A Concurrent Persistent Functional Language

Towards Practical Functional Databases

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IFL 2012, Oxford, UK
1 September, 2012

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Isolated: It seems as if the transactions are executed one by one (serializability and recoverability).

Durable: The effect of a transaction is permanent.

Transaction Processing Systems

Examples

- Banking

Transaction Processing Systems

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- Banking
- Ticket reservation

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- Inventarisation systems

Transaction Processing Systems

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- Banking
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- Inventarisation systems
- Websites

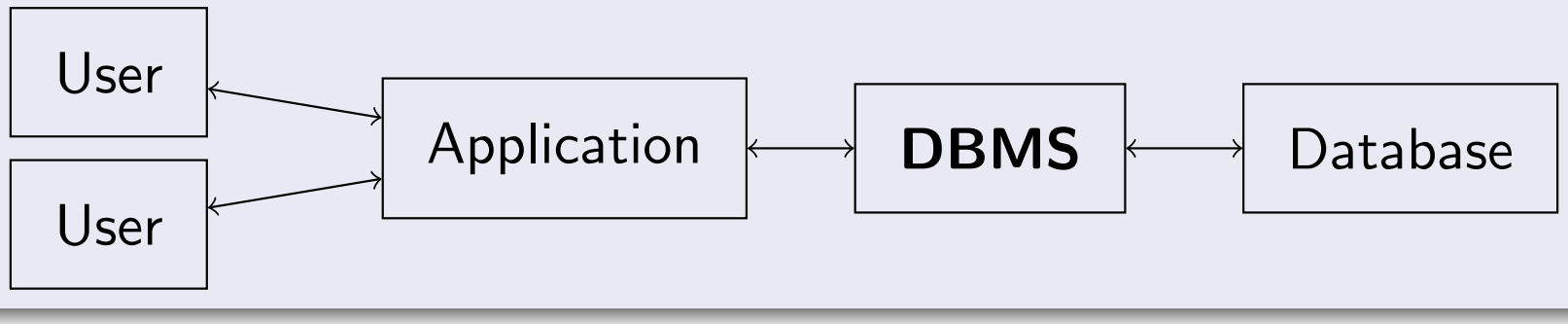
Challenges

Thousands of simultaneous users:

- Transactions have to be processed correctly.
- Everyone wants a quick response.
- We want to handle a lots of data.

Current Approach

Traditional Architecture



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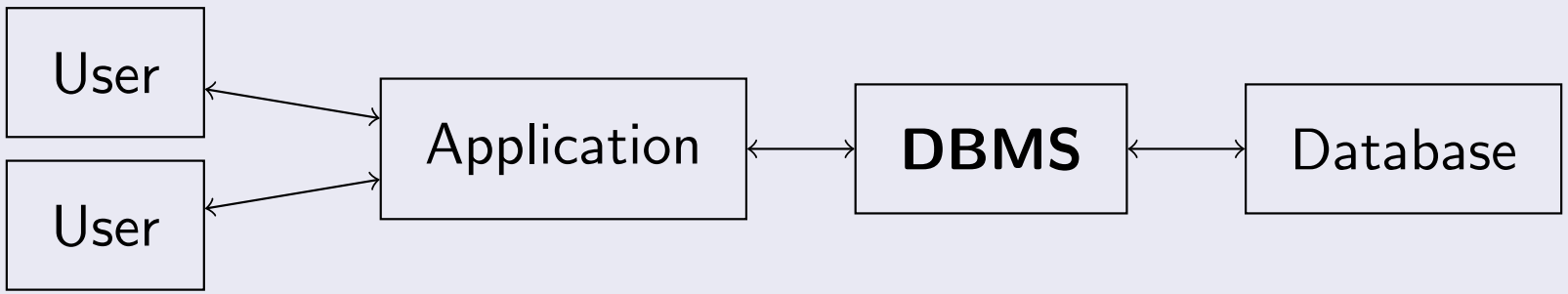

Database Management System

- Optimised to handle large amounts of data.

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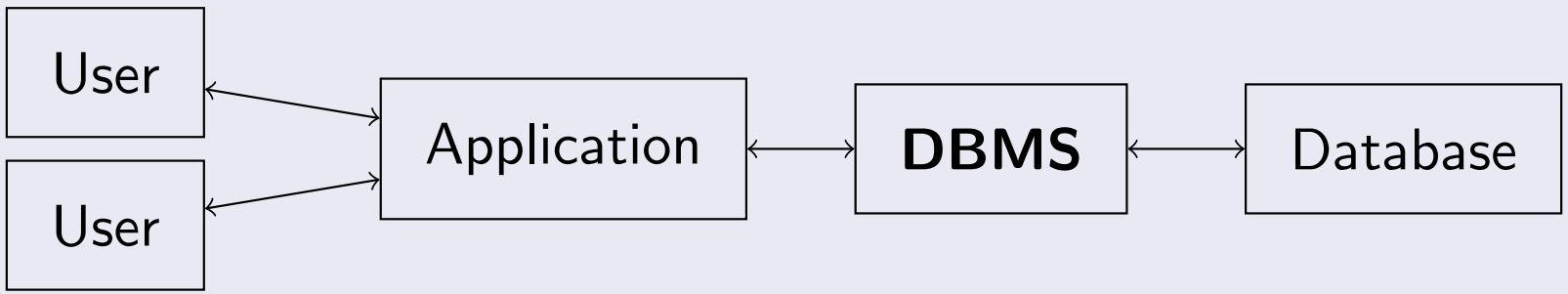

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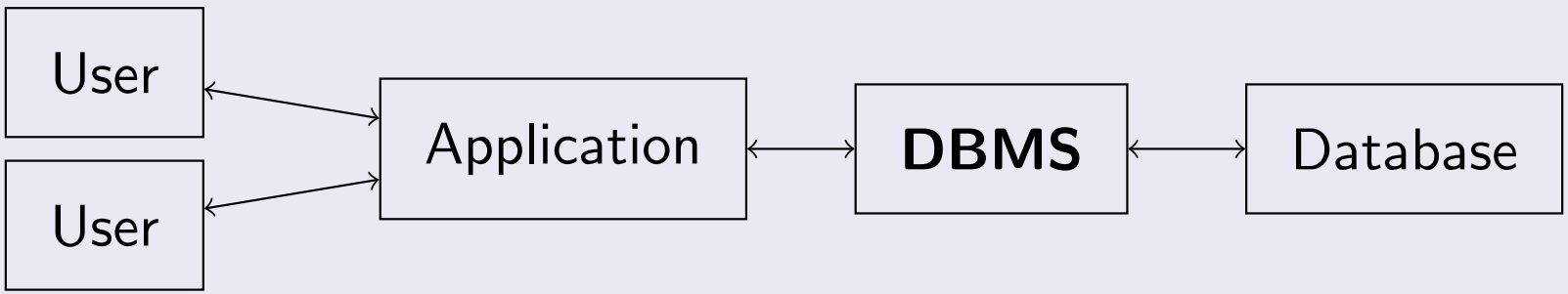

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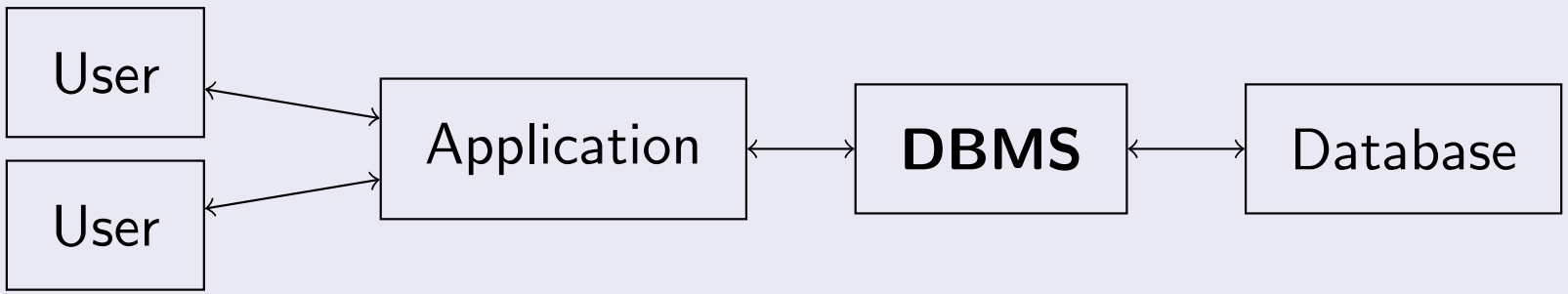

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Most DBMS's only partially support isolation of transactions due to efficiency reasons.

