A Concurrent Persistent Functional Language

Towards Practical Functional Databases

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TeReSe, Vrije Universiteit, Amsterdam
14 November 2012

Transaction Processing Systems

Transaction Processing Systems

- Banking

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- Ticket reservation

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- Transactions can be very large.
- We want to handle a lots of data.

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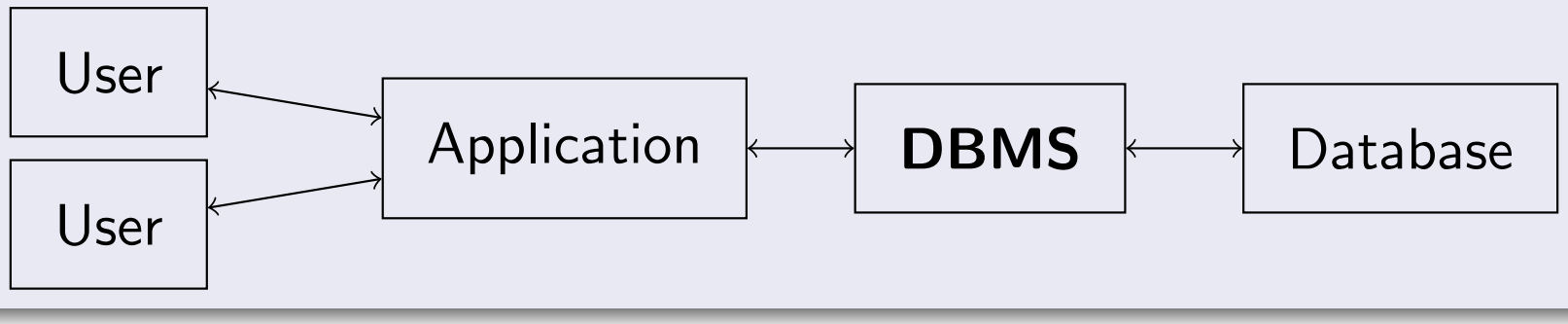
Isolated: It seems as if the transactions are executed one by one (serializability and recoverability).

Durable: The effect of a transaction is permanent.

Current Approach

Traditional Architecture



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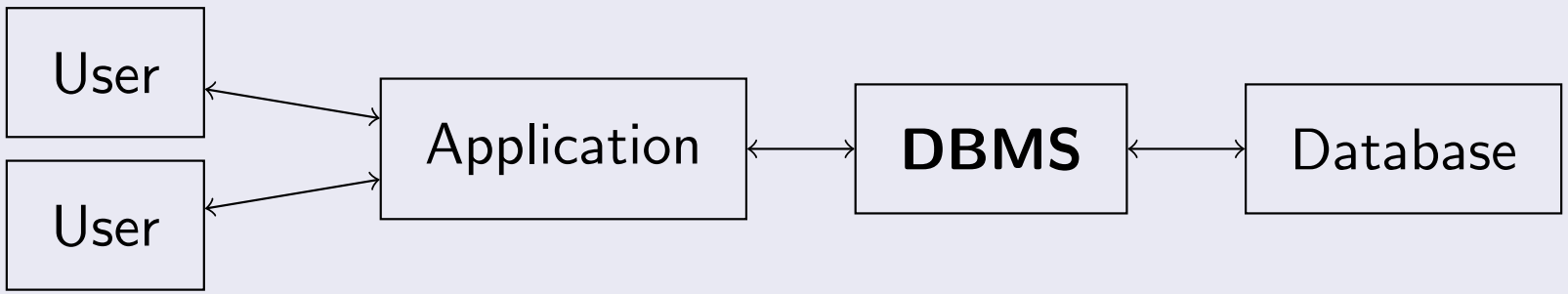

Database Management System

- Optimised to handle large amounts of data.

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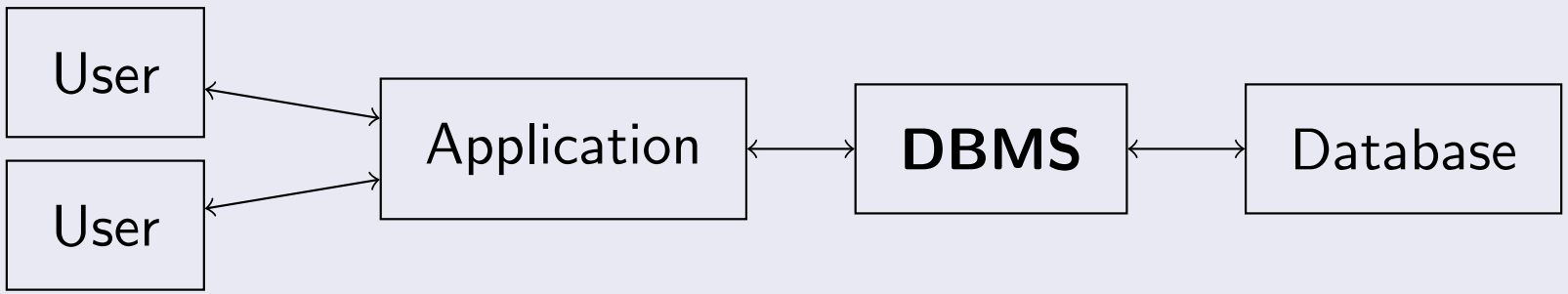

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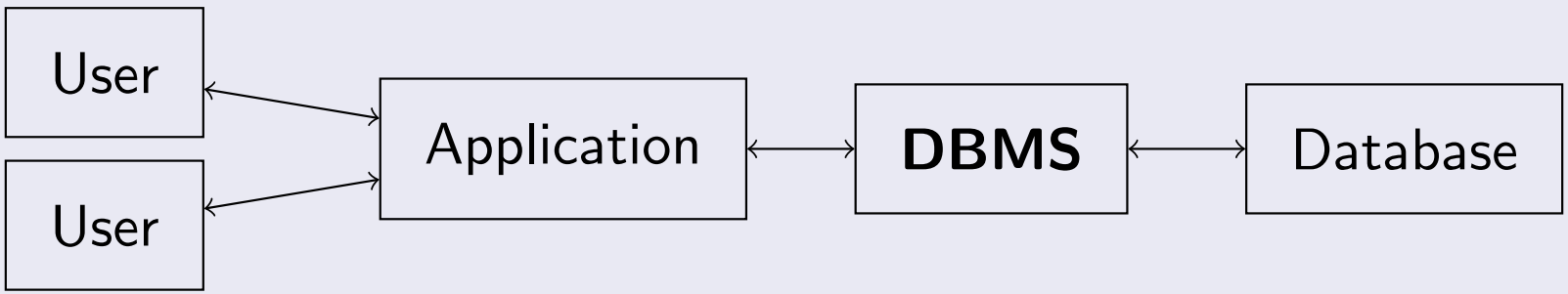

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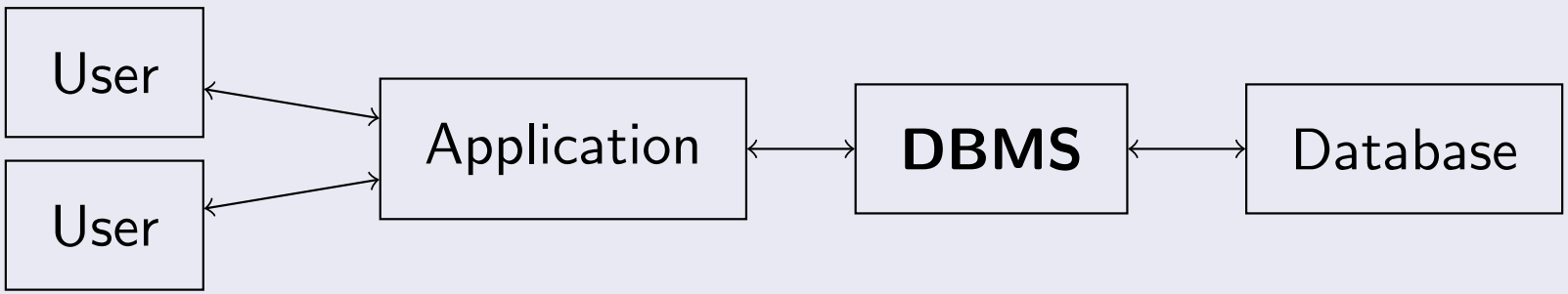

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Most DBMS's only partially support isolation of transactions due to efficiency reasons.

