY,
  old_text TEXT
);
```

	Size	Compression
Full Page Edit History	35.0 GiB	-
Current Version Only	1.1 GiB	-
History as File Diffs	14.0 GiB	59.77 %
History as Edit Diffs	9.4 GiB	72.71 %

Table: Estimation of saved storage when using compression techniques based on the *Simple English* Wikipedia page edit history dump of October 1, 2018.

Background: Wikipedia Articles for Benchmarking

Monopedia (VLDB 2017)

- single main-memory database server (HyPer) sufficient for web scale applications (full English Wikipedia)
- Monopedia Benchmark: simulate load of Wikipedia

Monopedia: Staying Single is Good Enough

The HyPer Way for Web Scale Applications

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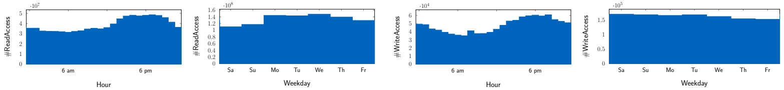
	#req	traffic [MiB]	#err	req/s	KiB/s	On Time	min	avg	max	last request	title	Rate
Σ Reads	2705	64782007	0	496.9	12766...	91.26%	803	3297.97	298488	3826		
Σ Writes	7	171728	0	0.0	0.0	100.00%	1426	64192....	403219	6487		
R0	2202	53455458	0	332.9	88998...	82.54%	803	3221.30	298488	3759	Isla_Fisher	
R1	503	11326549	0	164.0	38665...	99.99%	987	3374.64	298468	3826	Pope_Sergius_I	
W2	7	171728	0	0.0	0.0	100.00%	1426	64192....	403219	6487	A_Tale_of_Two_C...	

Interactive webinterface of Monopedia Benchmark: summarized informations and informations for each worker thread (request frequency, duration, timeliness, name of last article accessed); rate can be adjusted.



Traffic Data Analysis: March 25-31, 2017: aggregated by week and hour to find out the traffic peaks and the time-dependent load distribution; more read requests during weekdays; nearly constant number of updates. left: `SELECT SUM(reads) FROM week WHERE date BETWEEN '2017/03/25' AND '2017/03/31'`, right: `SELECT SUM(writes) FROM week WHERE data BETWEEN '2017/03/25' AND '2017/03/31'`

TardisBenchmark/TardisDB (SSDBM 2019, SIGMOD 2021)

- integrate versioning of tables into database systems
- benchmark performance (time/space) using Wikipedia articles

Versioning in Main-Memory Database Systems

From MusaeusDB to TardisDB

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ABSTRACT

As relational database systems do not support collaborative dataset editing, online lexicons—such as Wikipedia's MediaWiki—build their own version control above the database system to allow constraint-preserving version checkouts or commits involving multiple tables. To eliminate the need for purpose-specific solutions, we propose adding version control as a layer on top of the database system or integrating versioning in the database system's core.

This paper presents the first two architectures for versioning an entire state of a database system with respect to references among multiple relations. We design the prototype *MusaeusDB* as a solution for existing database systems, either as an external tool or as an extended SQL interface. The prototype *TardisDB*—an extended main-memory database system—reuses multi-version concurrency control for in-place updates while keeping older versions accessible. For performance tests on different storage layouts, we create—based on Wikipedia's page history—the *TardisBenchmark*. Our results show that it is indeed feasible to reduce wasted space while still ensuring constant retrieval time. Also, extending a main-memory database system's multi-version concurrency control has no negative impact on the transactional throughput. For further research

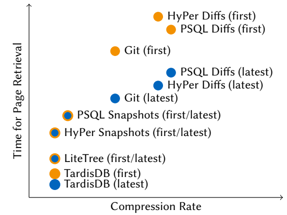


Figure 1: Sketch of the trade-off between storage savings (compression rate) and retrieval time: storing only one version snapshot and computing the others out of the changed differences (diffs) will reduce the amount of storage needed but will increase the retrieval time.

Space Compression

- **Question:** How to reduce the space consumption of Wikipedia articles within a database system?

Requirements for a Versioning System

$\rightarrow \mid \leftarrow$	Δ	$\rightarrow$	ACID/MVCC	SQL
compressing full articles	Enable delta compression	Efficient retrieval times (focus on latest version)	Database system guarantees	SQL as the declarative programming language

