Persistent Functional Languages: towards Functional Relational Databases

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Persistent Languages

Integrate programming languages and database systems:

- Resolve impedance mismatch
- Optimize database updates
- Simplify verification

Pure Functional Languages

Pure functions always return the same result for the same arguments.

Opportunities for optimization:

- Memoization
- Lazy and parallel evaluation
- Rewriting

Functional Persistent Languages

Functional languages are successfully used for *querying* databases: e.g. XQuery.

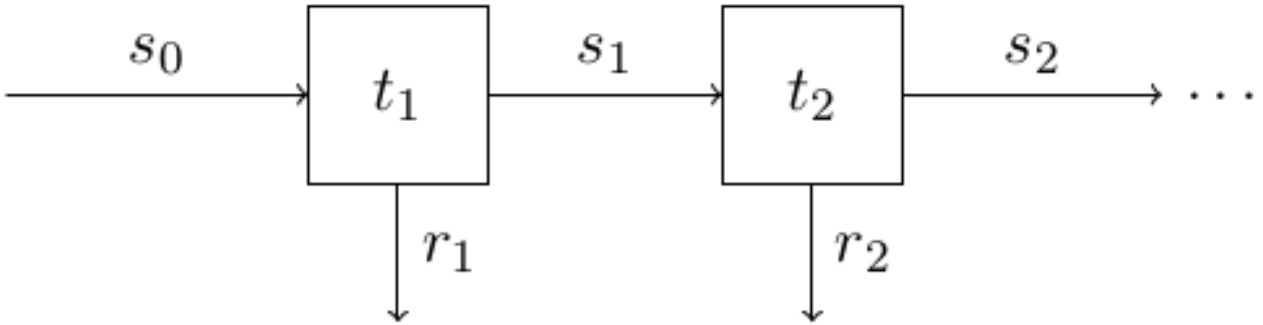
Using functional languages for the *updating* of databases has not really been explored.

Functional Transactions

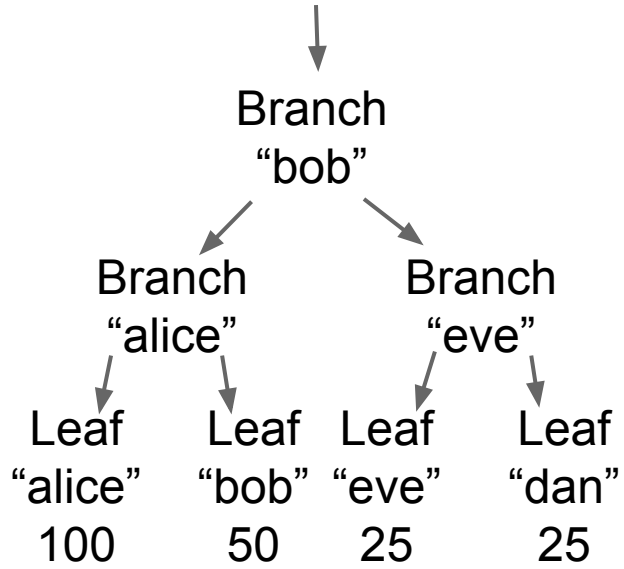
```
transaction : State -> State x Result
```

Functional Transaction Processing

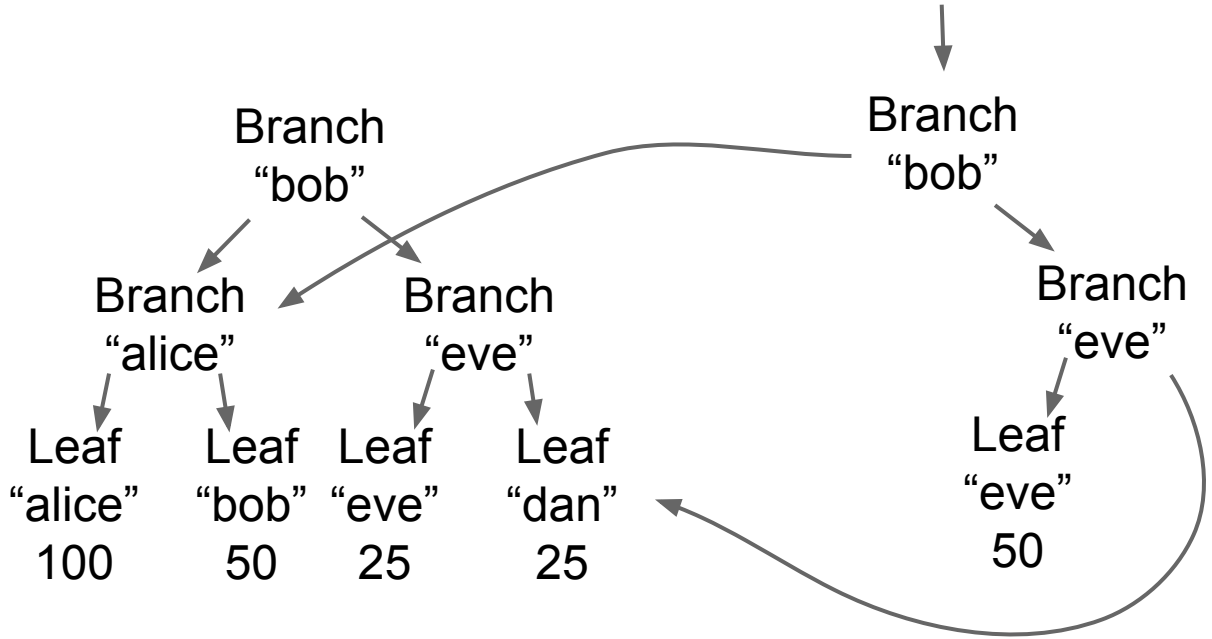
```
tm : State x [Transaction] -> [Result]
```



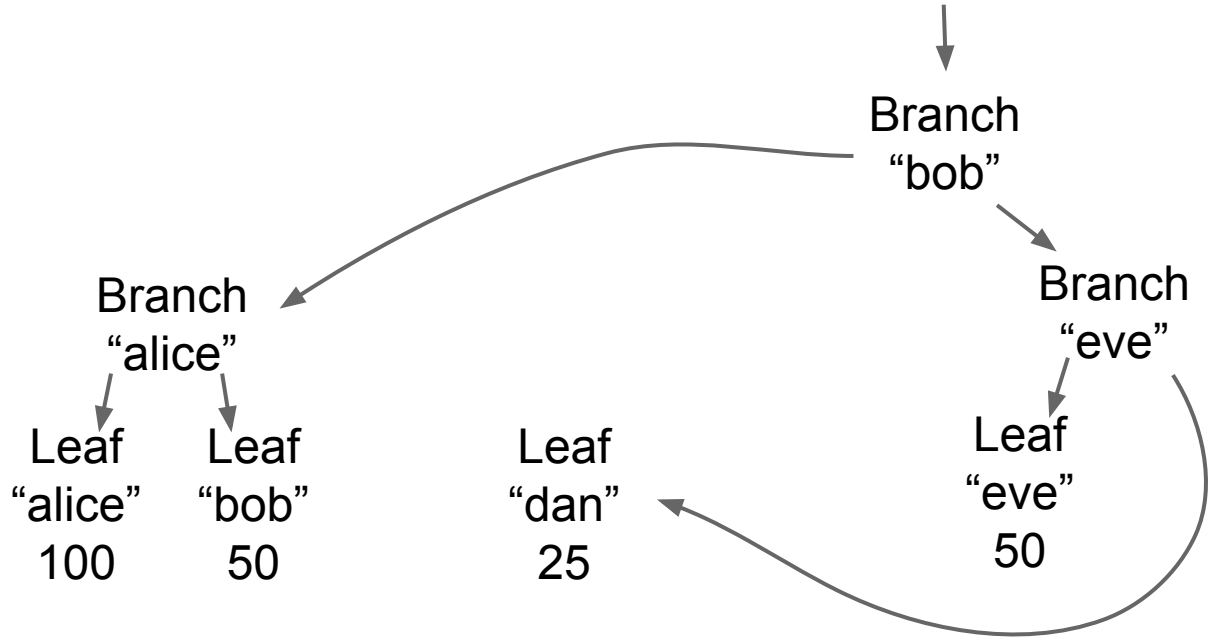
Functional States



Functional Updates



Functional Updates



Persistence & Durability

Simple persistence model:

- Journal transactions before executing.
- Regularly snapshot the state.
- Recover state from latest snapshot by replaying journaled transactions from the last snapshot.