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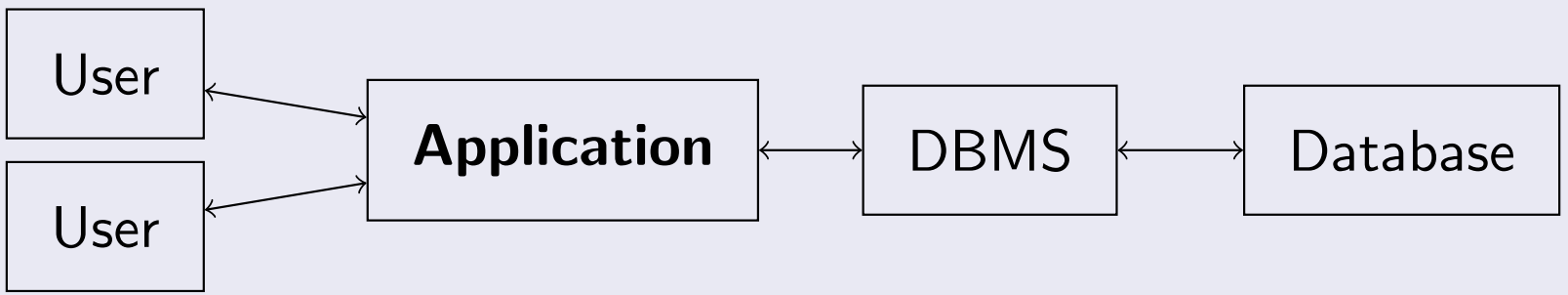

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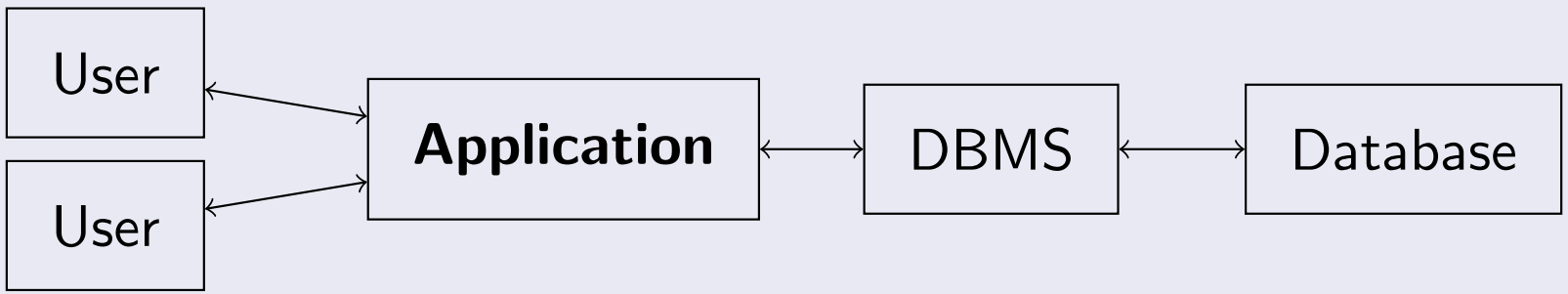

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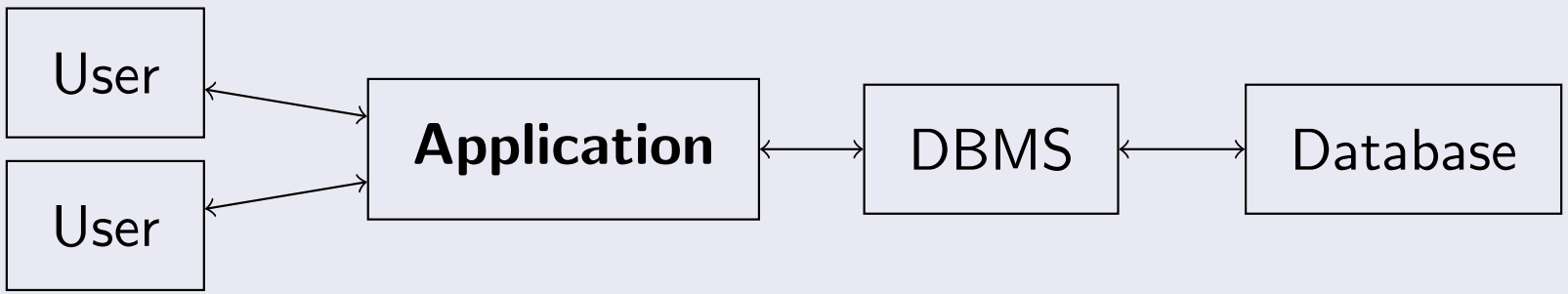

Application

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- Can enforce additional security constraints.

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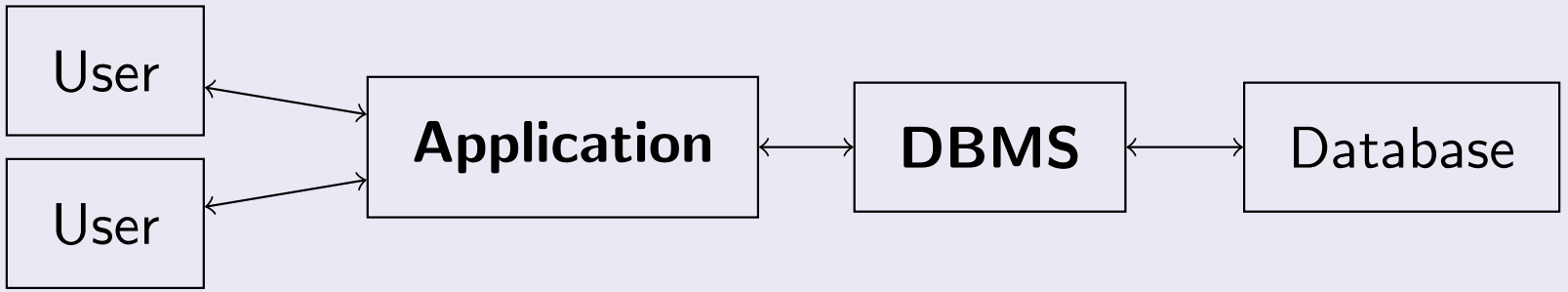

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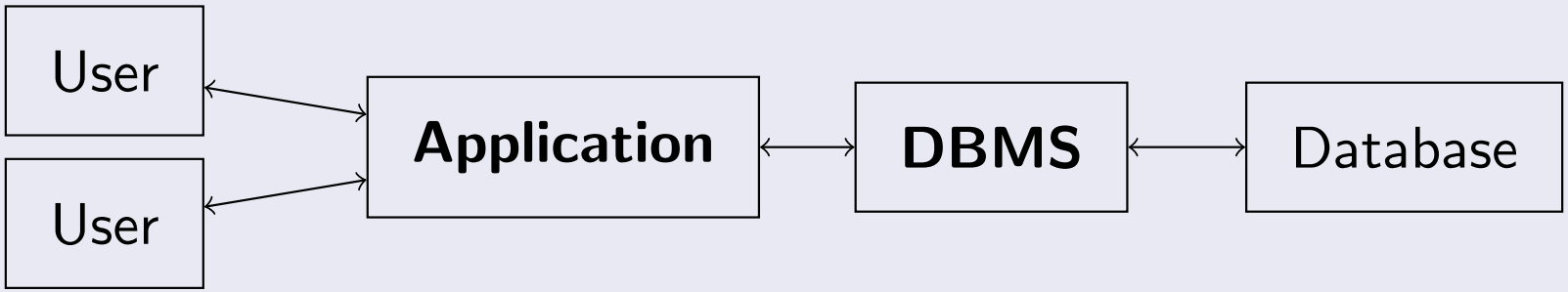

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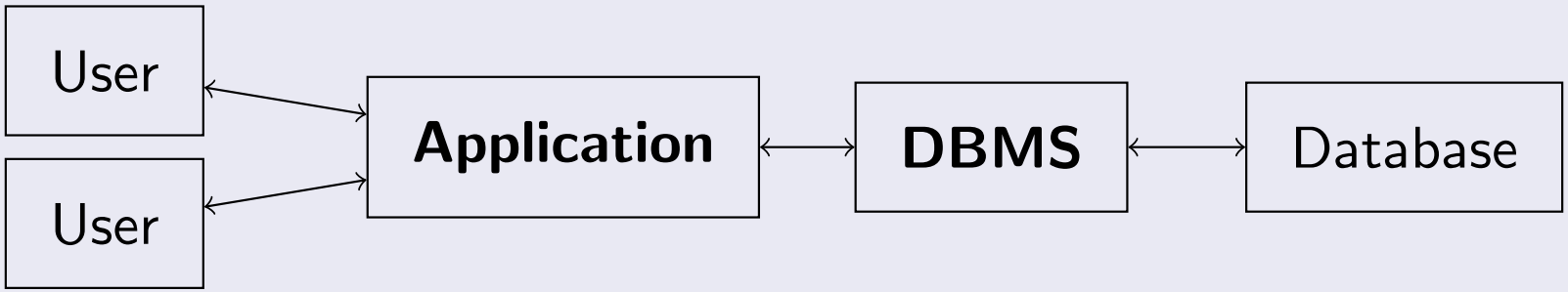