```
CREATE TABLE page (page_id INT PRIMARY KEY, page_title TEXT, old_text DIFFTEXT);
```

Space Compression through `DiffText` Datatype

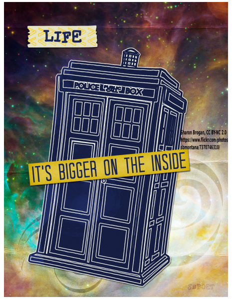
- **Question:** How to reduce the space consumption of Wikipedia article within a database system?
- **Solution:** SQL datatype, that compresses text by avoiding redundancy

```
CREATE TABLE wikidiff (title text, content difftext);
INSERT INTO wikidiff (SELECT 'example', BUILD('first', 'first␣version', 'second␣version'));
SELECT GET_CURRENT_VERSION(difftext) FROM wikidiff;
```

UMBRA

Umbra Integration

SQL Integration



Evaluation

Umbra Integration

Umbra Integration

$D_{T_2 \rightarrow T_1}$	$D_{T_3 \rightarrow T_2}$	$\mathbf{T_3}$	$D_{T_5 \rightarrow T_4}$	$\mathbf{T_5}$

Figure: Chain of diffs, every third version a complete snapshot (bold).

- Umbra: code-generating database system with in-memory performance
- offers SQL datatype for flexible sized strings
- DiffText datatype based on this datatype for variable length data
- latest version as a snapshot followed by backward deltas
- snapshots inbetween for efficient retrieval time

Umbra Integration

- Umbra: code-generating database system with in-memory performance
- offers SQL datatype for flexible sized strings
- DiffText datatype based on this datatype for variable length data
- latest version as a snapshot followed by backward deltas
- snapshots inbetween for efficient retrieval time

$D_{T_2 \to T_1}$	$D_{T_3 \to T_2}$	$\mathbf{T_3}$	$D_{T_5 \to T_4}$	$\mathbf{T_5}$

Figure: Chain of diffs, every third version a complete snapshot (bold).

```
struct DiffTextRepresentation {
   uint32_t currentOffset;     // Offset of current version in data section
   uint32_t currentLength;     // Length of current version
   uint32_t arraySize;         // The size of the version pointer's array
   uint16_t diffsToFullCount;  // Counter of diffs until next full version
   struct {                    // Array of pairs, pointing into the data section
      uint32_t offset;         // Offset of version in data section
      bool full;               // Is this a full version?
      uint32_t patchStart;     // Start of patch
      uint32_t patchEnd;       // End of patch
   } versionPointers[];
   // Data section follows this struct immediately
};
```

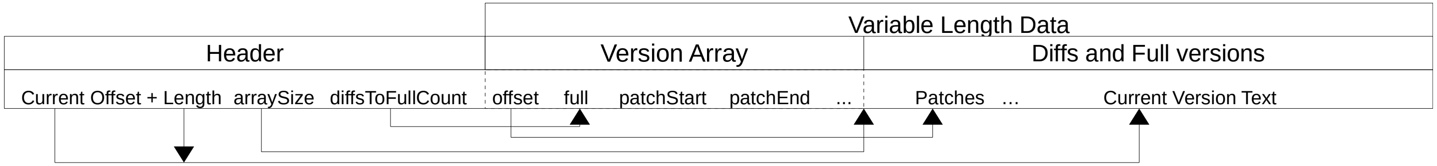


Figure: Structure of a DiffText tuple.

SQL Integration

SQL Integration: Operations

- `BUILD(`$T_1, \ldots, T_N$`)`: creation of a DiffText object out of N versions.
- `APPEND(`$D, T_1, \ldots, T_N$`)`: appending N versions to an existing object.
- `SET_CURRENT_VERSION(`D, T`)`: adding a new version, equal to `APPEND(`D, T`)`.
- `GET_VERSION_BY_ID(`D, N`)`: extract version N.
- `GET_CURRENT_VERSION(`D`)` returns the latest version, equal to `GET_VERSION_BY_ID(`D, N`)` (#Versions=N).
- `EXPAND(`D, M, N): unary database operator for extracting versions M to N.

SQL Integration: Example