Constraints and Aborts

Enforcing constraints over the state:

```
if check(next_state)
  then (next_state, result)
  else (prev_state, Error)
```

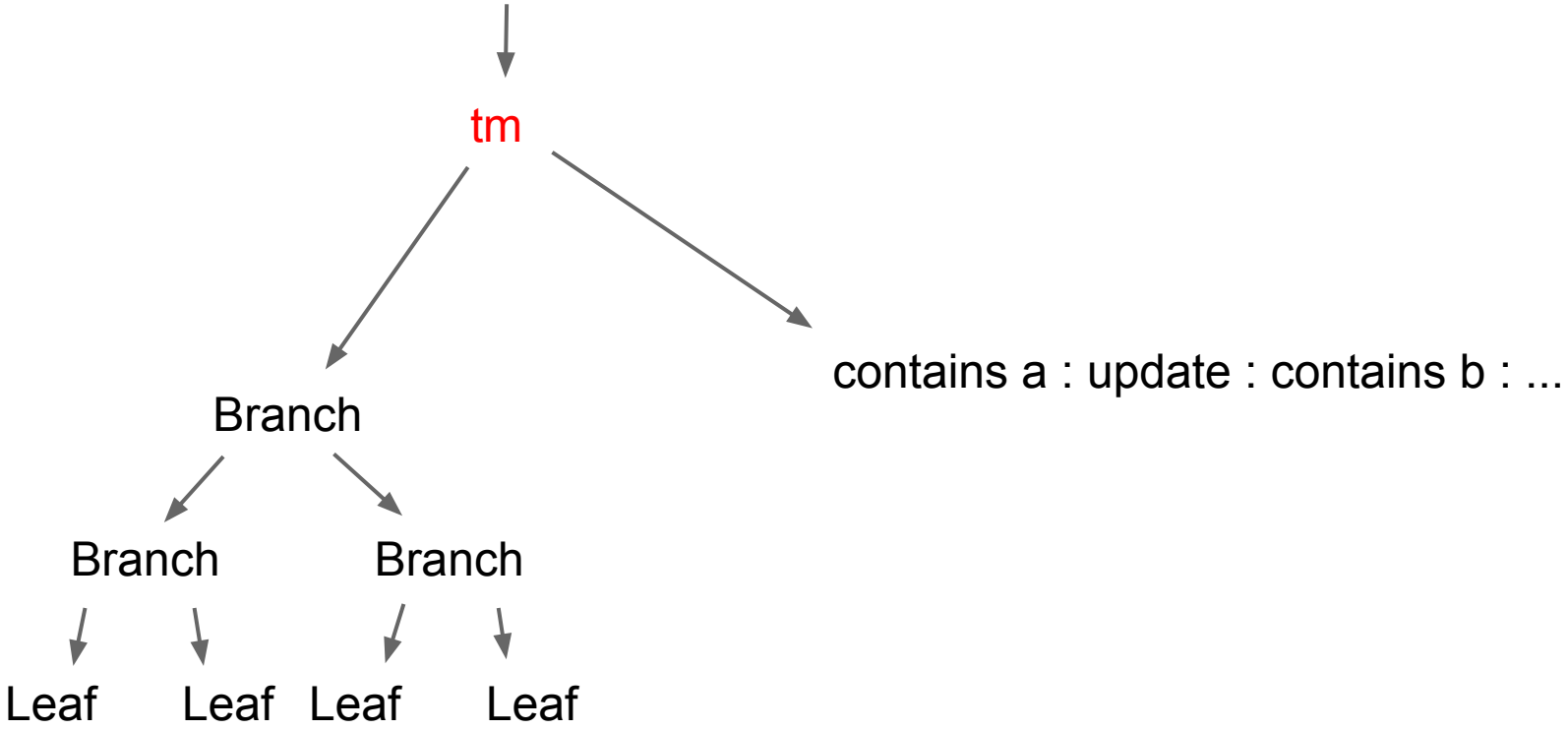
Transactions

This model satisfies the ACID properties:

- Atomic
- Consistent
- Isolated
- Durable

But how do we execute transactions in parallel?

Concurrent Transaction Processing



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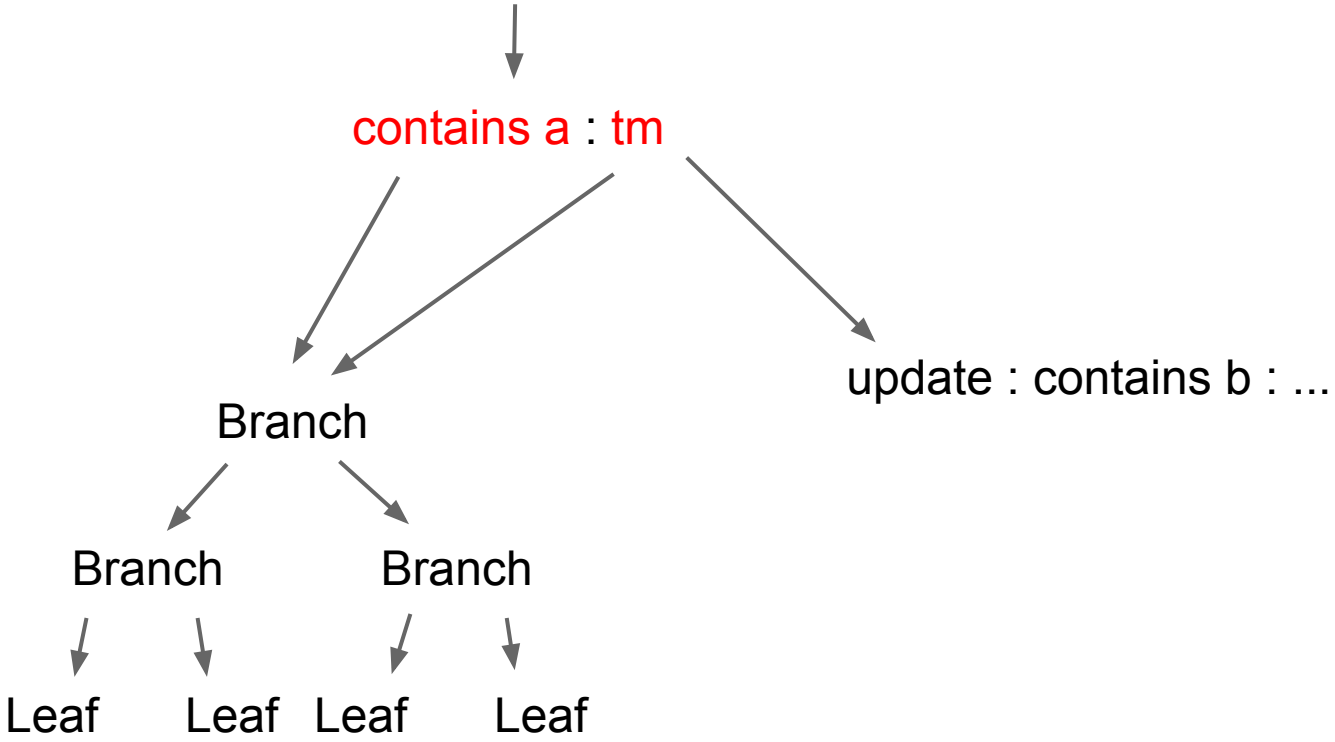