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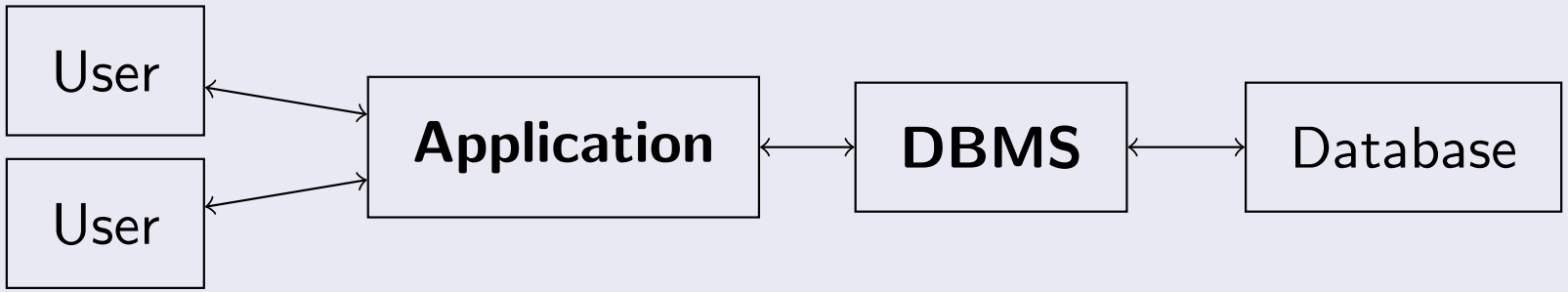

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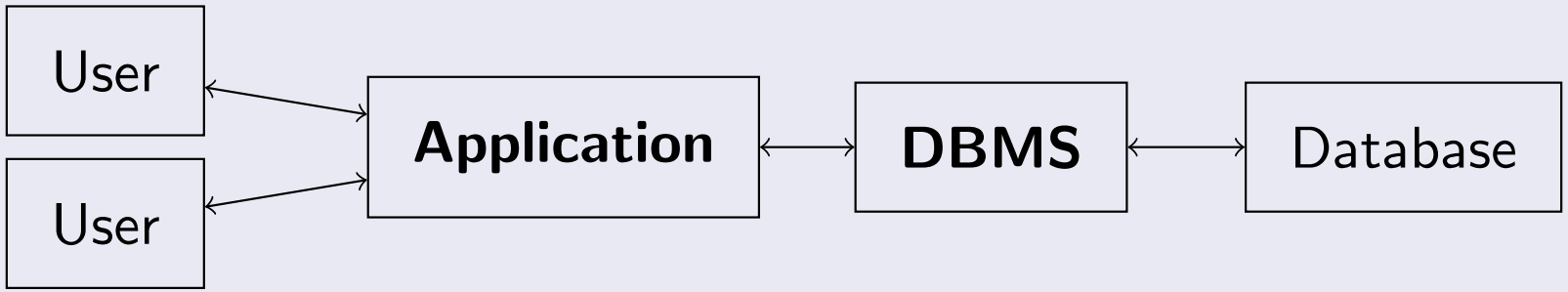

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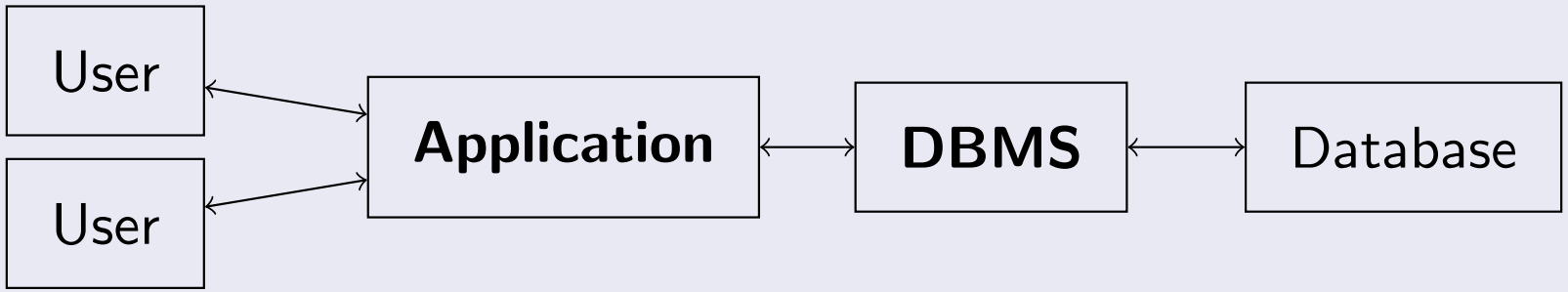

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- Serial interface between application and DBMS.
- Distributed system complicates implementation.
- DBMS's are vulnerable to command injection attacks.
- System as a whole is difficult to verify.

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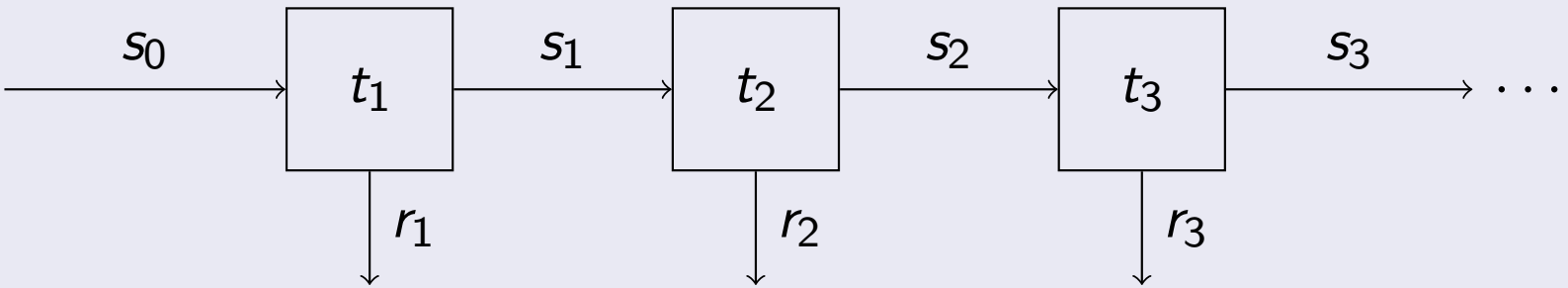

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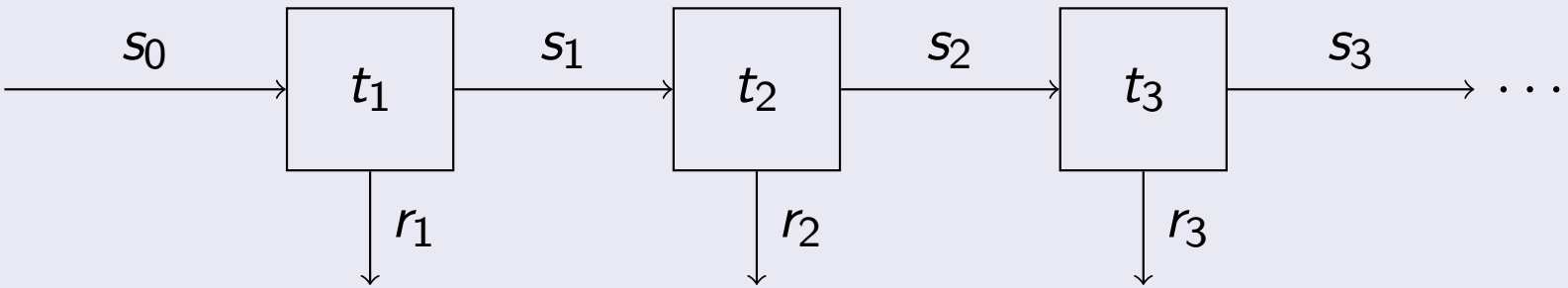