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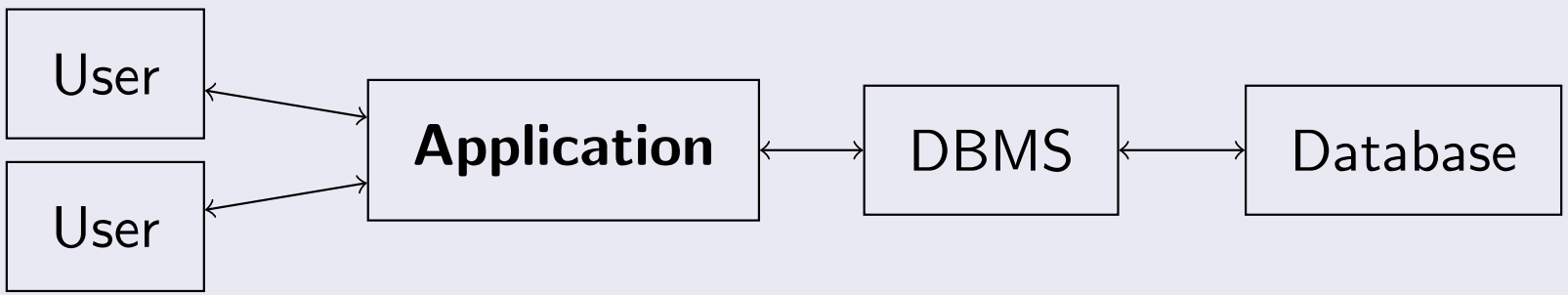

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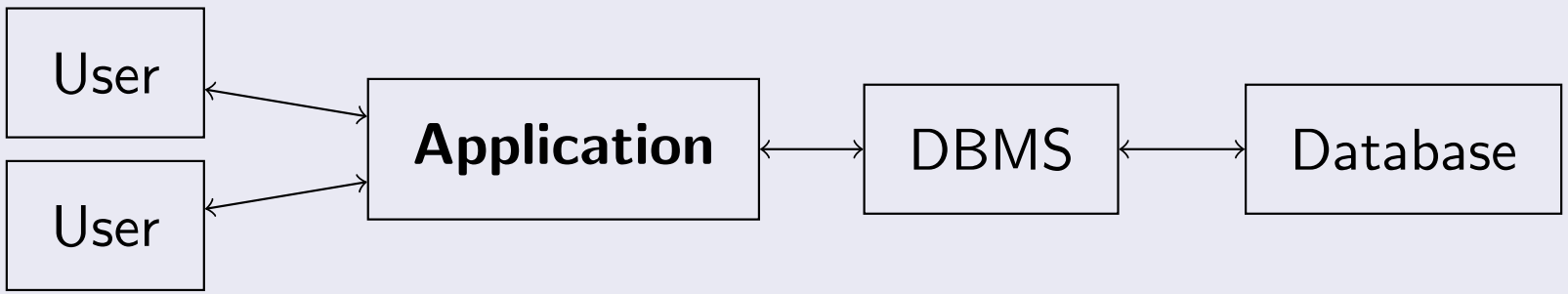

Application

- Interface to the outside world.

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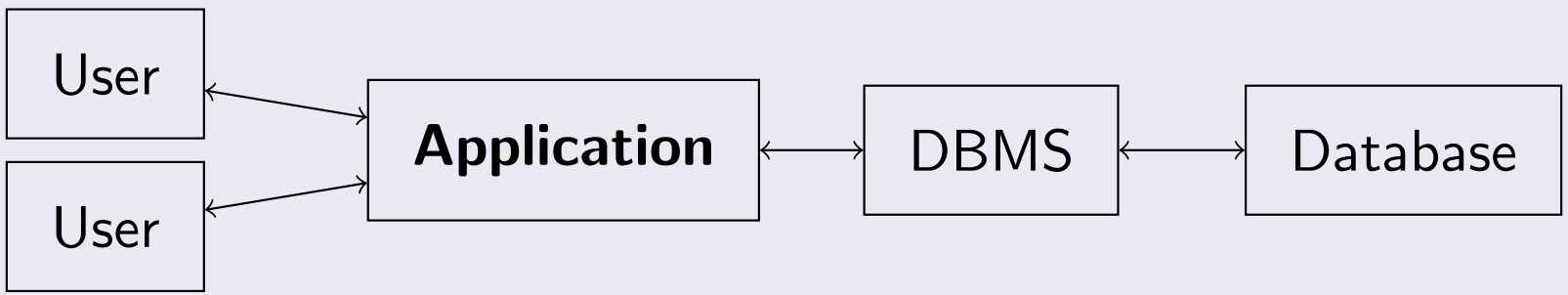

Application

- Interface to the outside world.
- Can enforce additional security constraints.

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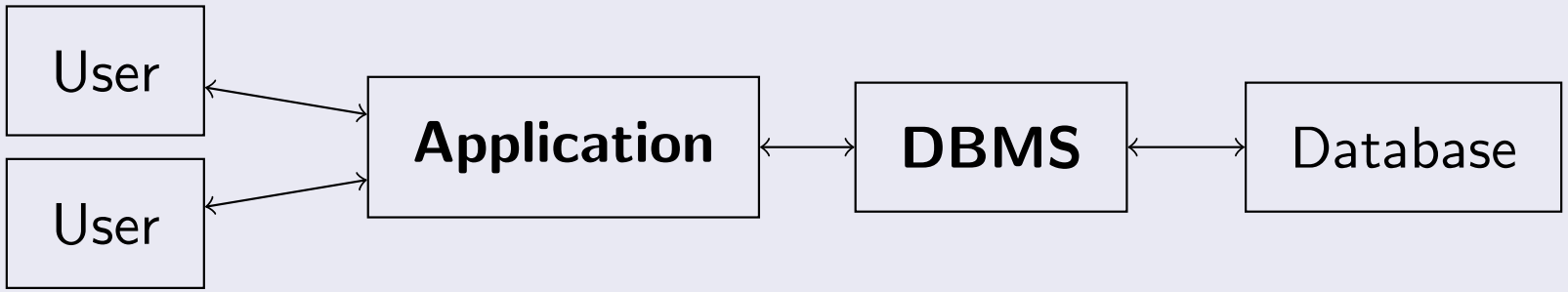

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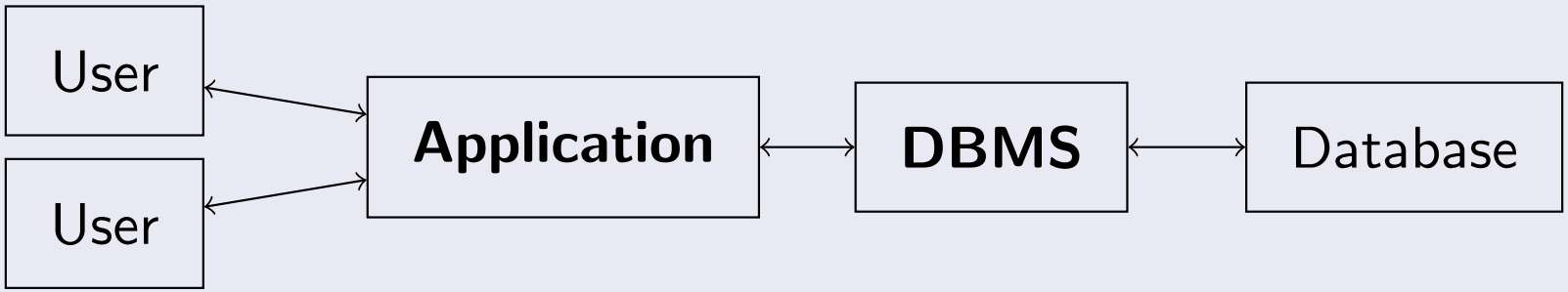

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- Application and DBMS have different type system.