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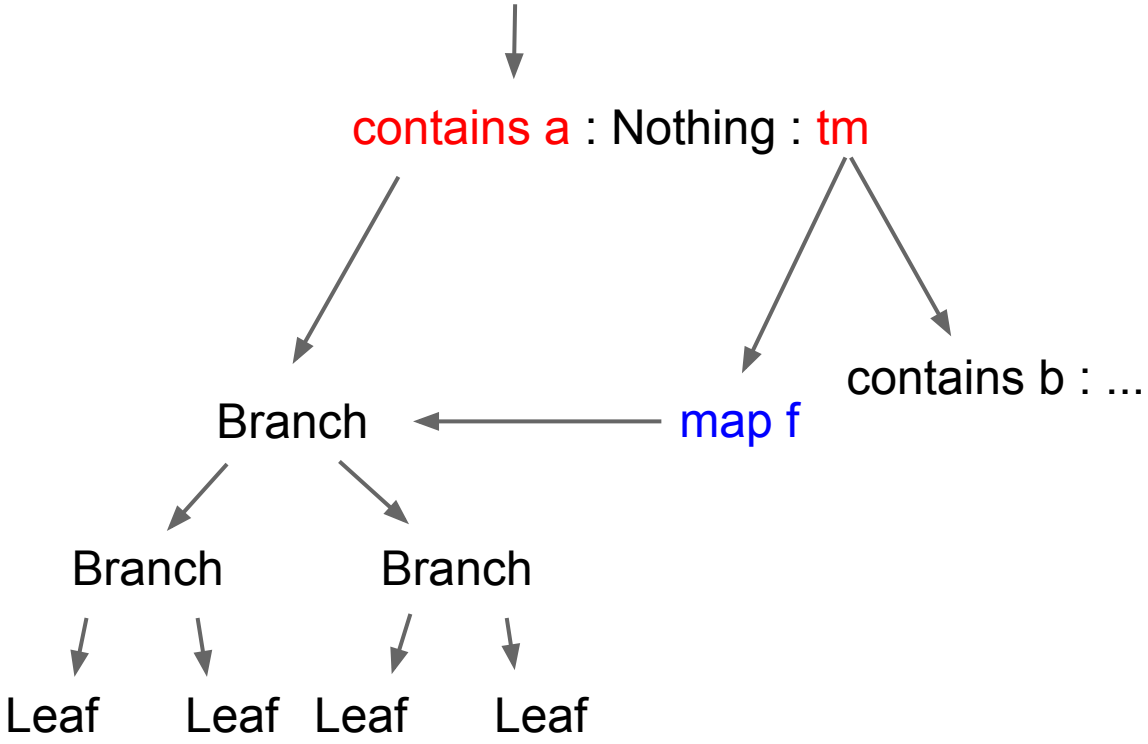

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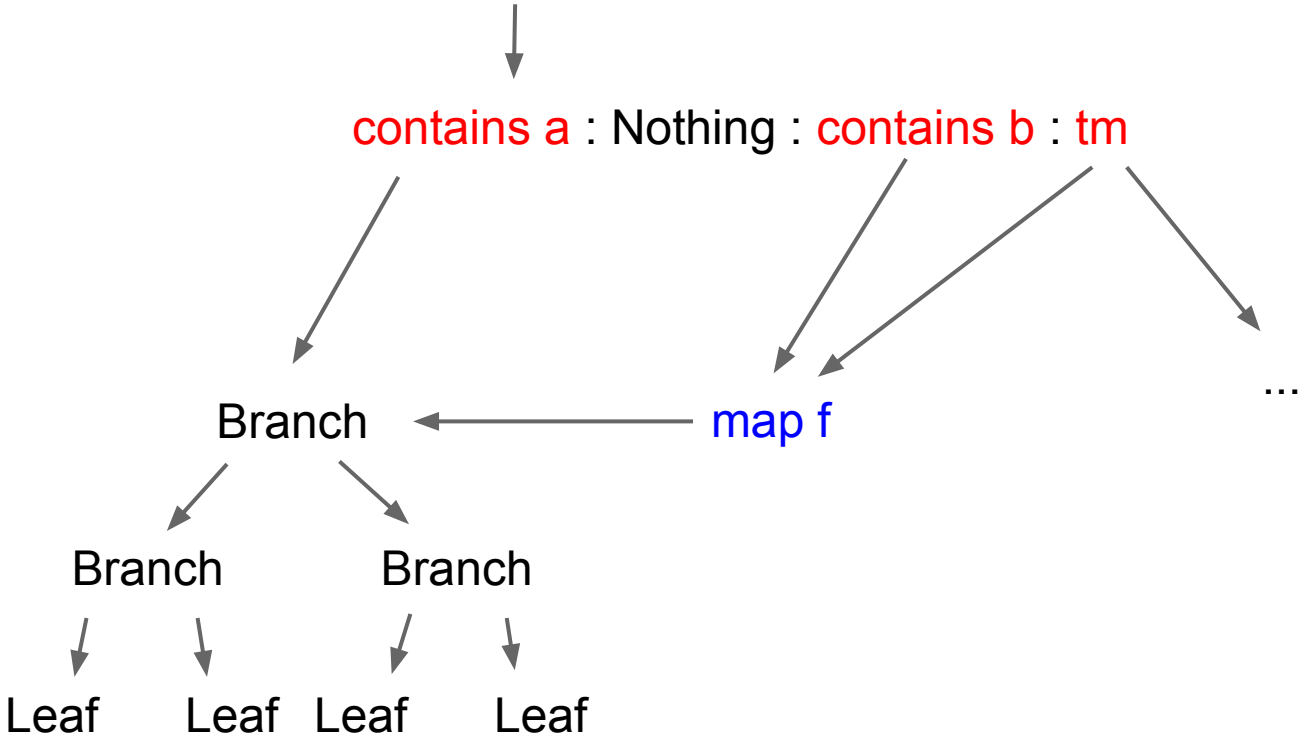