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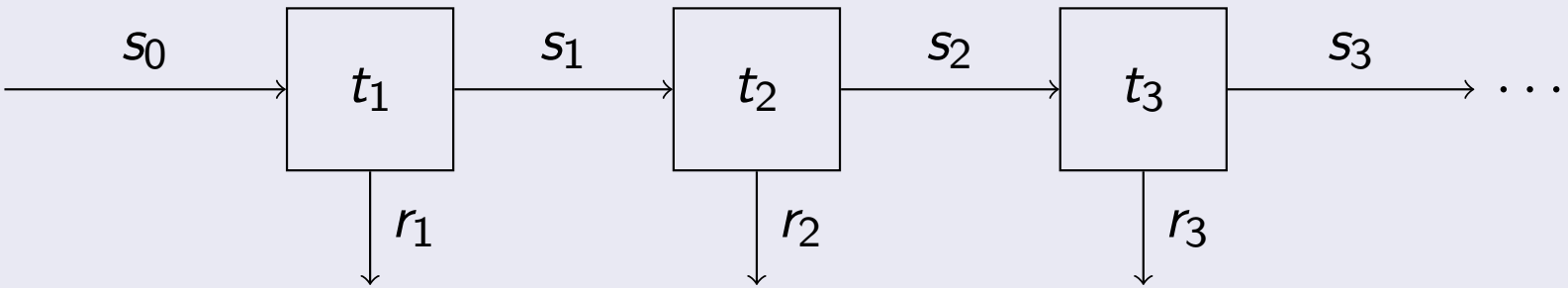

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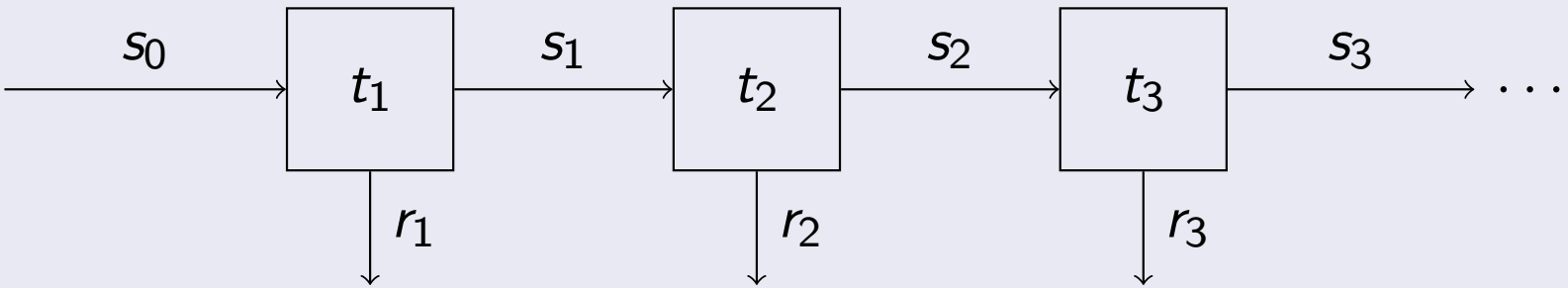

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- Implementation can easily support durability.

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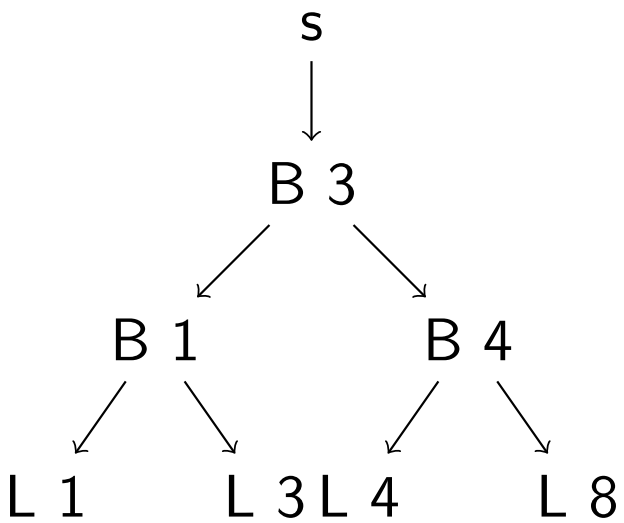

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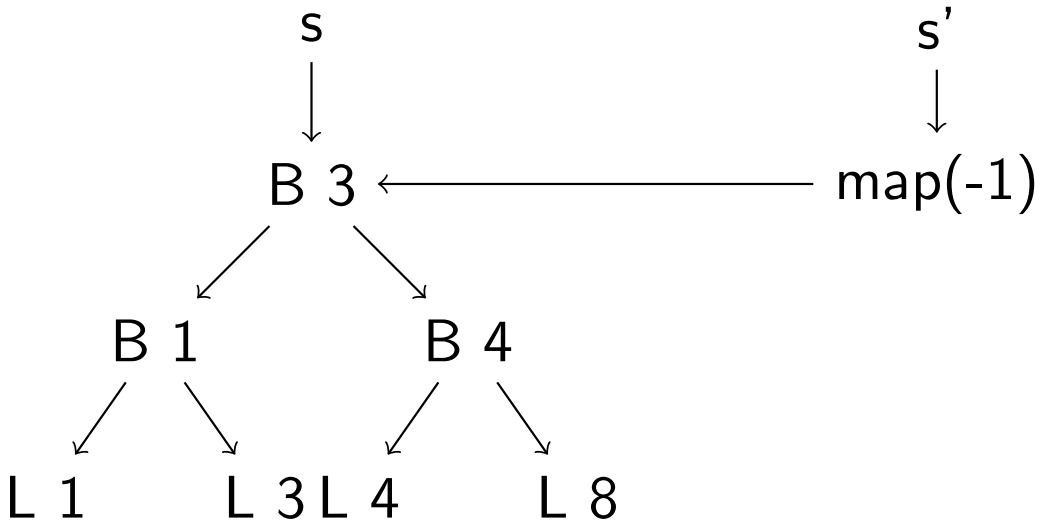

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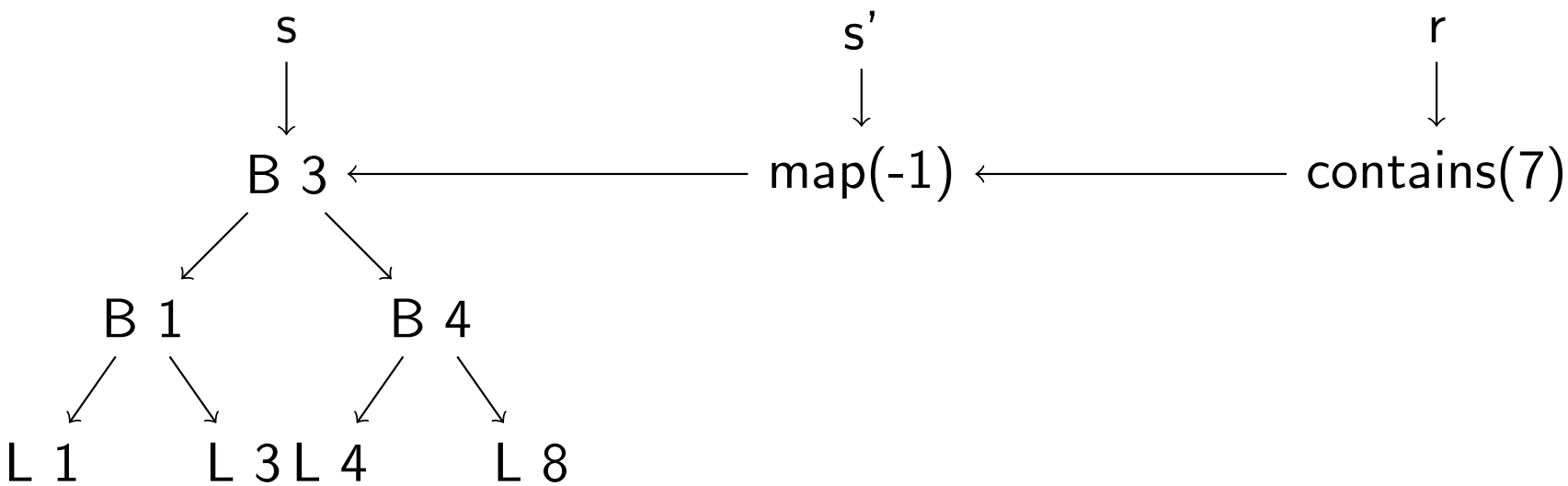