```
CREATE TABLE example (value DiffText); INSERT INTO example (SELECT BUILD('first'));
```

currentOffset	0
currentLength	5
arraySize	0
diffsToFullCount	0

Data	First

SQL Integration: Example

```
CREATE TABLE example (value DiffText); INSERT INTO example (SELECT BUILD('first'));
UPDATE example SET value=SET_CURRENT_VERSION(value,'first version');
```

currentOffset	0
currentLength	13
arraySize	1
diffsToFullCount	1

offset	0
full	*false*
patchStart	5
patchEnd	13

Data	First_Version

SQL Integration: Example

```
CREATE TABLE example (value DiffText); INSERT INTO example (SELECT BUILD('first'));
UPDATE example SET value=SET_CURRENT_VERSION(value,'first version');
UPDATE example SET value=SET_CURRENT_VERSION(value,'second version');
```

currentOffset	5
currentLength	14
arraySize	2
diffsToFullCount	2
offset	0
full	*false*
patchStart	5
patchEnd	13
offset	0
full	*false*
patchStart	0
patchEnd	6
Data	FirstSecond_Version

SQL Integration: Example

```
INSERT INTO example (SELECT BUILD('first', 'first␣version', 'second␣version'));
```

currentOffset	5
currentLength	14
arraySize	2
diffsToFullCount	2
offset	0
full	*false*
patchStart	5
patchEnd	13
offset	0
full	*false*
patchStart	0
patchEnd	6
Data	FirstSecond_Version 0123456789012345678

```
>SELECT GET_CURRENT_VERSION(value) FROM example;
Second_Version
```

SQL Integration: Example

```
INSERT INTO example (SELECT BUILD('first', 'first␣version', 'second␣version'));
```

currentOffset currentLength arraySize diffsToFullCount	5 14 2 2
offset full patchStart patchEnd	0 *false* 5 13
offset full patchStart patchEnd	0 $\Rightarrow$ Patch: $[0,5)$ *false* 0+5 6+5
Data	First~~Second~~_Version 0123456789012345678

```
>SELECT GET_CURRENT_VERSION(value) FROM example;
Second_Version
 >SELECT GET_VERSION_BY_ID(value,2) FROM example;
First_Version
```

SQL Integration: Example

```
INSERT INTO example (SELECT BUILD('first', 'first version', 'second version'));
```

currentOffset currentLength arraySize diffsToFullCount	5 14 2 2
offset full patchStart patchEnd	0 ⇒ Patch: [0,0) *false* 5 13+6
offset full patchStart patchEnd	0 *false* 0 6
Data	First~~Second_Version~~ 0123456789012345678