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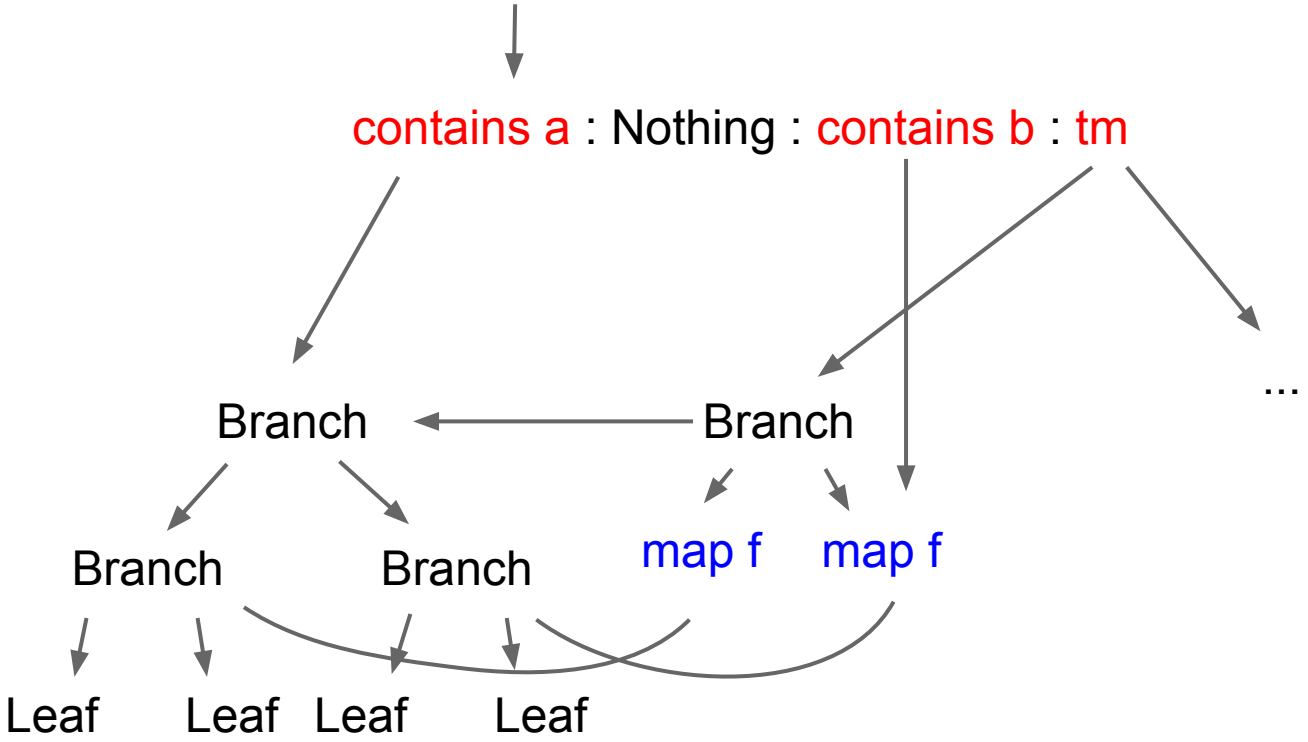

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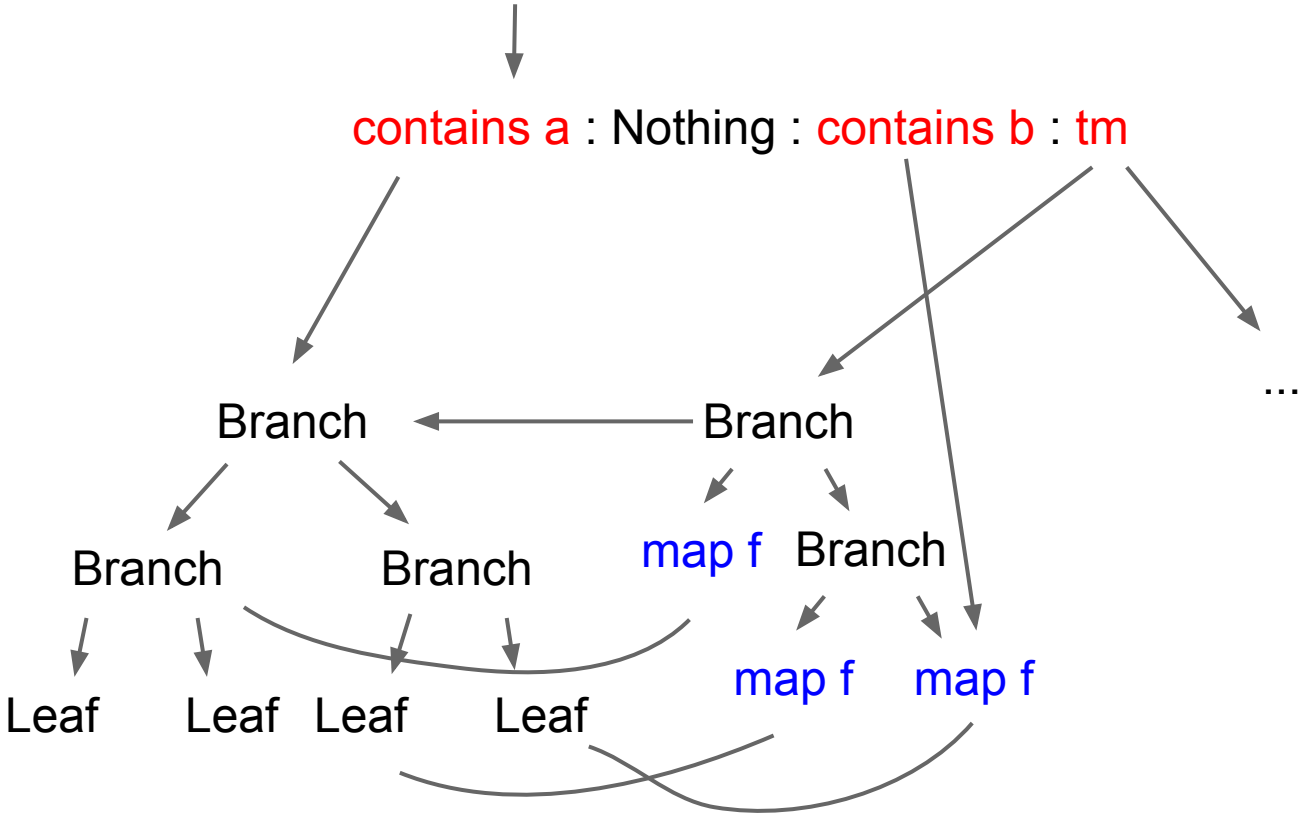

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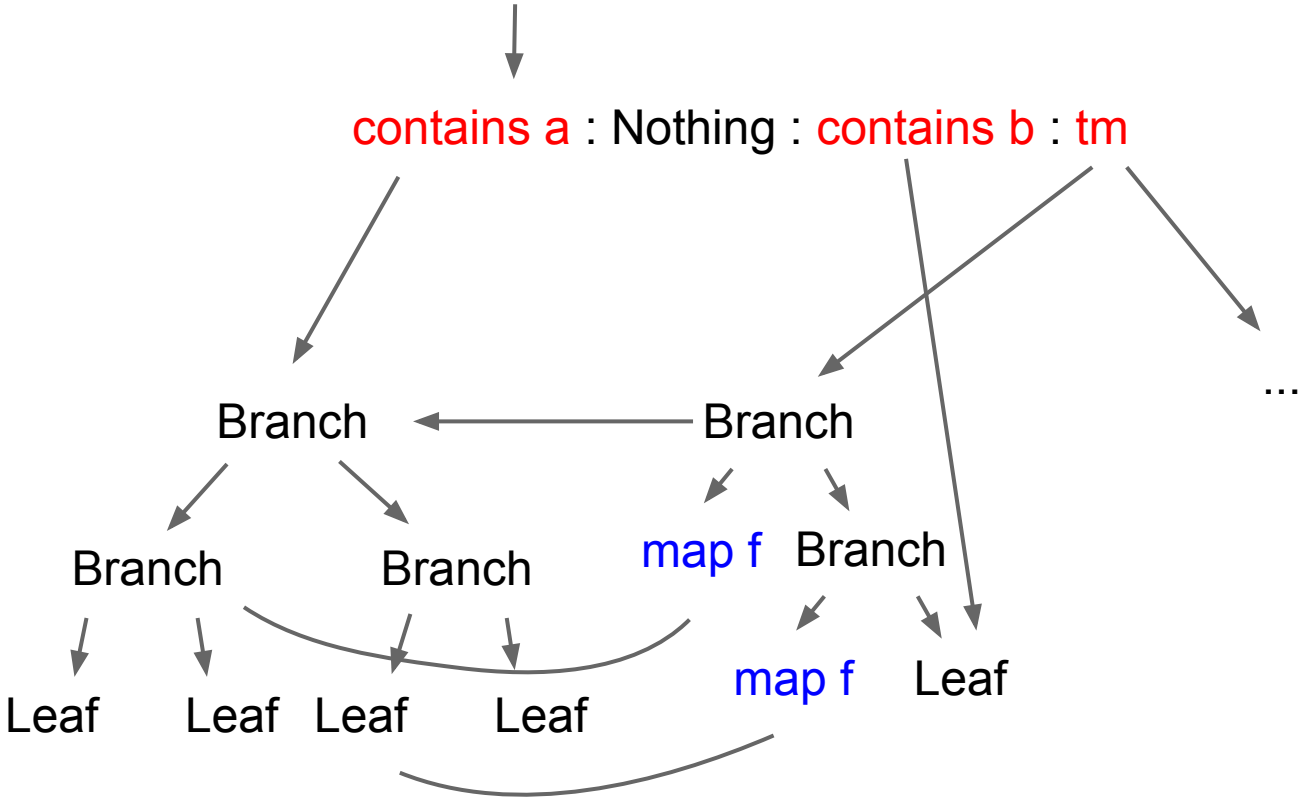