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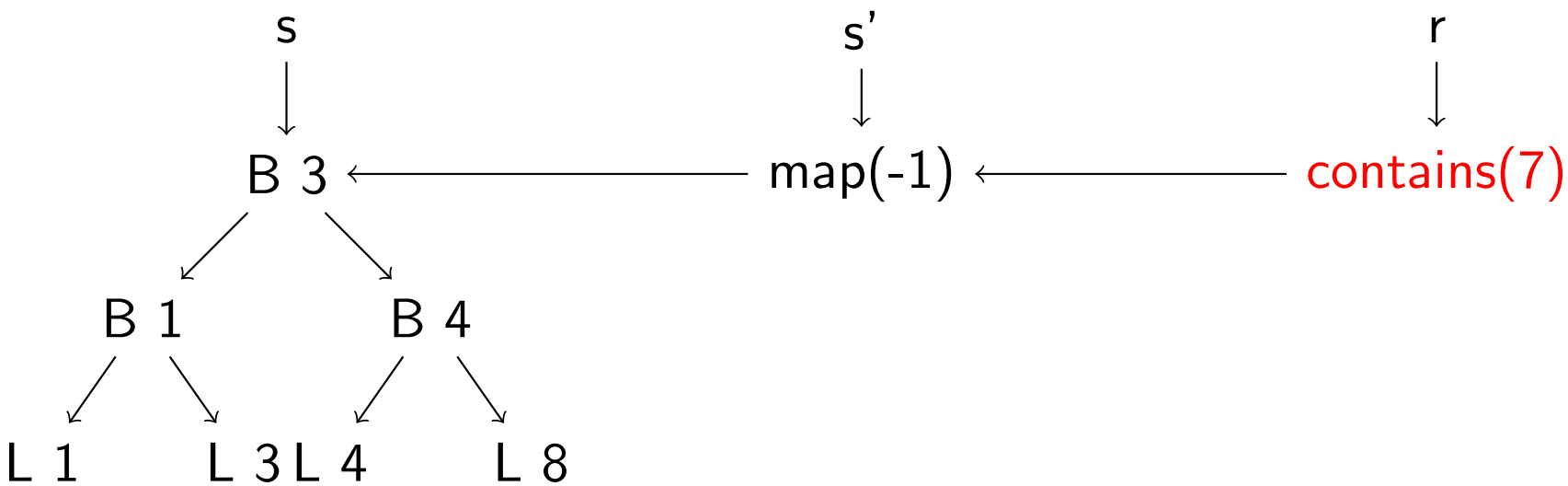

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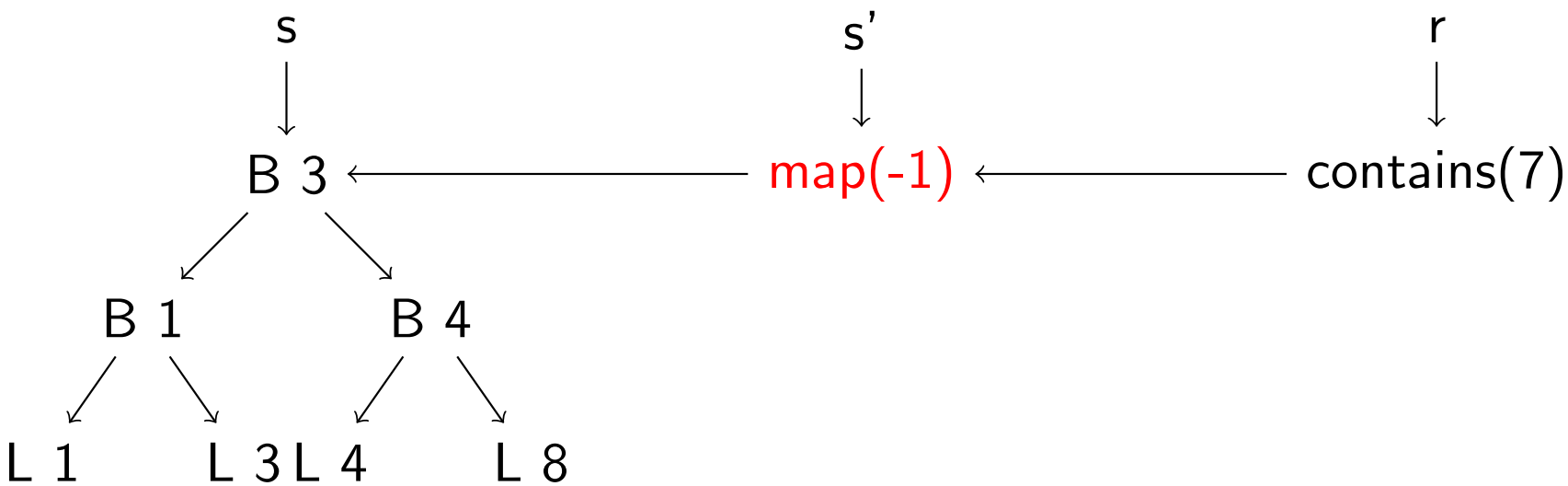

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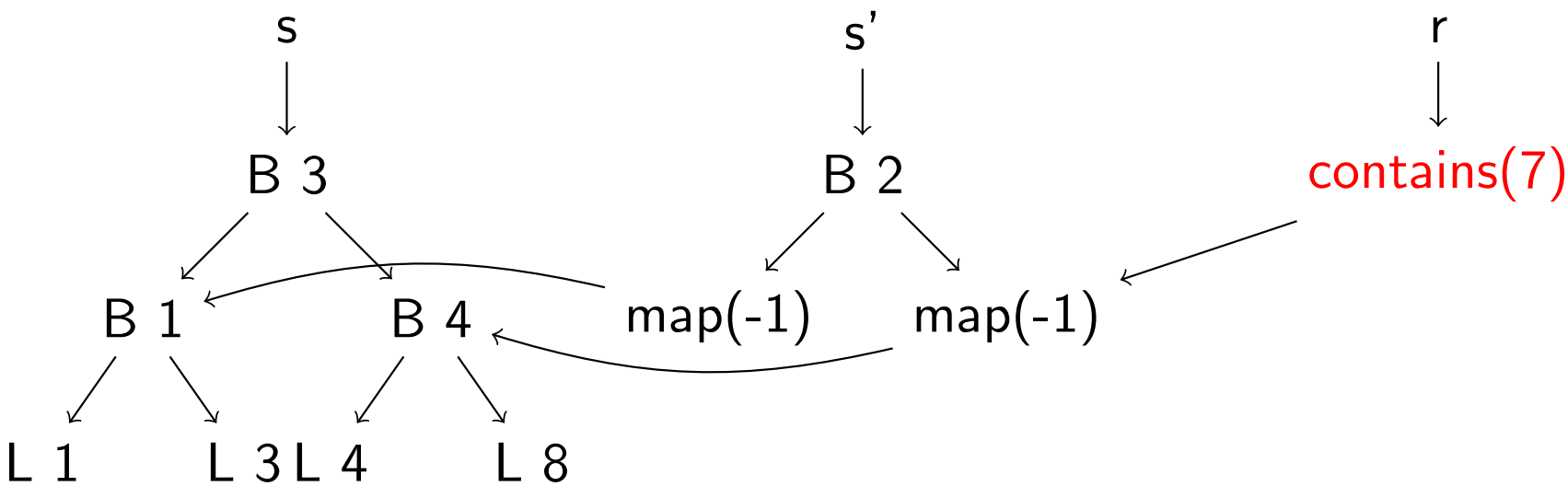

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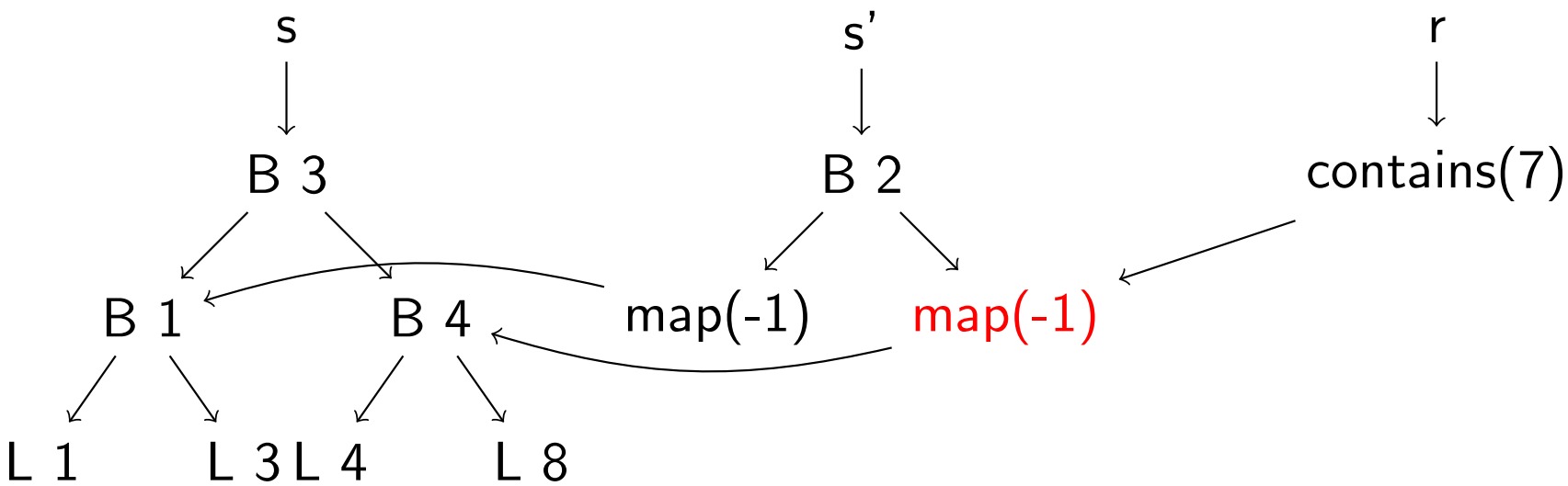