```
>SELECT GET_CURRENT_VERSION(value) FROM example;
Second_Version
 >SELECT GET_VERSION_BY_ID(value,2) FROM example;
First_Version
 >SELECT GET_VERSION_BY_ID(value,1) FROM example;
First
```

Evaluation


POLICE PUBLIC CALL BOX
Sharon Brogan, CC BY-NC 2.0
https://www.flickr.com/photos/
sbmontana/7370746310/
IT'S BIGGER ON THE INSIDE

Evaluation: Space Consumption

- **System:** Ubuntu 18.04 LTS, Intel Xeon CPU E5-2660 v2 processor, 2.20 GHz (20 cores), 256 GiB DDR4 RAM
- **Data:** Wikipedia dumps from 09/01/2019 (pages 971896 to 972009), Size of XML file: about `120` MB
- **Observation:** Good compression when storing every 20th version as a snapshot

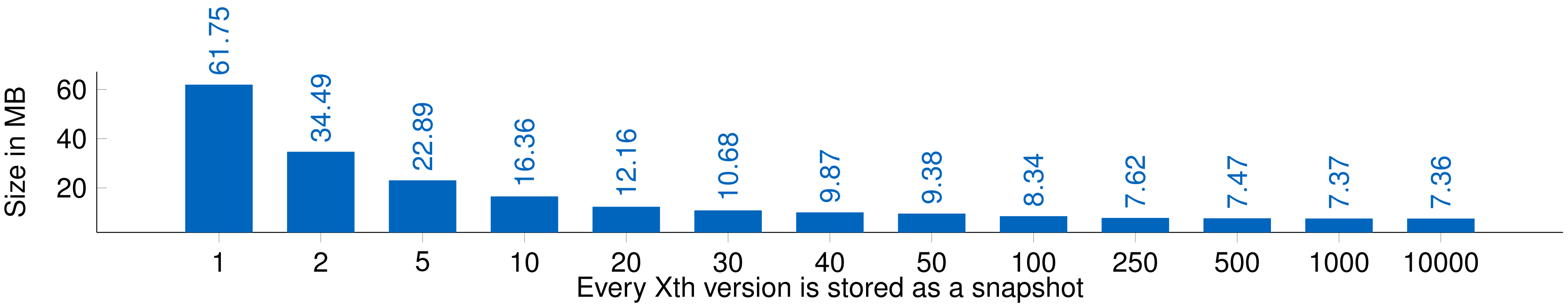


Figure: Memory consumption depending on the frequency of stored snapshots.

Evaluation: `X=50`

Listing 1: Diff

```
INSERT INTO t (text) VALUES (BUILD(T1, ..., TN));
SELECT EXPAND(text, 1, N) from t;
```

Listing 2: Snapshot

```
INSERT INTO t (rev_id, text) VALUES (1, T1), ..., (N, TN);
SELECT text from t;
```

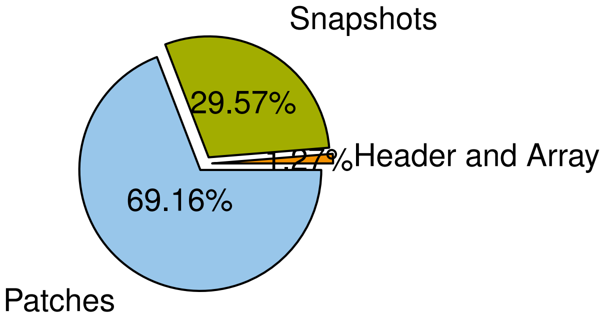


Figure: Fractions.

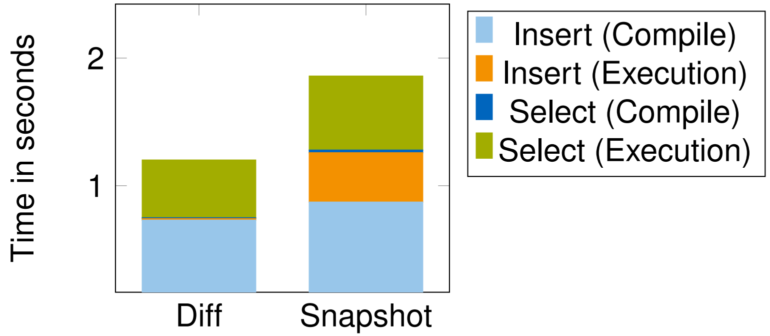


Figure: Each version as a single snapshot or in one DiffText object.

- **Observation:** DiffText datatype faster for insertion and retrieval as less operations are required.
- Parsing time for text input part of compile time for insertion.

Conclusion and Future Work

```
CREATE TABLE wikidiff (title text, content difftext);
INSERT INTO wikidiff (SELECT 'example', BUILD('first', 'first␣version', 'second␣version'));
SELECT GET_CURRENT_VERSION(difftext) FROM wikidiff;
```

Conclusion

- SQL text data type for compression
- focus: retrieval times, not build time
- achieved compression rate of about 88 % (62 MB each snapshot within the database, 7.36 MB when storing the differences for $X = 10000$)

Future Work

- investigate on algorithms with stronger compression
- optimise build times
- store older versions on background memory
- combine with table versioning

Thank you for your attention!