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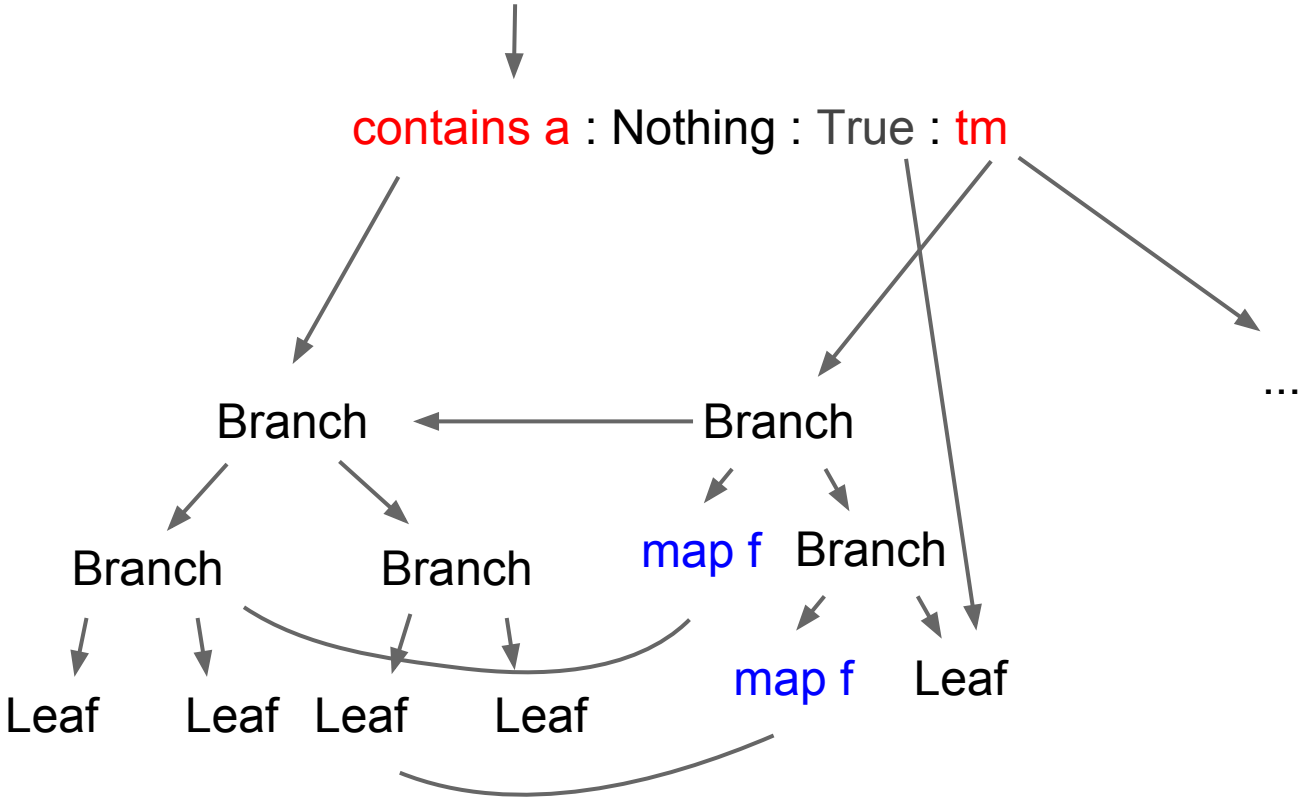

Limitations of lazy evaluation

- Concurrency is limited by data dependencies

  e.g. `if c then a else b`

  cannot be evaluated until `c` is evaluated
- Transaction functions must be total
- Memory requirements

Proposed Alternatives

Optimistic concurrency control

- Evaluate (part of) the state before committing
- Use memoization to speed up retries
- Integrates seamlessly with lazy evaluation

Splitting transactions

- Allows for weaker isolation guarantees

Persistent Functional Language

Language derived from Haskell, featuring:

- Functional transaction processing
- Ad-hoc transactions
- Stored transactions

Ongoing work:

- Runtime system
- Type system
- Execution strategies

Modelling Relational Databases

Challenges:

- Automatically using and updating indices
- Automatic optimization
- Exploiting functional execution strategies

Potential solutions:

- Embedded DSL
- Runtime support

Online Schema Transformations

Ongoing work:

- Classifying transformations
- Criteria for online schema transformations
- Benchmark based on TPC-C

We want to perform schema transformations lazily.

Verifying Functional Transactions

Verify postconditions on stored transactions:

- Avoid runtime constraint checks
- Verify functional behaviour

We want to leverage existing tools to this new setting.

Conclusion

Functional persistent languages:

- Integrate programming language and database system
- New techniques for concurrency control
- Many opportunities for optimization

Ongoing and future work:

- Optimistic concurrency control & Memoization
- Modelling relational databases
- Online schema transformations
- Verification of stored transactions

Thank You

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Persistent Functional Language

{ }

names’ = []

{ names = [] }

names’ = “alice” : names

{ names = [“alice”] }

result = names

[“alice”]

{ names = [“alice”] }

Persistent Functional Language

{ names = [“alice”] }

names’ = “bob” : names

result = names

[“alice”]

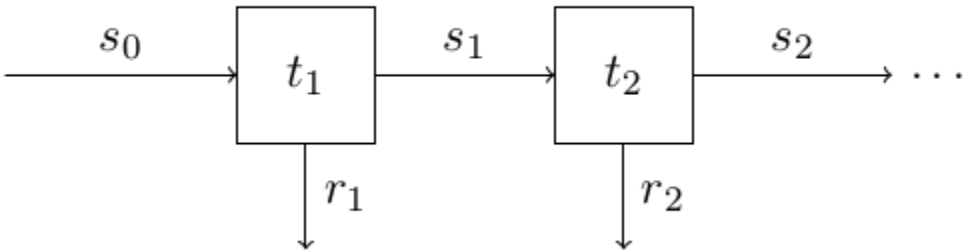
{ names = [“bob”, “alice”] }

Persistent Functional Language

```
{ names = [“bob”, “alice”] }
    length’ list = list match
        [] ->  0
        (x:xs) -> 1 + length’ xs
{ names = [“bob”, “alice”], length = λ list → ... }
    result = length names
    2
{ names = [“bob”, “alice”], length = λ list → ... }
```

Functional Transaction Processing

```
tm : DB x [Transaction] -> [Result]
tm s (tx:txs) =
   let (ns, r) = tx(s) in
      r : (tm ns txs)
```