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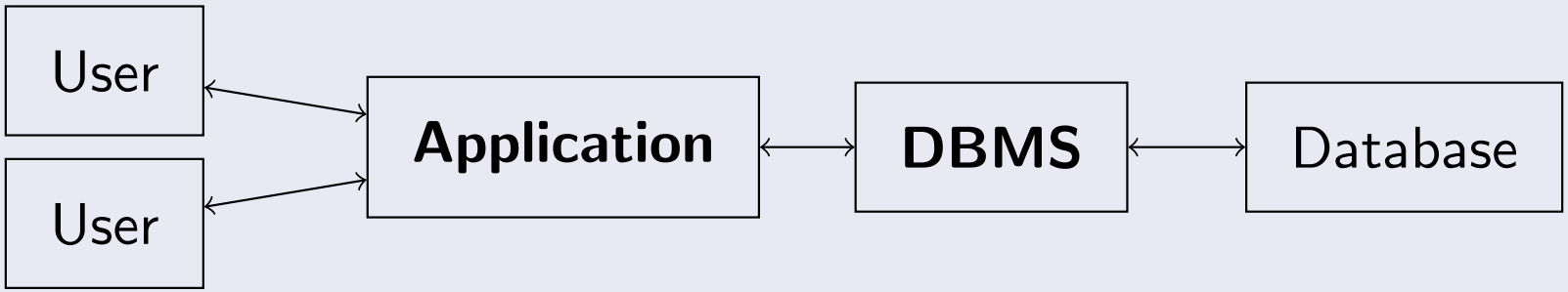

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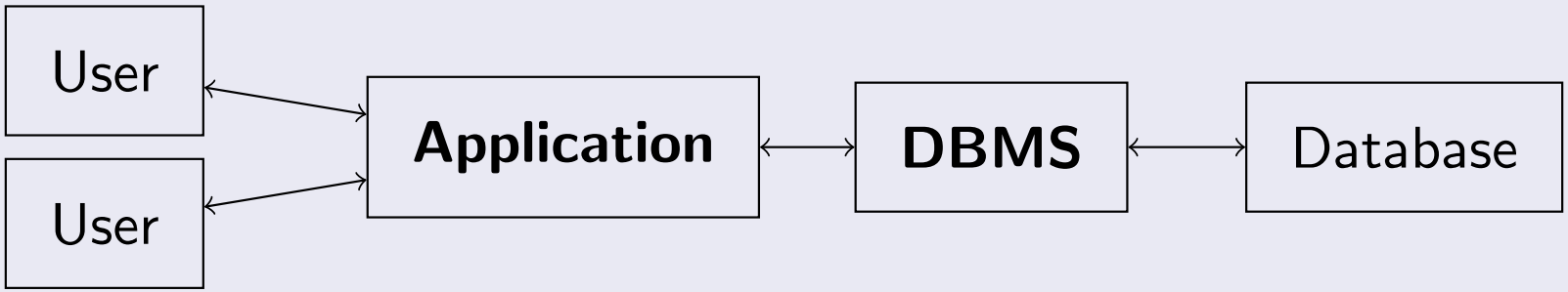

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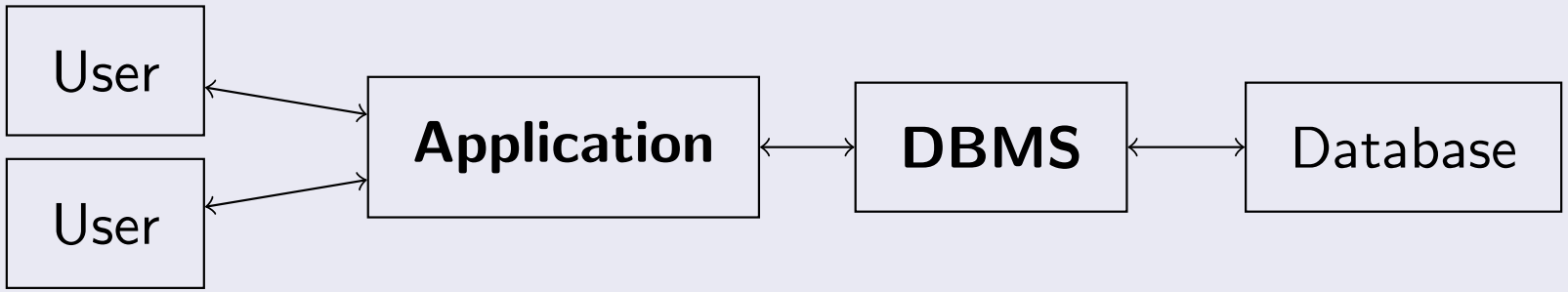

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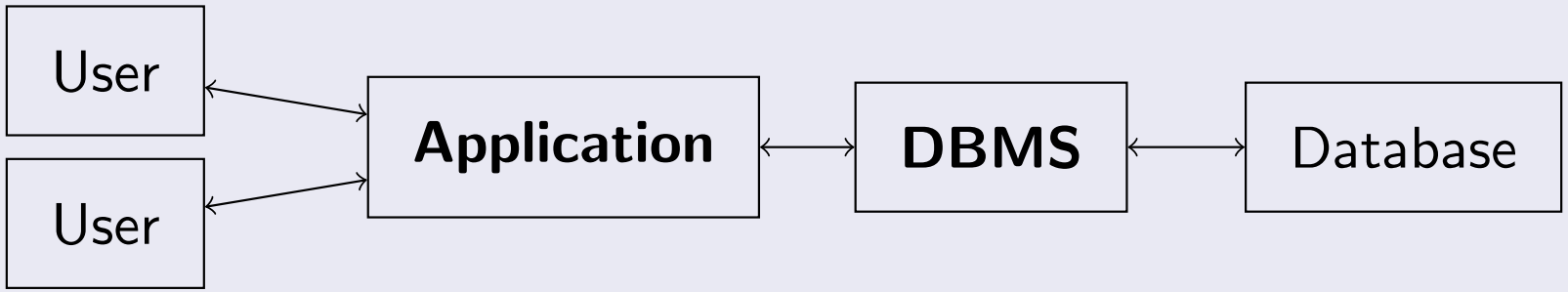

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- DBMS's are vulnerable to command injection attacks.
- System as a whole is difficult to verify.

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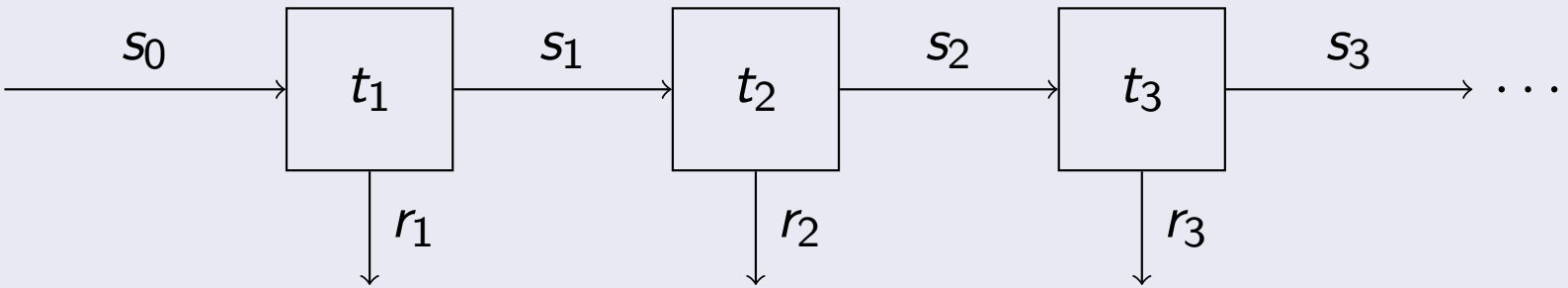

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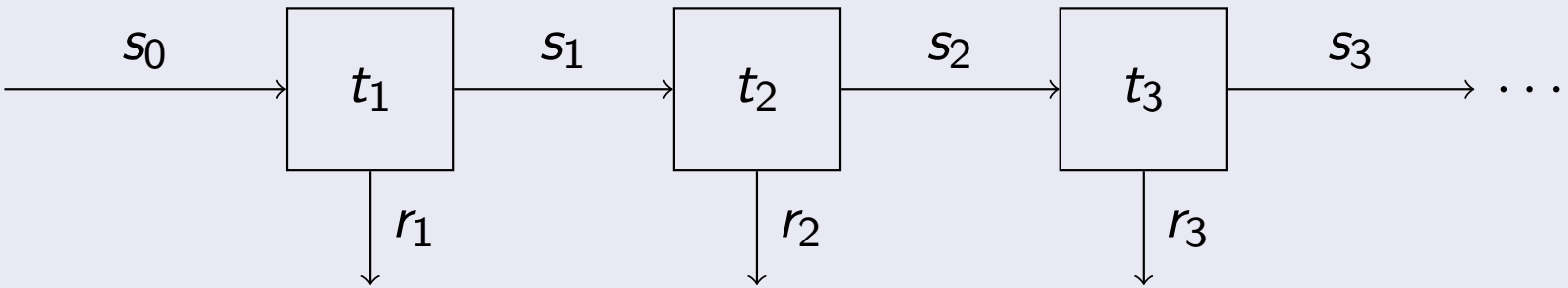

Correctness (ACID)