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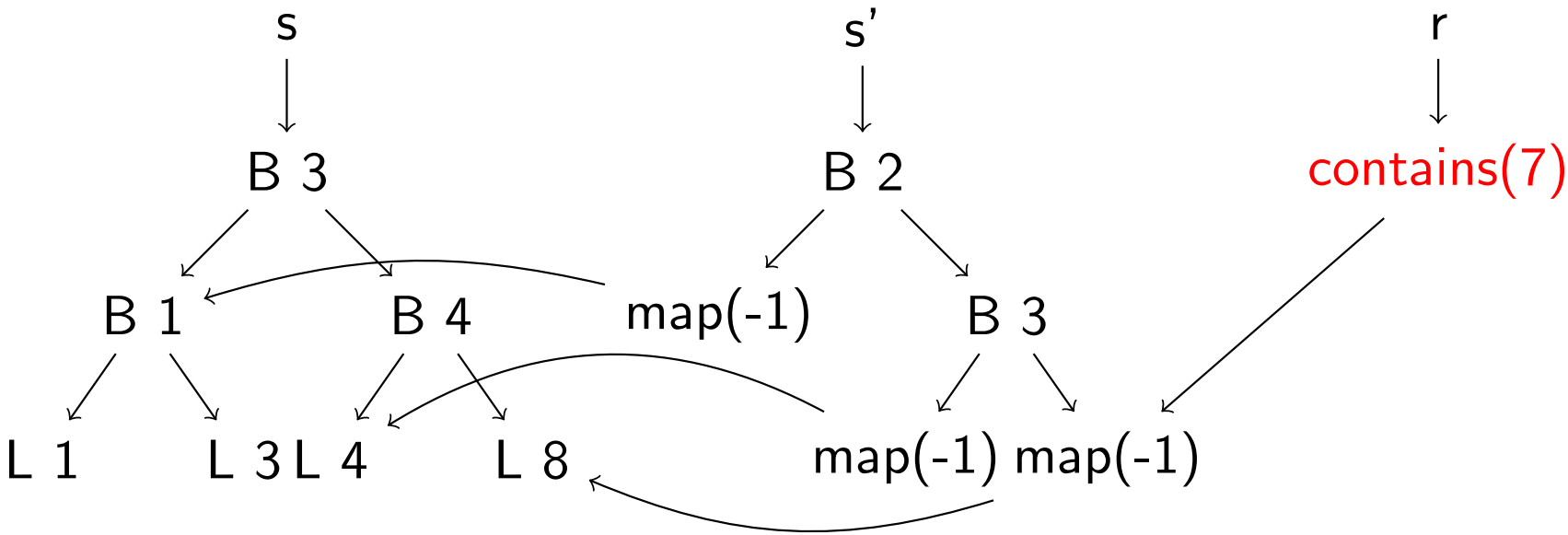

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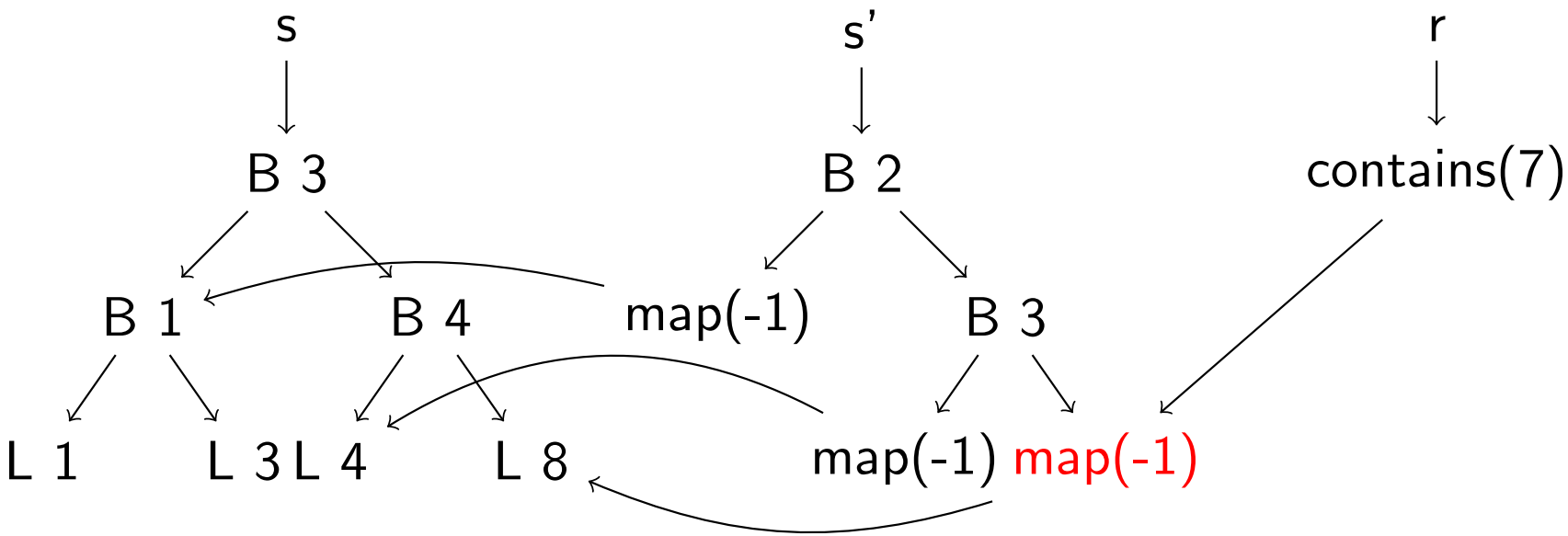

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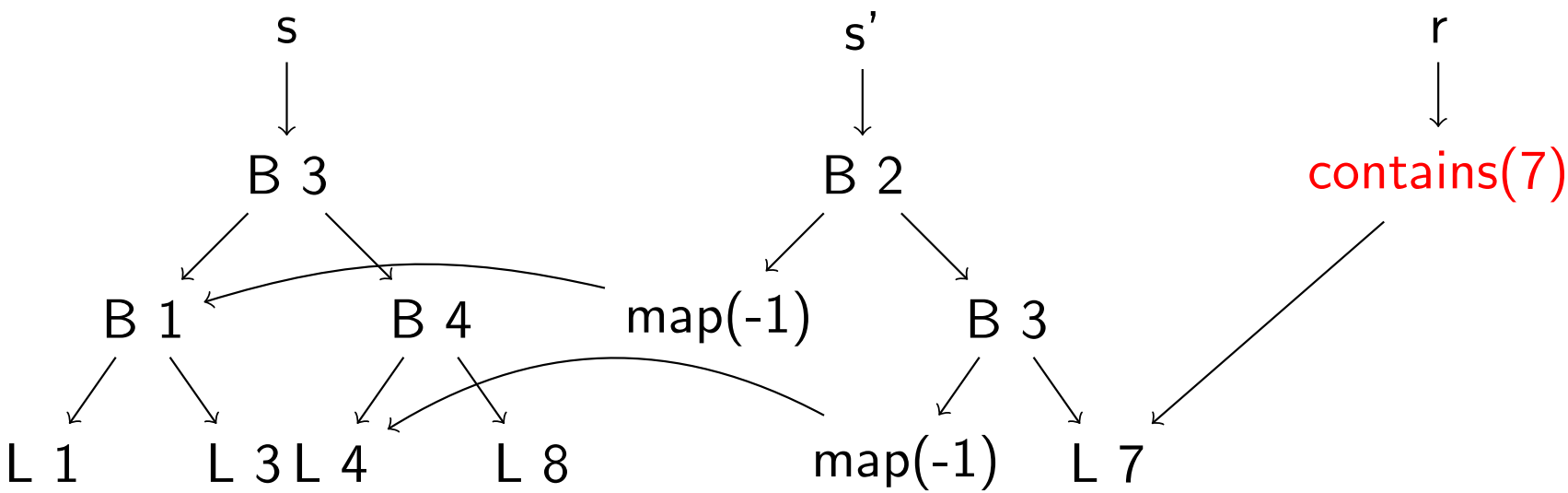