Concurrent Transaction Execution

Idea: Evaluate states lazily.

```
update s = (map f s, Nothing)
contains k s = (s, contains k s)

tm (Branch ...) [contains a, update,
contains b, ...]
```

Concurrent Transaction Processing

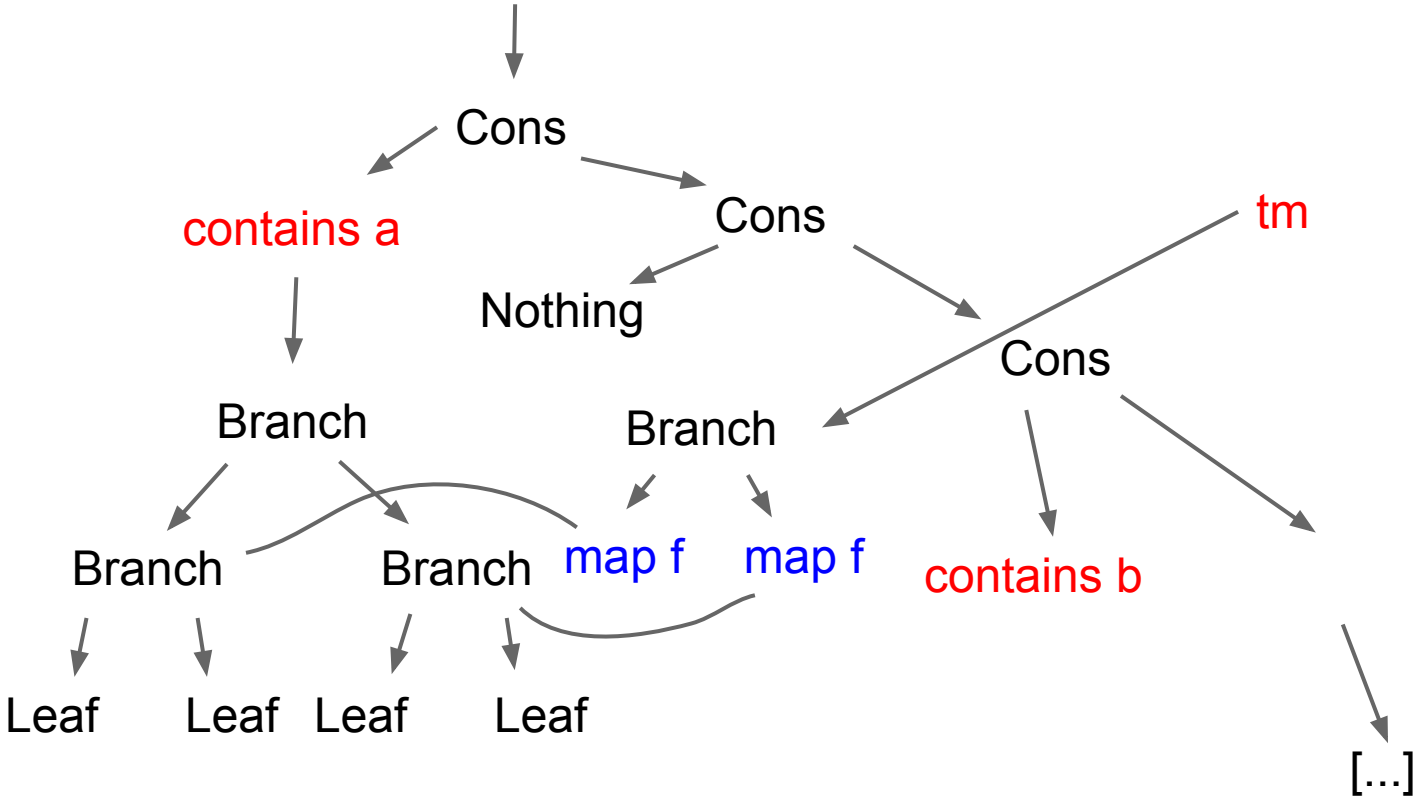
tm (Branch ...) [contains a, update, contains b, ...]

Future work: Memoization

Remember results of function applications:

- Optimistic execution & retrying transactions
- Aggregate functions:
  - sum, min, max, …
  - constraint checks
- Materialized views

Concurrent Transaction Processing



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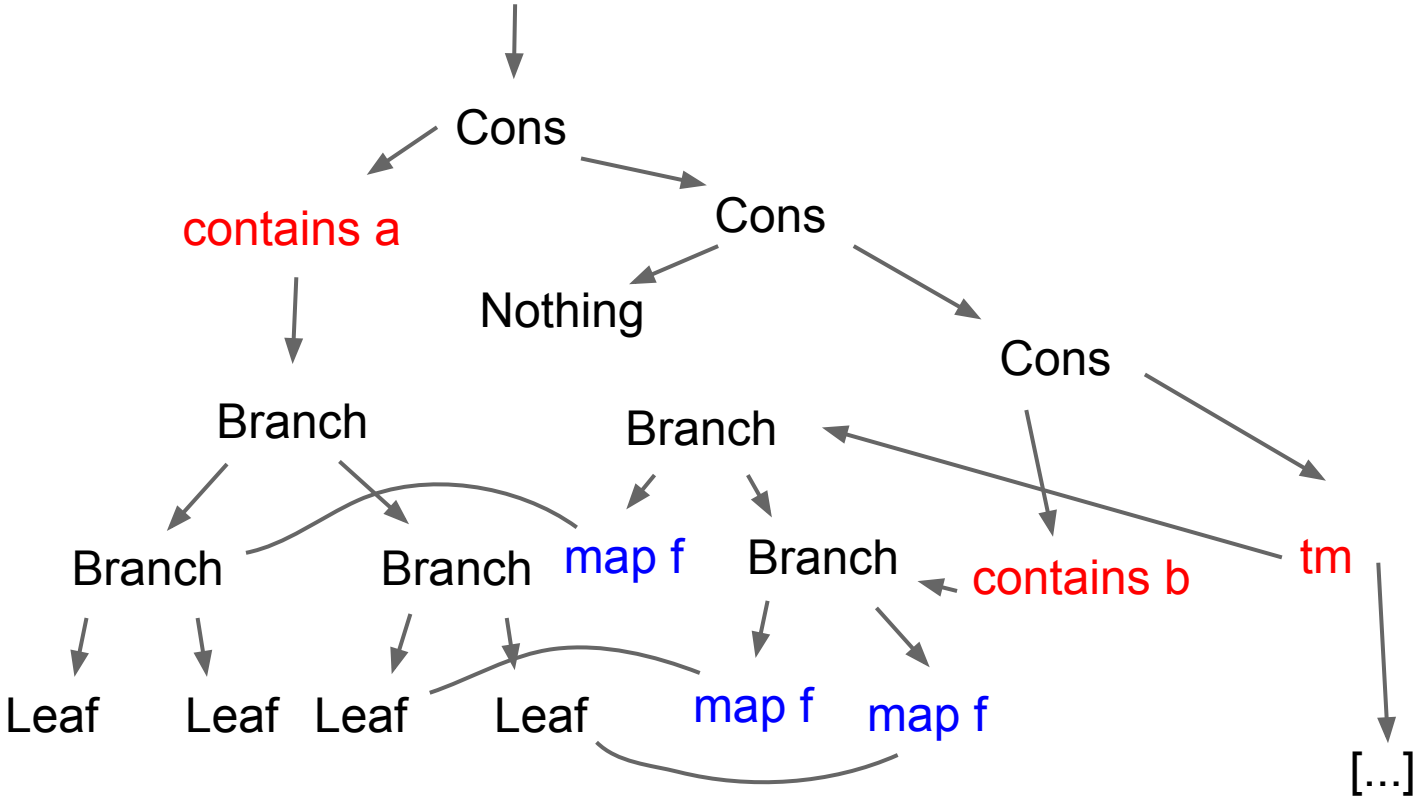