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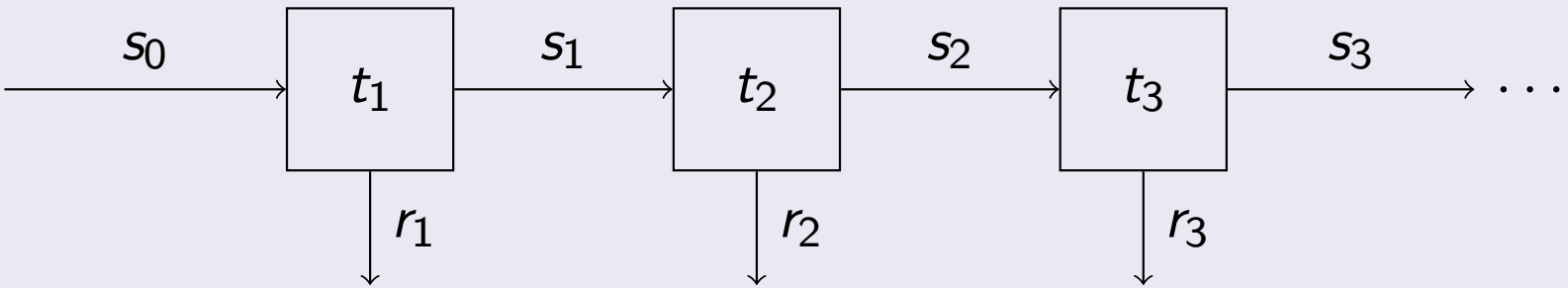

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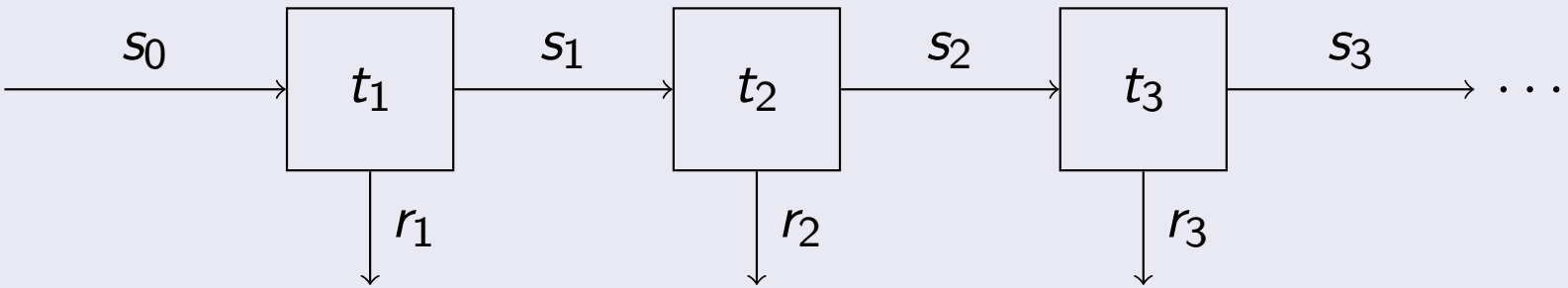

Correctness (ACID)

- Atomicity and isolation hold trivially for *total* transactions.
- A transaction must enforce consistency rules.
- Implementation can easily support durability.

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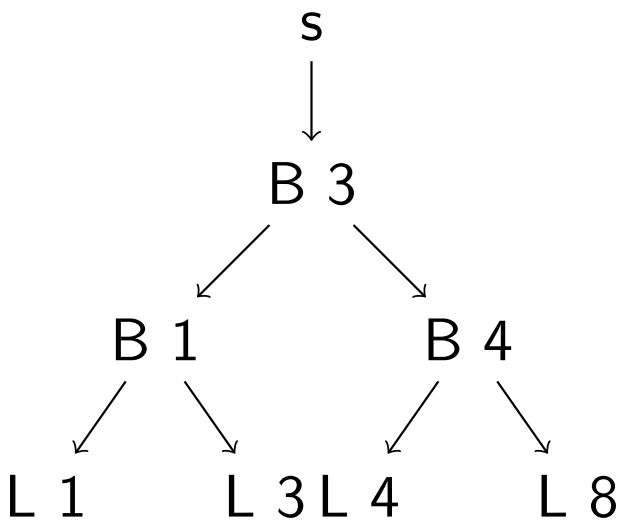

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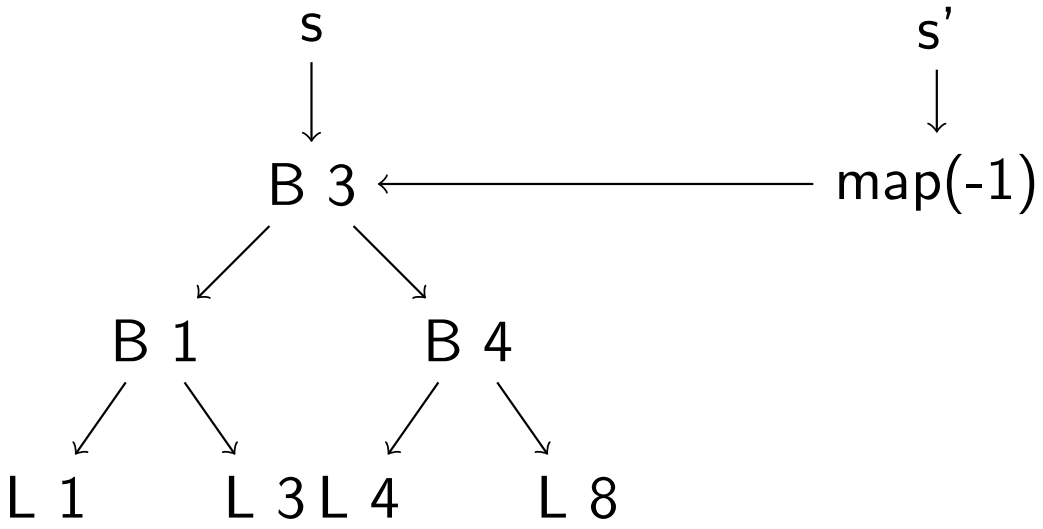

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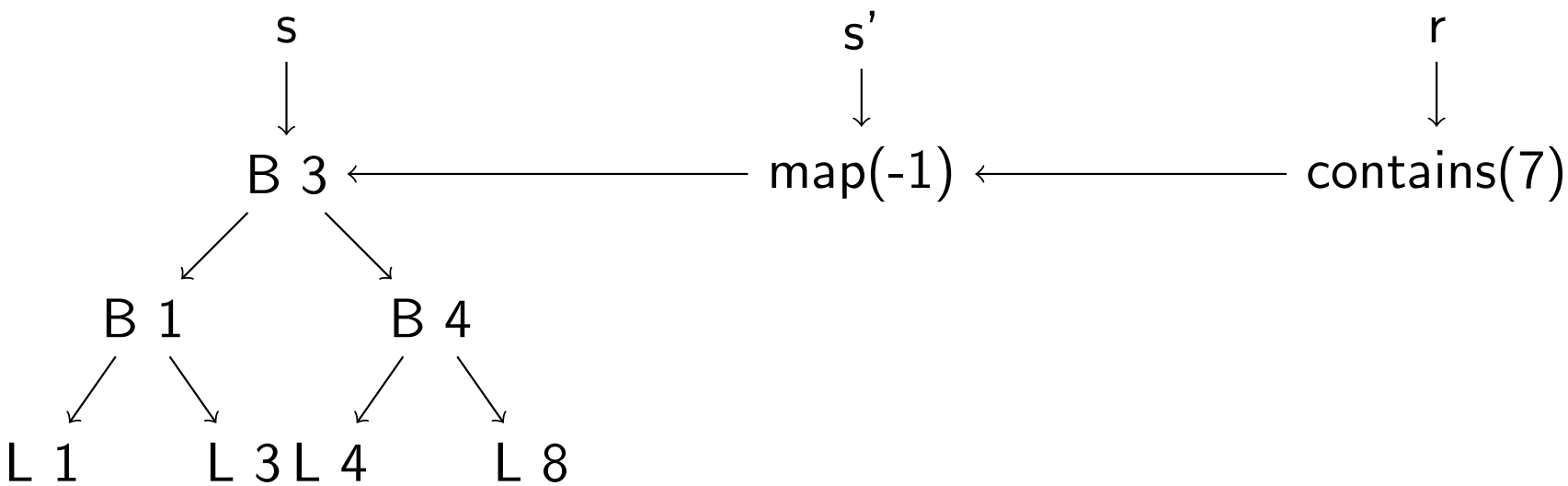