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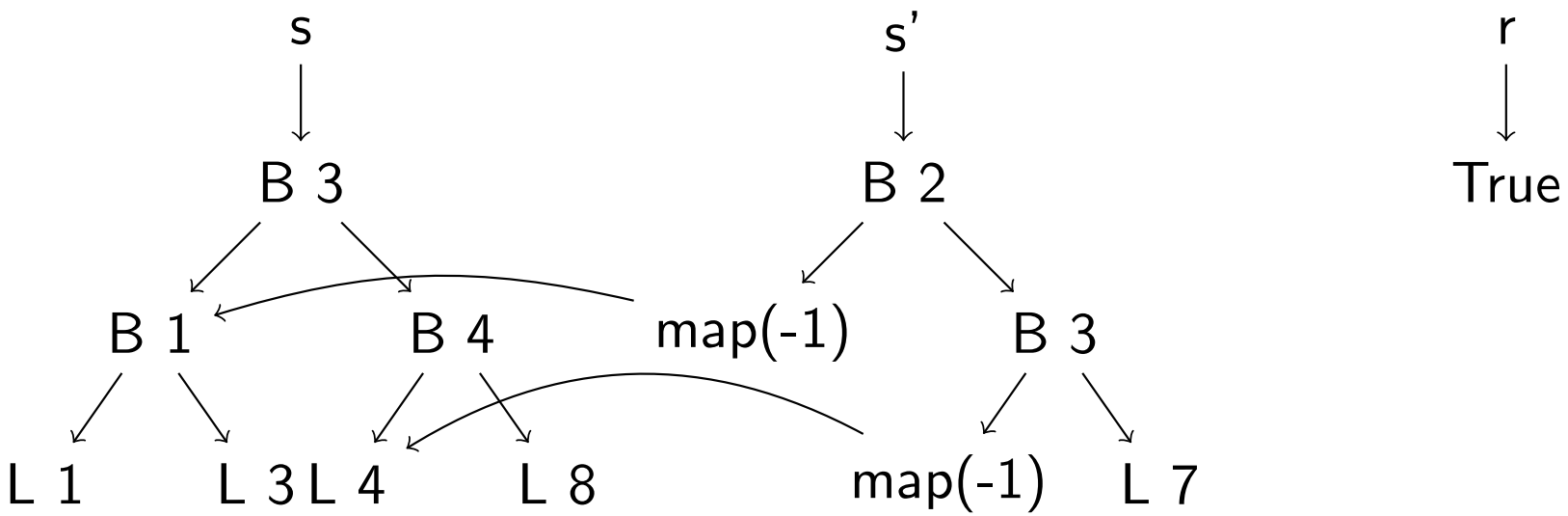

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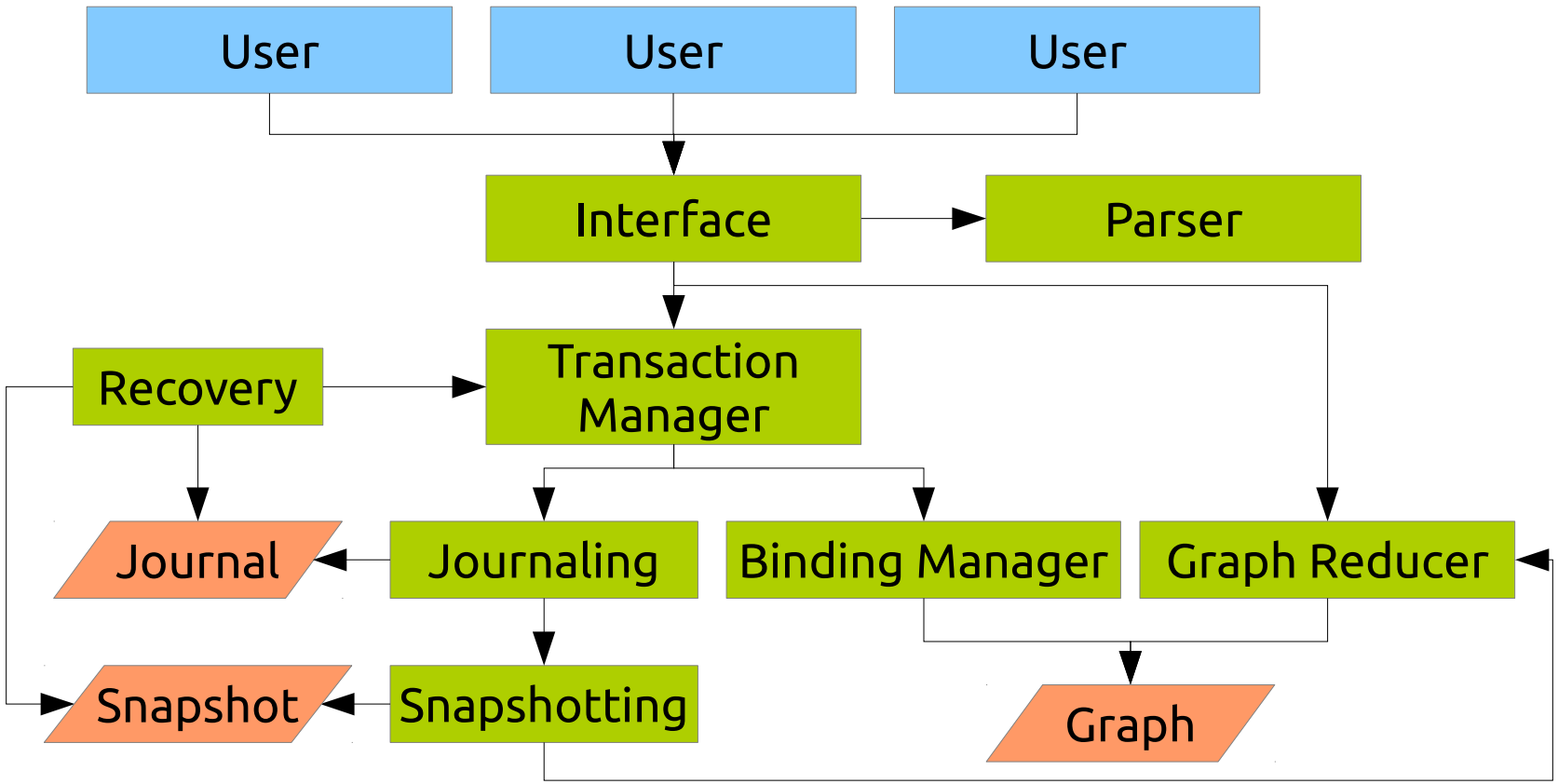
Architecture



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- For every supercombinator we construct a *template graph*.

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  - Each template graph has a name.

Graph Reduction

Template Instantiation Approach

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- Reduction is done in a *reduction graph*.
  - Initialised with graph of expression to be reduced.
  - Beta-reduction: $(f\ E) \rightarrow T_f[f := E]$, where T_f is the template graph associated with x.

Graph Reduction

Dynamic Bindings

Transactions may:

- Create and remove bindings in an ad-hoc manner.
- Define temporary 'local' bindings.

Problems

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- How do we name local bindings?

Solution: Anonymous Templates

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- We resolve references to template graphs statically.
- Garbage collection cleans up unused templates.

Graph Reduction

Scheduling

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- Keep workers busy.

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- Avoid contention between workers.

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Concurrency Minimize latency of individual transactions.

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Distributing Work

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- Avoid contention between workers.
- *Minimise latency of transactions.*

Graph Reduction - Distributing Work

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- Permutation
- Left to right / right to left

Graph Reduction - Distributing Work

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- ☐ Fast random number generator
- ☐ Coordination between workers ← we implemented this

Orders

- ☐ Permutation
- ☐ Left to right / right to left ← we implemented this

Graph Reduction - Distributing Work

```
whnf(Add(left, right, left_to_right) : Node) : Node {
  left_to_right ← !left_to_right;
  if(left_to_right) {
    l ← whnf(left); r ← whnf(right);
  } else {
    r ← whnf(right); l ← whnf(left);
  }
  return Int(l.value + r.value);
}
```

Graph Reduction - Sharing Results

Problem

Multiple workers can work on the same task:

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Problem

Multiple workers can work on the same task:

- Duplicate (small) computations.

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- Avoid duplicate computations.

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Multiple workers can work on the same task:

- Duplicate (small) computations.
- Duplicate results → Duplicate (large) computations.

Solution Strategies

- Avoid duplicate computations.
- Ensure sharing of duplicate results.