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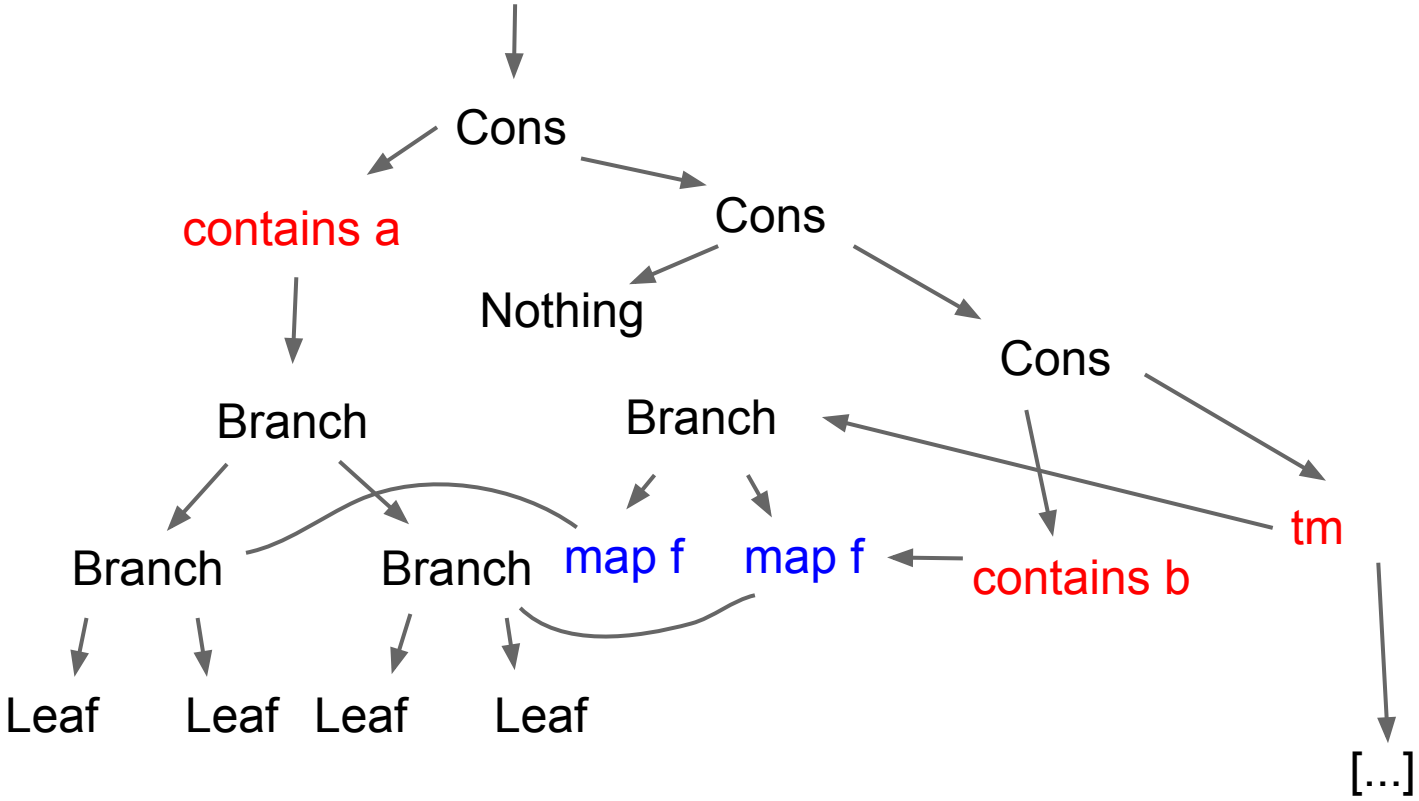

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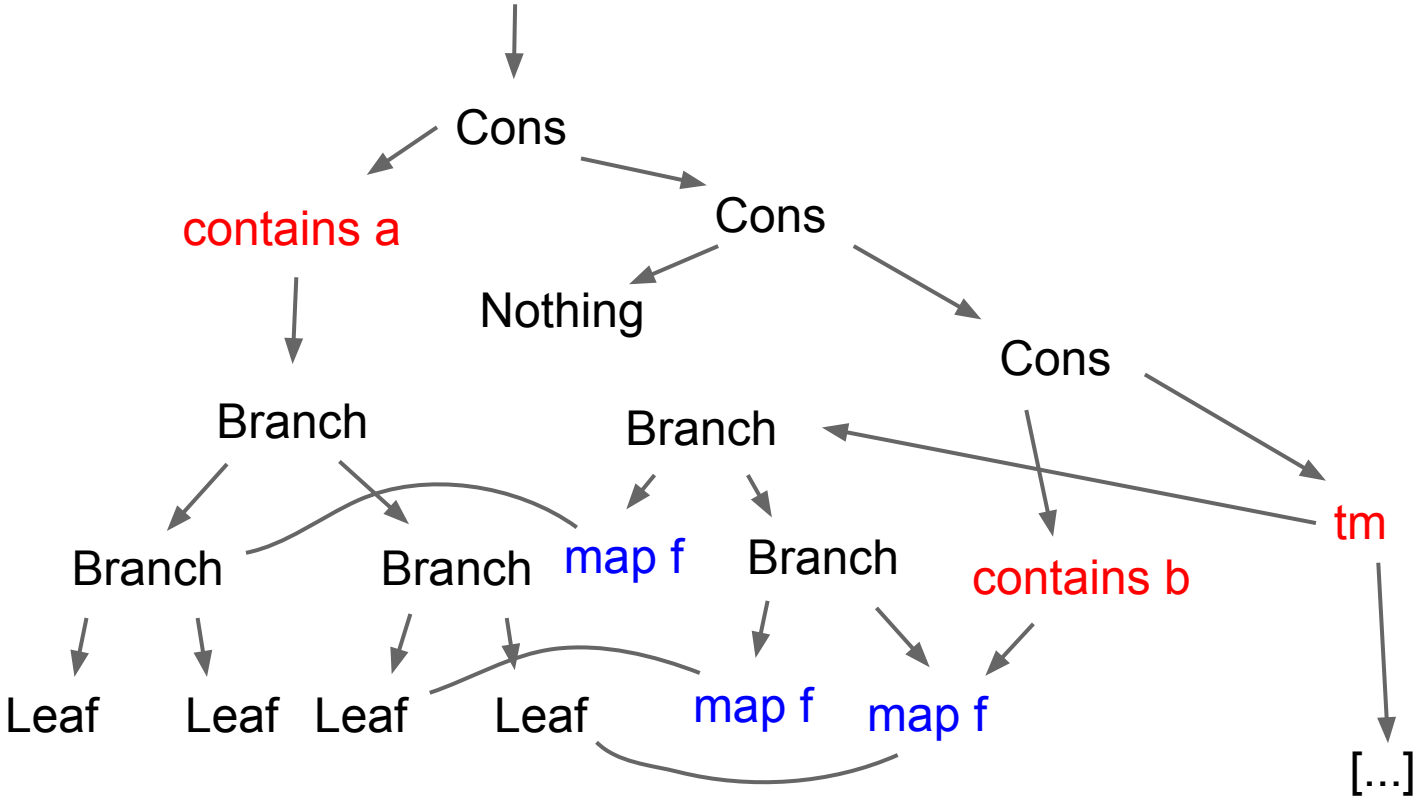