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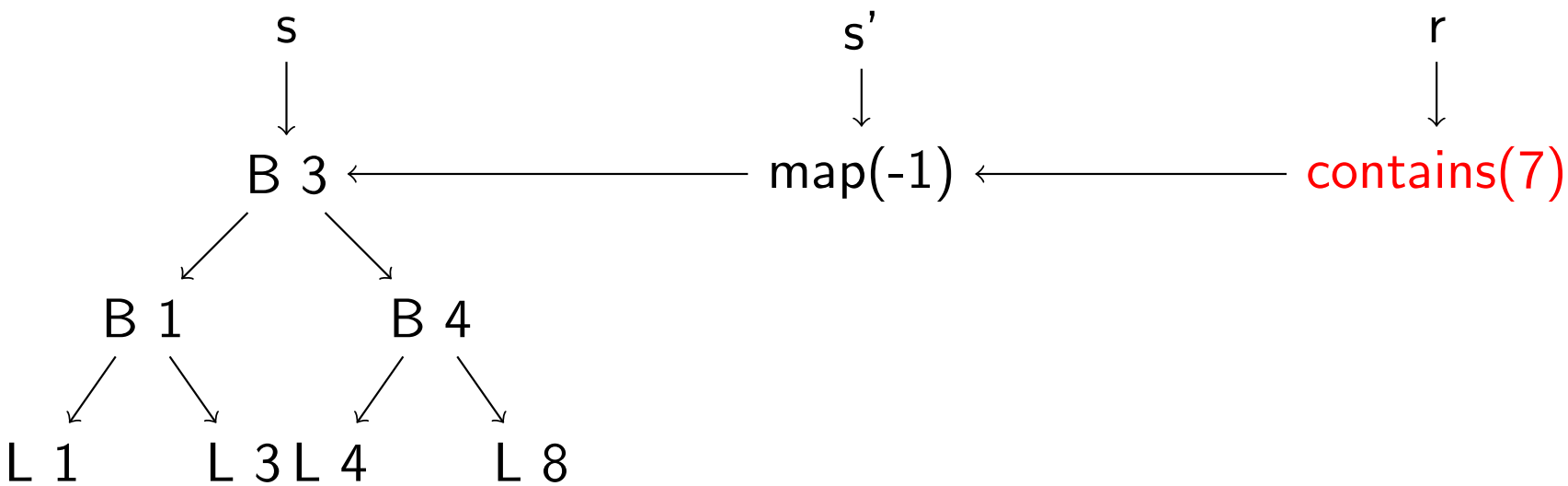

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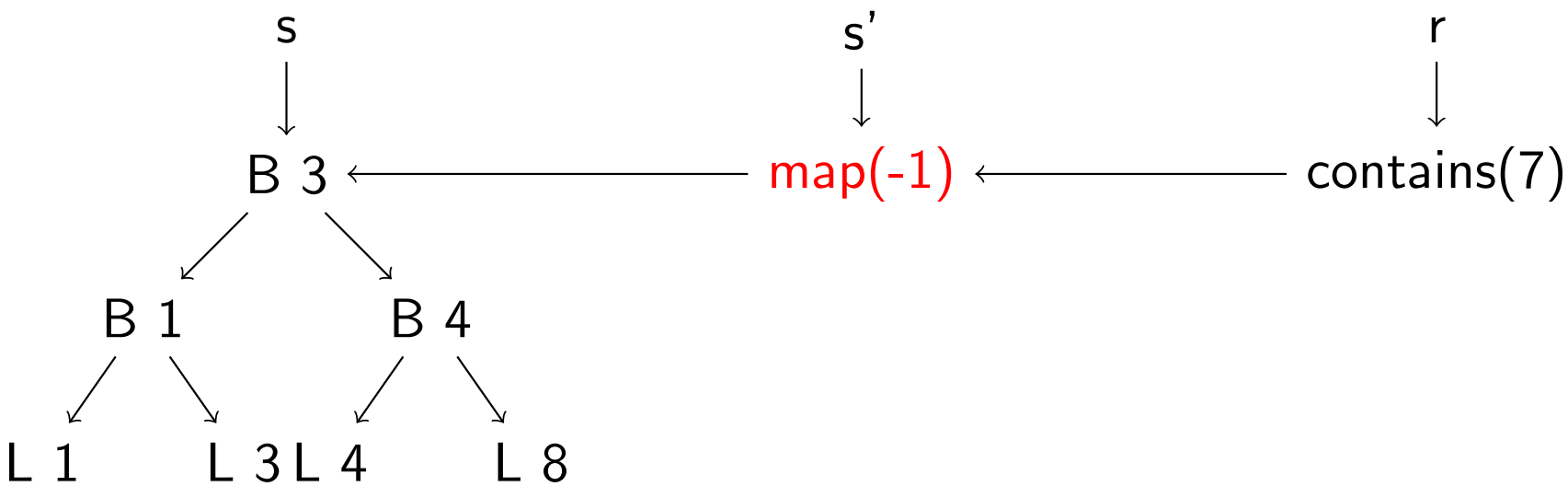

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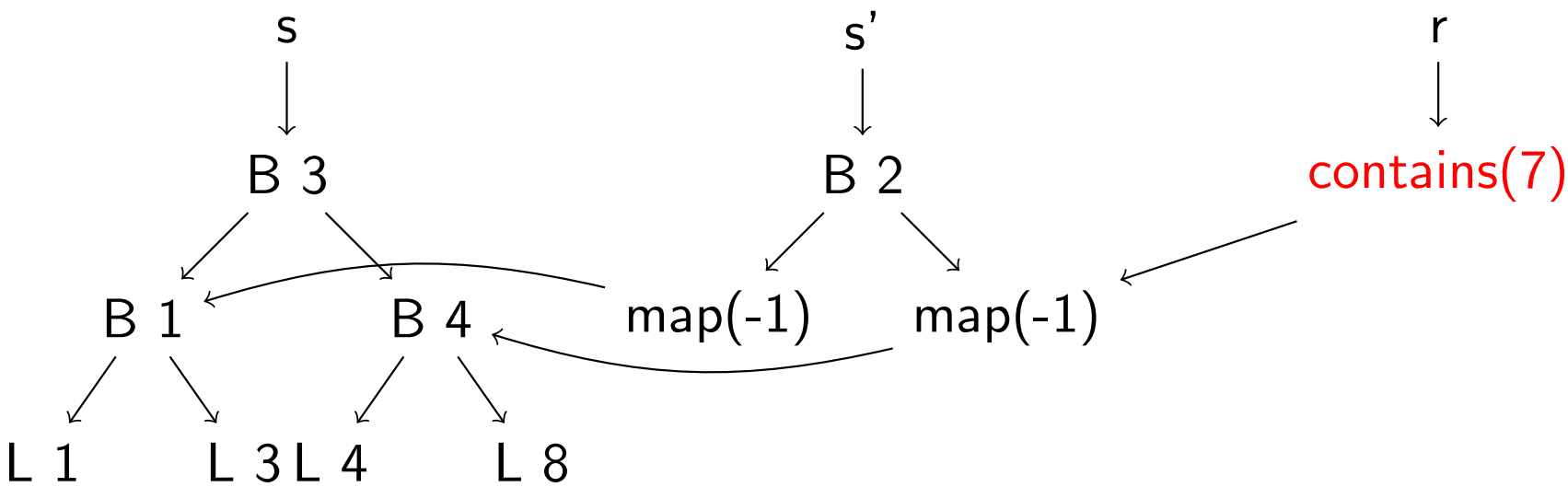

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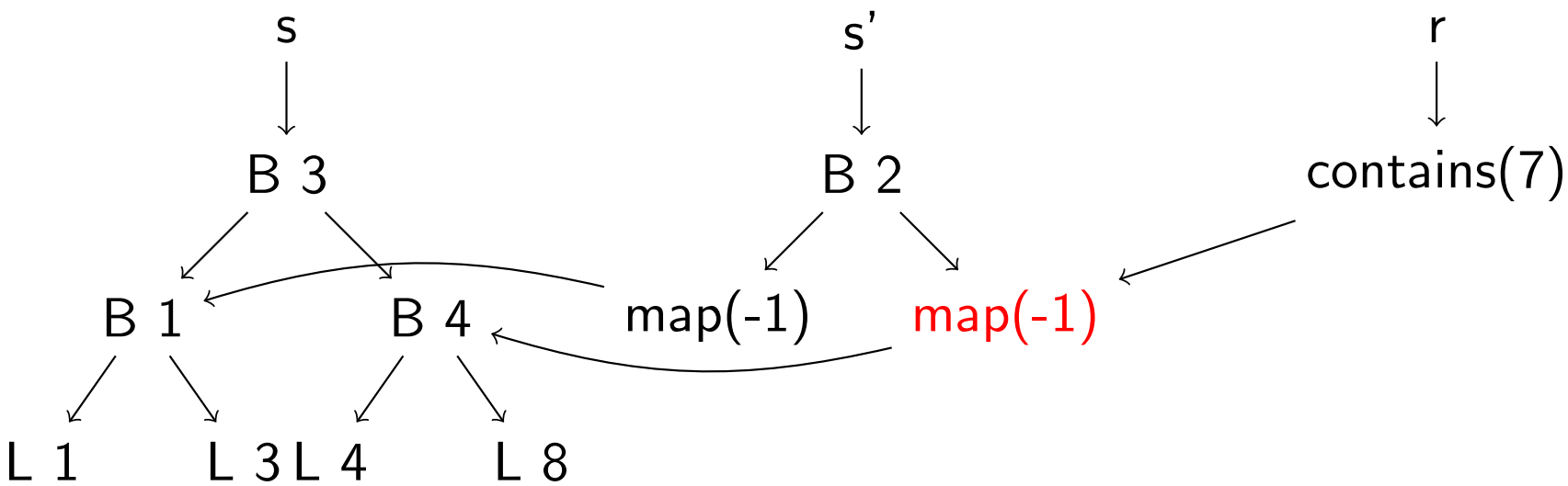