Graph Reducting - Ensure sharing of duplicate results

```
whnf(Sharing(shared) : Node) : Node {
  local ← shared;
  reduced ← reduce(local);
  while(local ≠ reduced) {
    if(compareAndSet(shared, local, reduced)):
      local ← reduced;
    } else {
      local ← shared;
    }
    reduced ← reduce(local);
  }
  return local;
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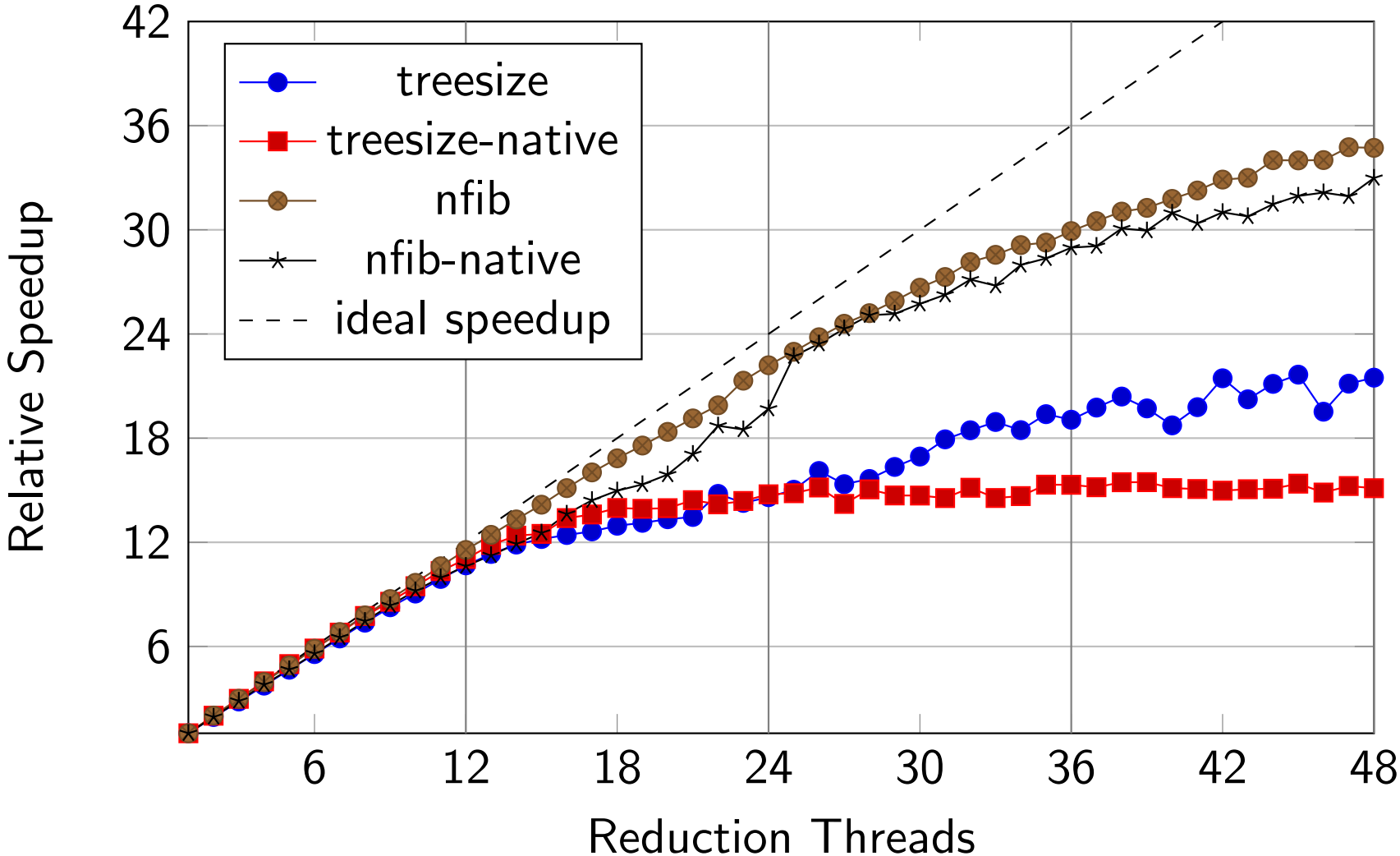
Graph Reduction - Evaluation

TODO: Worker always makes progress on given task Bad for sequential computations

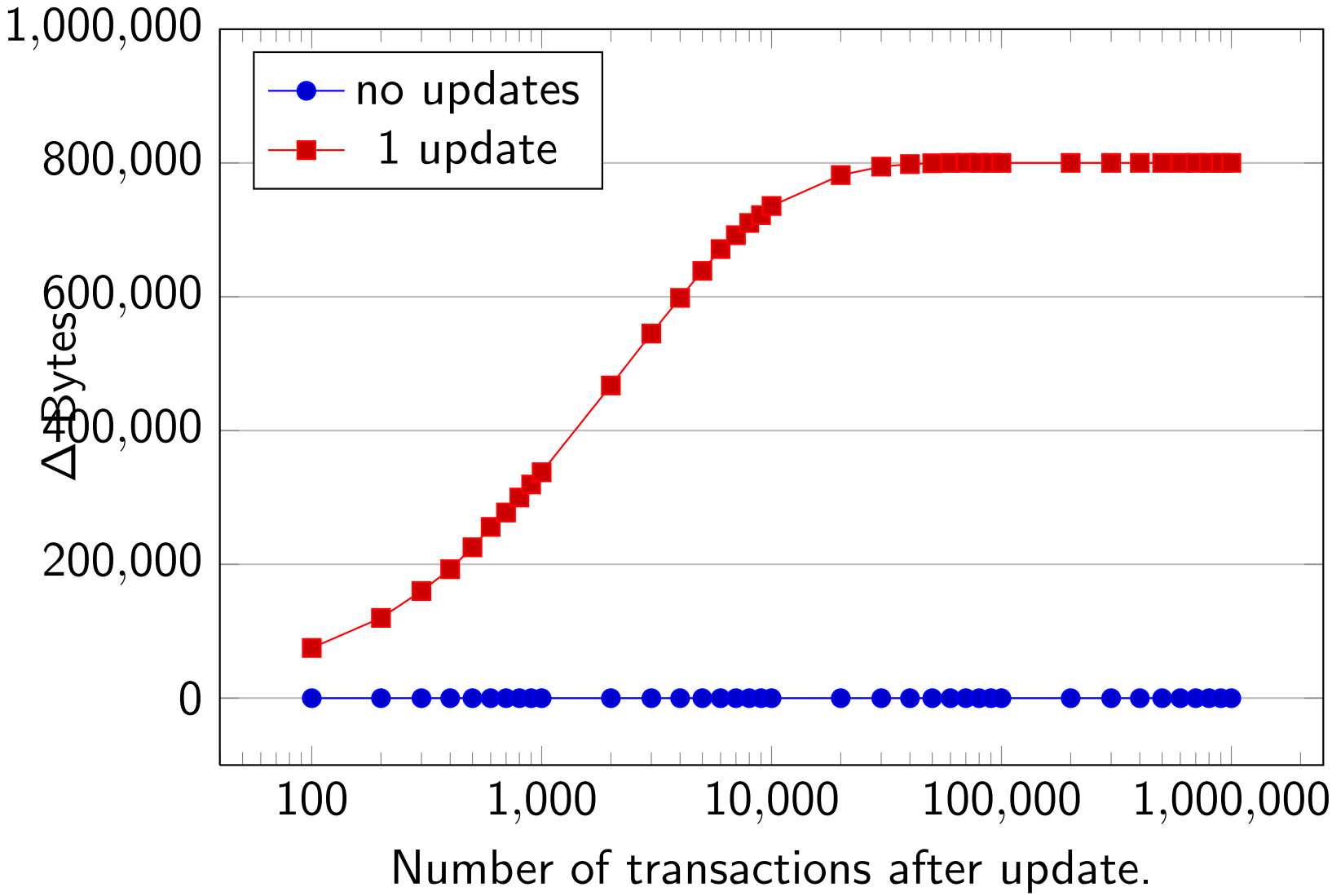
Evaluation


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
Δ Bytes
no updates
1 update
100
1,000
10,000
100,000
1,000,000
Number of transactions after update.

Conclusions

Results

We designed a functional language for transaction processing:

- Prototype implementation.

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Results

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.

Conclusions

- Persistent functional languages are feasible.
- There are still open problems.

Future Work

Future Work

(1) Lazy evaluation leads to space leaks.

(2) Practical use of system.

(3) Handling run-time errors.

(4) Concurrent data structures.

(5) Optimistic concurrency control.