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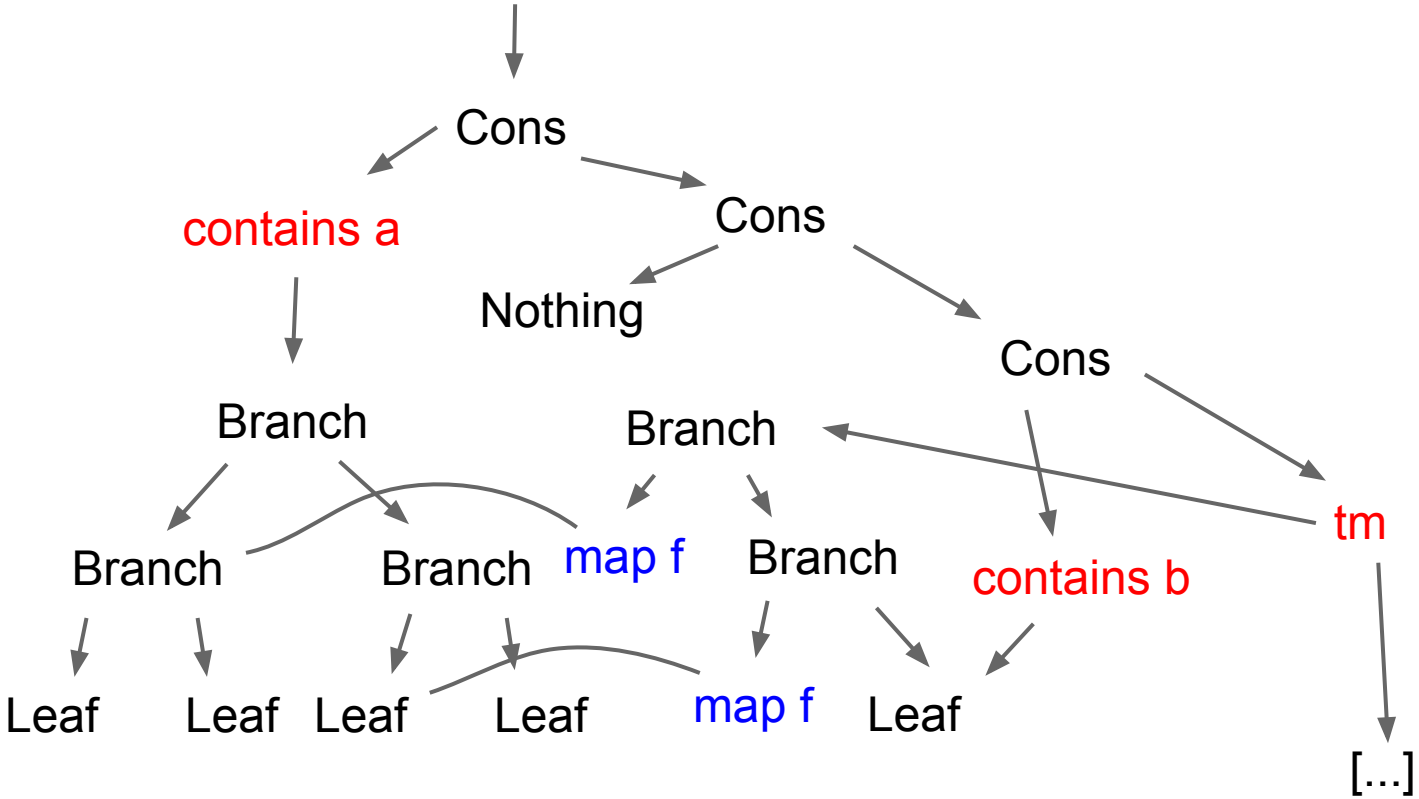

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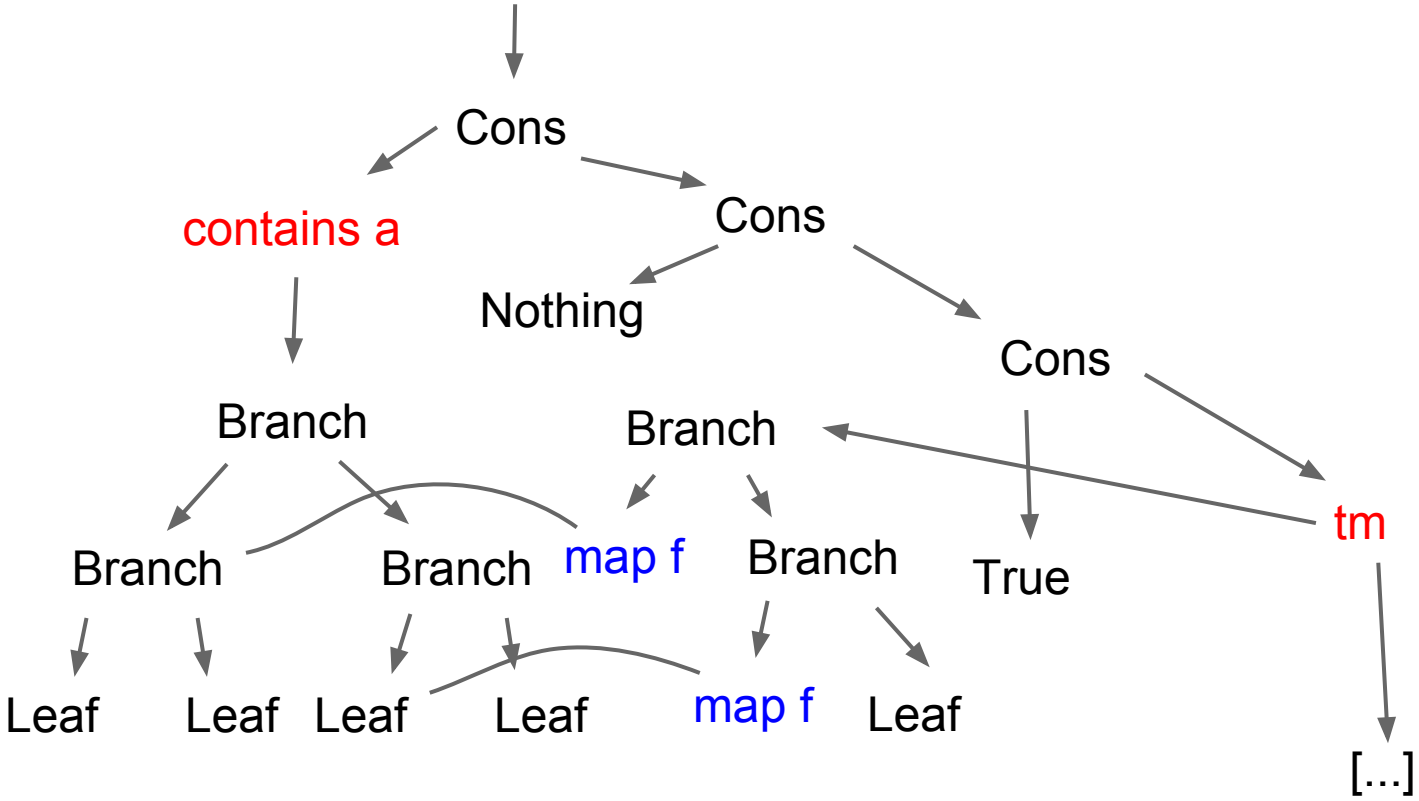

Persistent Functional Languages

ACID-State for Haskell implements many of these ideas, however:

- There are no ad-hoc transactions:
  - We can’t do schema changes on the fly
  - We can’t share the state with other programs
- GHC not optimized for this use case:
  - State is limited to main memory
  - Task scheduling not optimized for latency
- ACID-State is limited to lazy evaluation.