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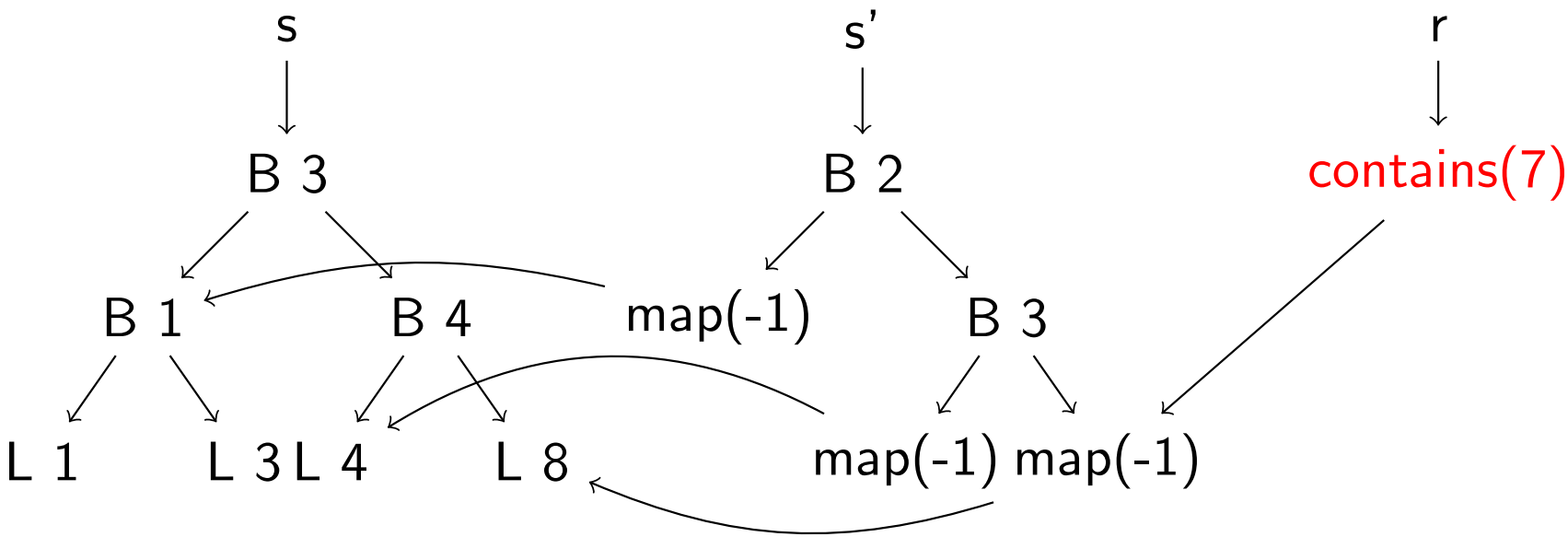

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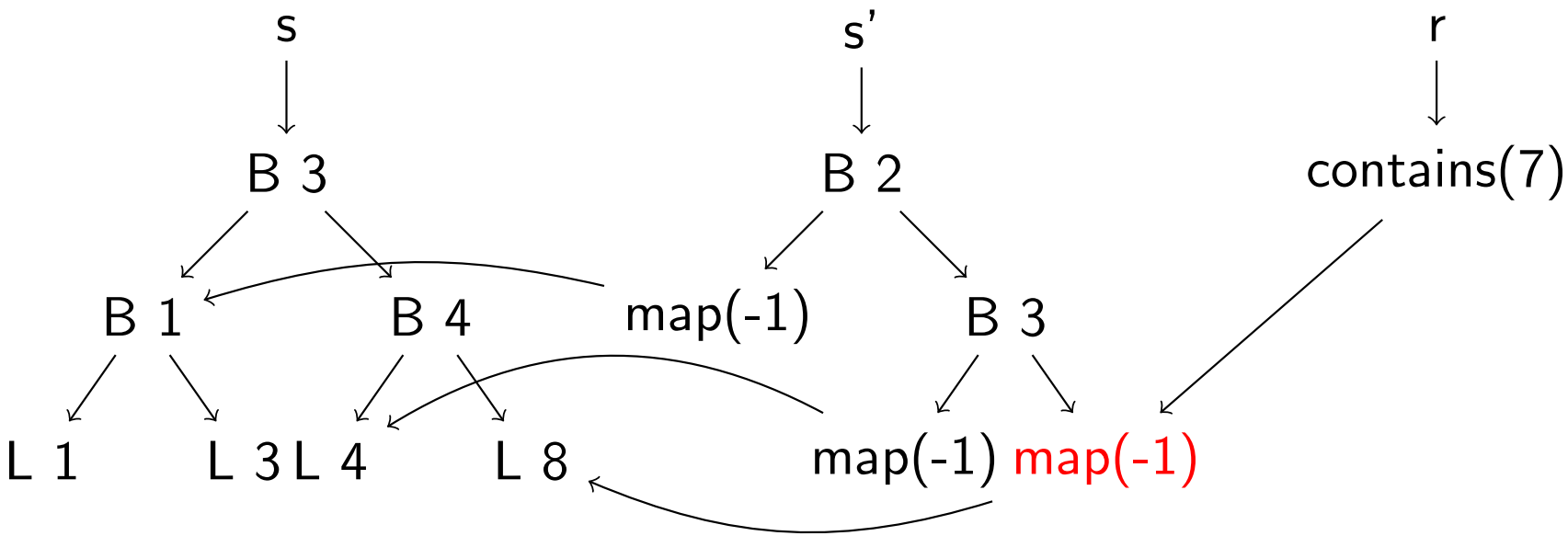

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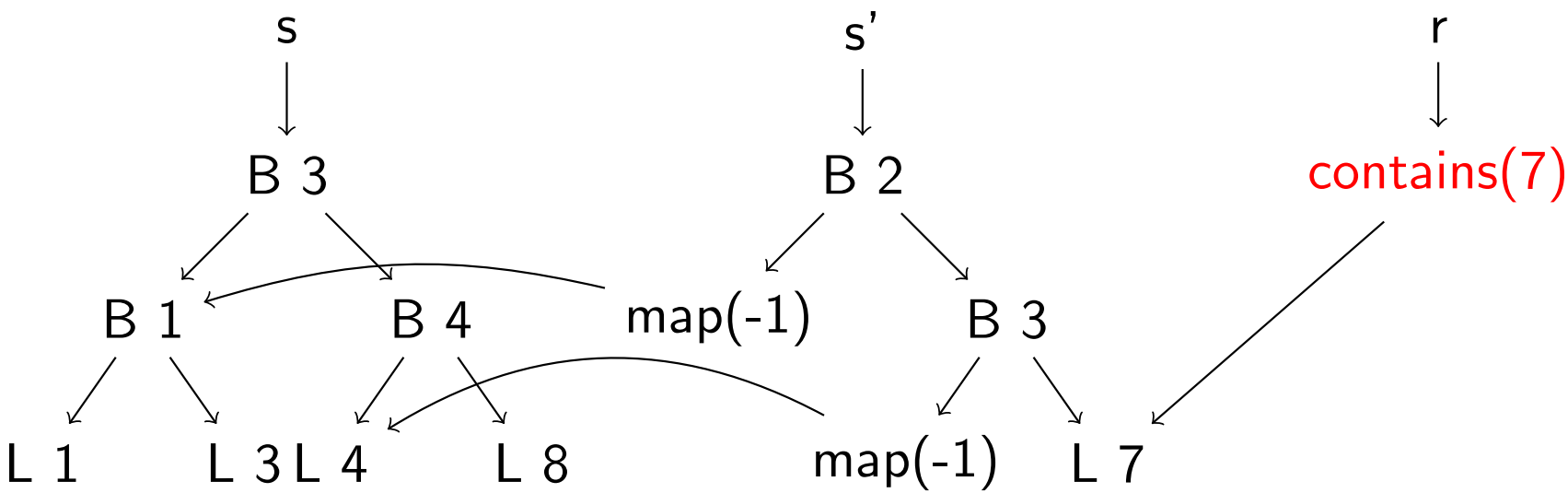

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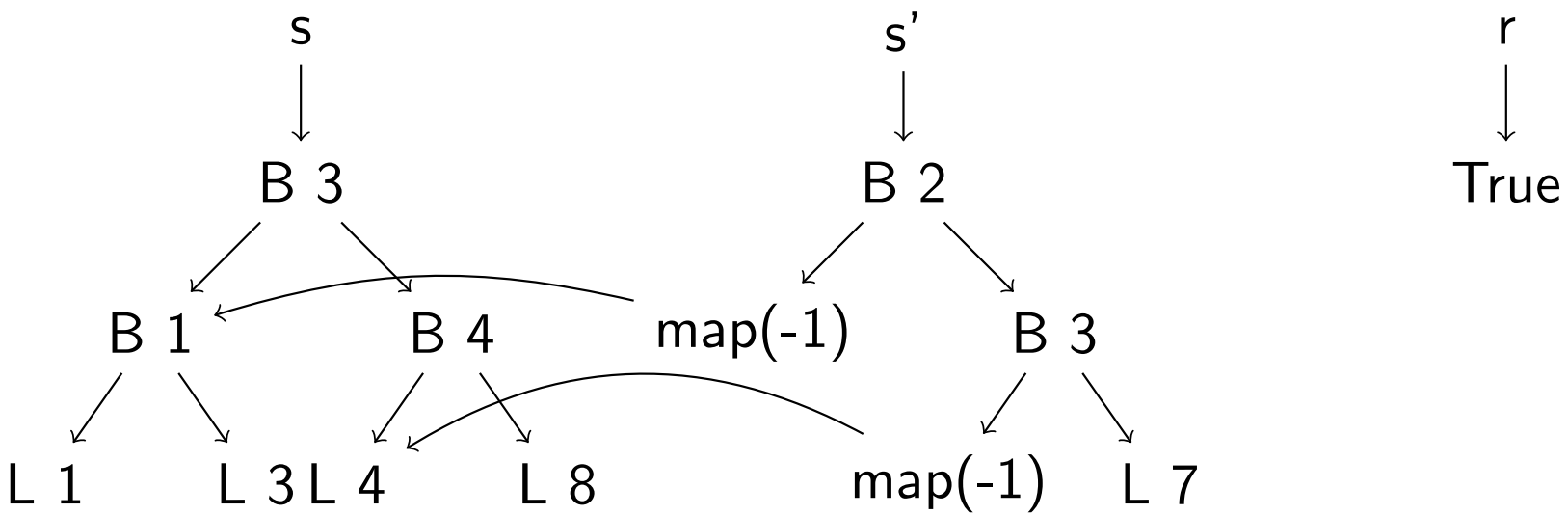

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- *Result variable*: `result`

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t_3: `result = length names` $\rightarrow r_3 : 3$

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Prototype

We implemented a prototype in Java.

Implementation - Graph Reduction

Graph Reduction

Based on template instantiation:

- For every binding we have a template graph.

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Adaptations to support dynamic bindings

We resolve references to template graphs statically.

- Templates are anonymous, and can be garbage collected.

Implementation - Graph Reduction

Concurrent and Parallel Graph Reduction

We use multiple reduction threads to:

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Concurrent and Parallel Graph Reduction

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Reduction threads:

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- Take random reduction "paths".

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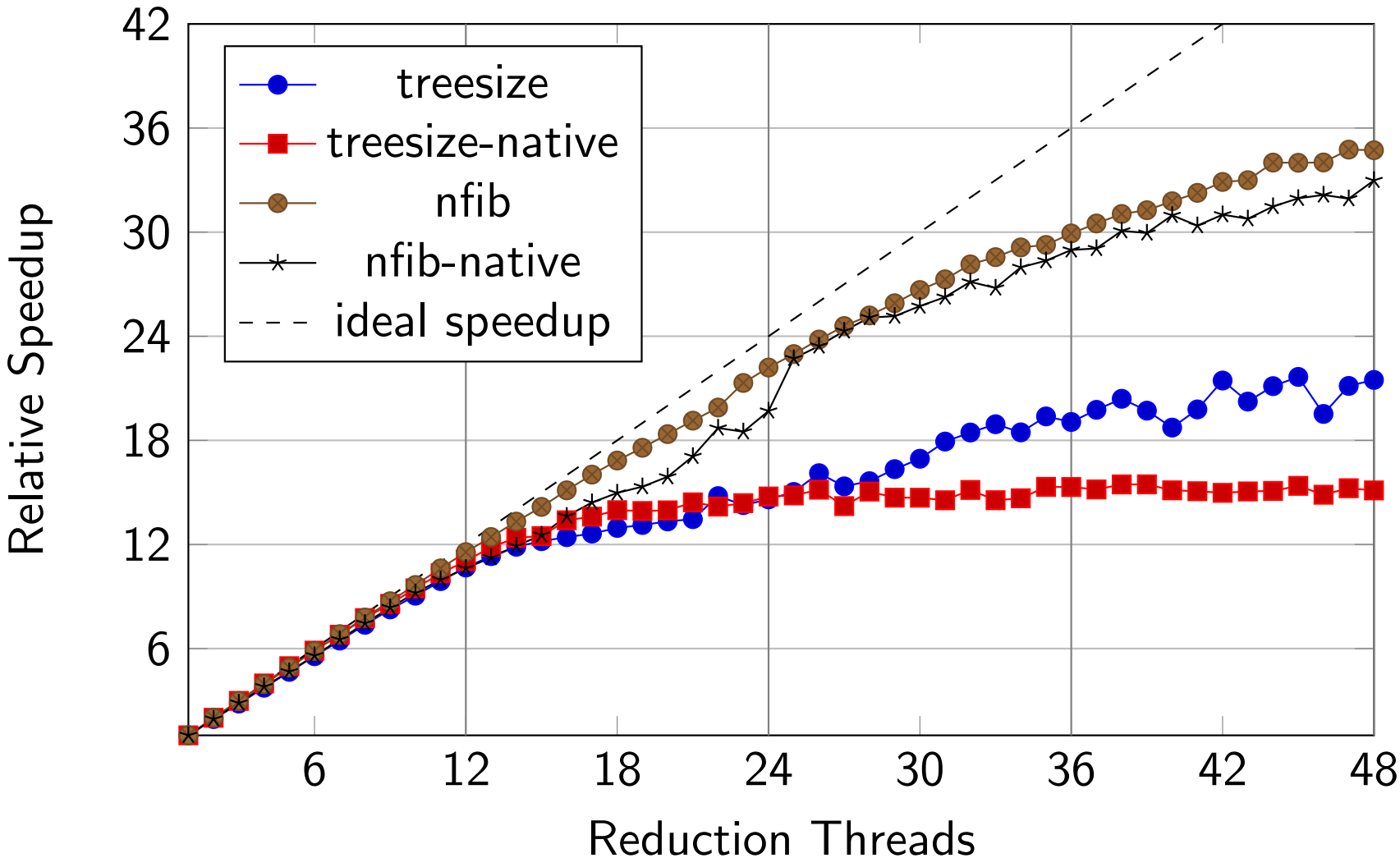
Randomisation

- We reduce strict-function arguments in a random order:
- We reduce data elements in a random order.

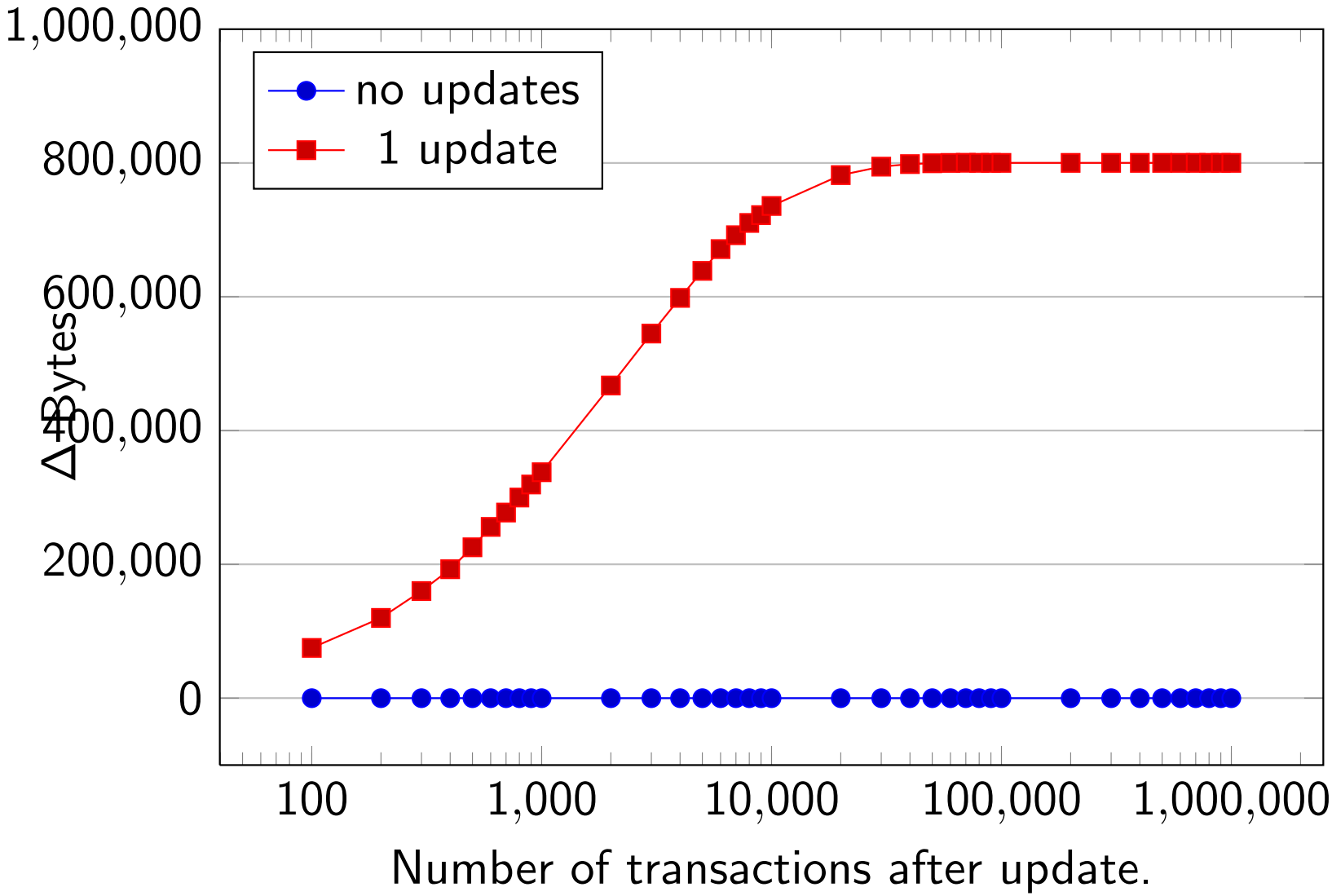
Evaluation


Relative Speedup
Reduction Threads
treesize
treesize-native
nfib
nfib-native
ideal speedup
6
12
18
24
30
36
42
48

Evaluation

	treesize	treesize-native	nfib	nfib-native
Serial	2666 ms	819 ms	3294 ms	626 ms
Parallel	3243 ms	1291 ms	4162 ms	819 ms
Overhead	21.6%	57.6%	26.4%	30.1%

Evaluation


1,000,000
800,000
600,000
400,000
200,000
0
ΔBytes
no updates
1 update
100
1,000
10,000
100,000
1,000,000
Number of transactions after update.

Persistence - Journaling

Journaling

Journaling ensures *atomicity* and *durability*:

- Transactions are logged to a journal before execution.
- If the system crashes, the state can be *recovered* by re-executing the logged transactions.

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Persistence - Snapshotting

Approach

Serialise the state to a snapshot file.

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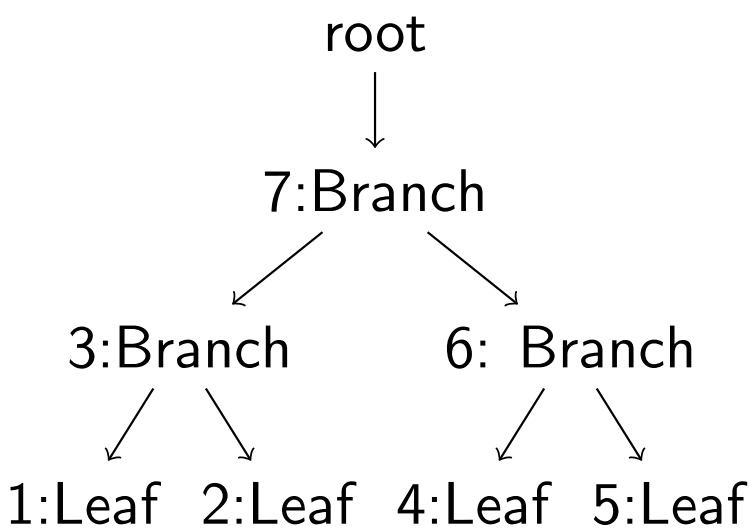
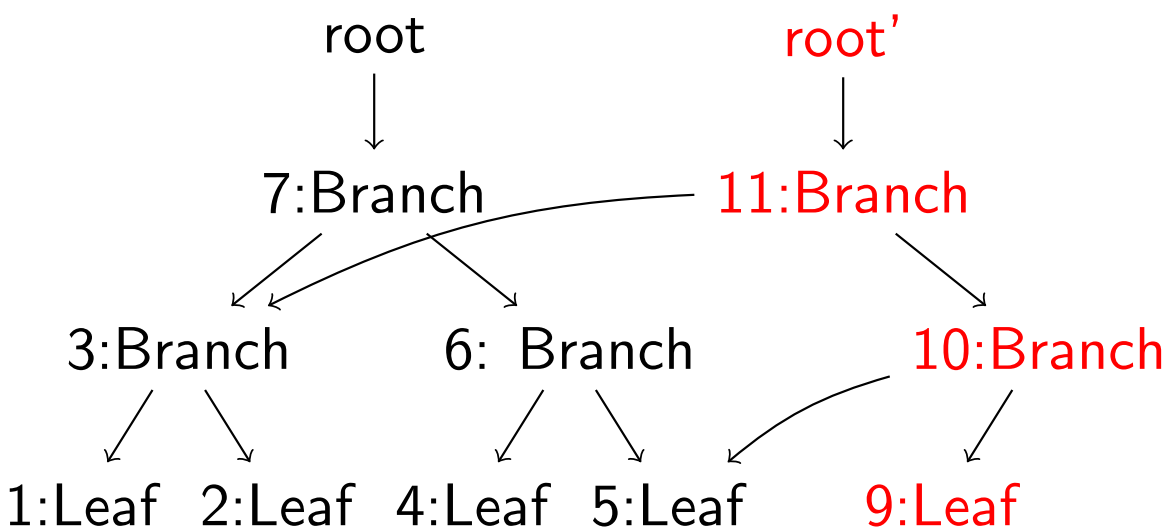
Persistence - Log-Structured Storage




```
1: Leaf
2: Leaf
3: Branch 1 2
4: Leaf
5: Leaf
6: Branch 4 5
7: Branch 3 6
8: Root 7
```

Persistence - Log-Structured Storage

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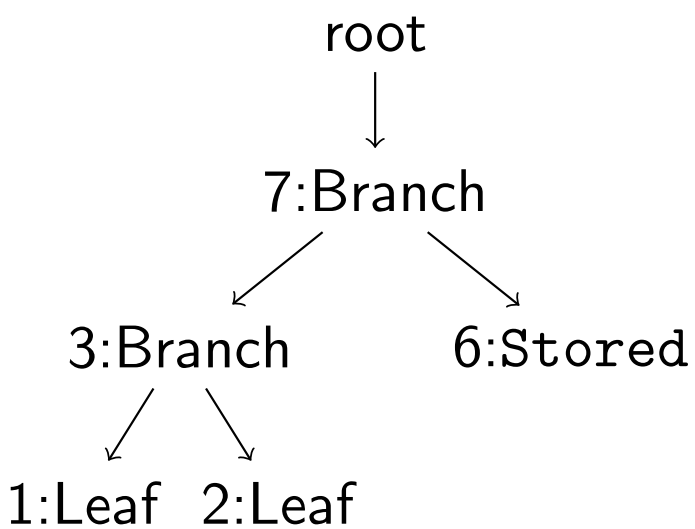
8 : Root 7
9 : Leaf
10 : Branch 9 5
11 : Branch 3 10
12 : Root 12
```

Persistence - Log-Structured Storage

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Persistence - Log-Structured Storage

Advantages

- States larger than main-memory.

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- We need to maintain locality of reference.

Persistence - Combined Approach

Approach

We split the heap into two parts:

Unreduced: Snapshotting

Reduced: Log-structured storage

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- There is no sharing in the reduced heap.

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We designed a functional language for transaction processing:

- Prototype implementation.

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We designed a functional language for transaction processing:

- Prototype implementation.
- Concurrent execution of transactions.
- Allow bindings to be created dynamically.
- New approach to parallel graph reduction.
- Investigated method for storing states in persistent memory.

Future Work

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(1) Resolving thunk leaks in lazily constructed states.

(2) Implementation of storage mechanisms.

(3) Practical use of system.

(4) Scheduling of reduction threads.