Sequential Programming for Replicated Data Stores

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ICFP 2019

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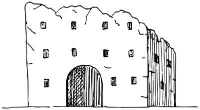
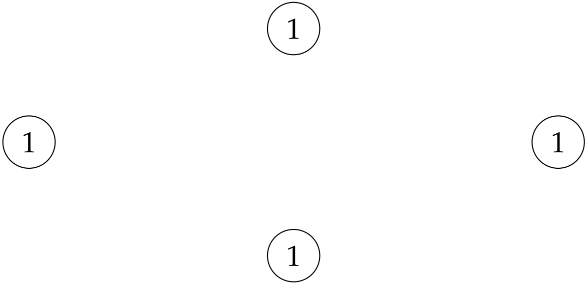


REPLICATED DATA STORES



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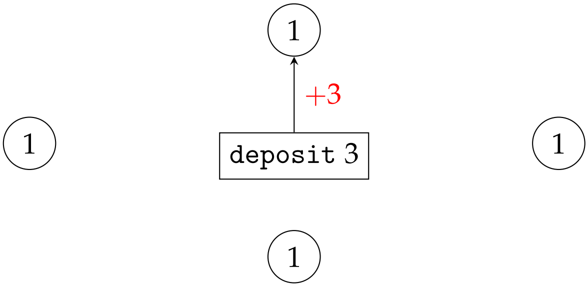

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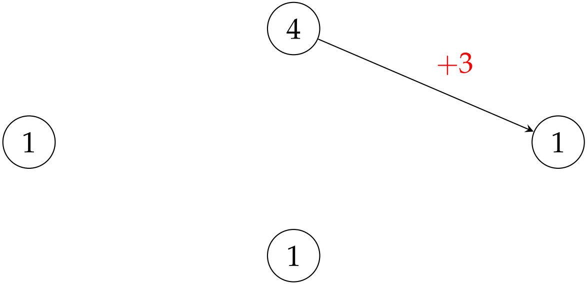

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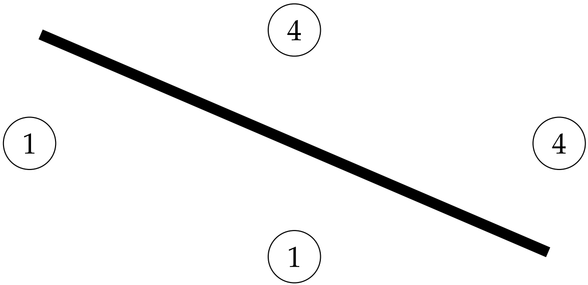

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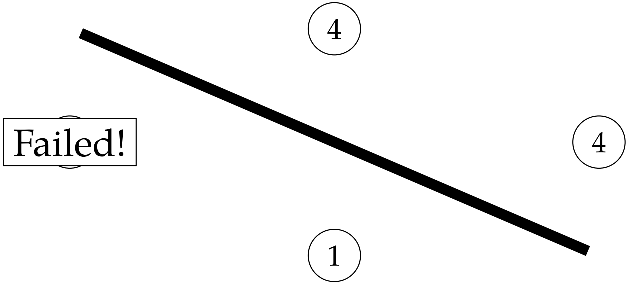

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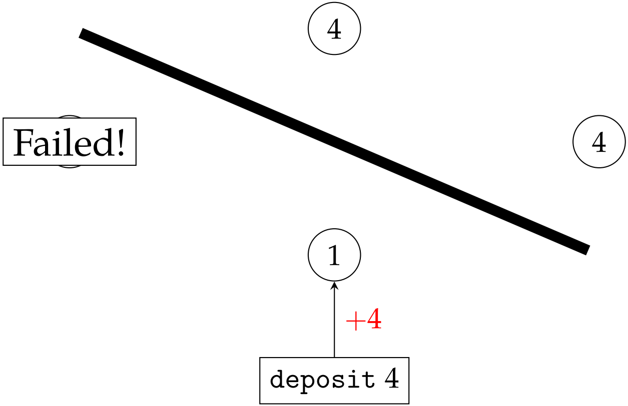

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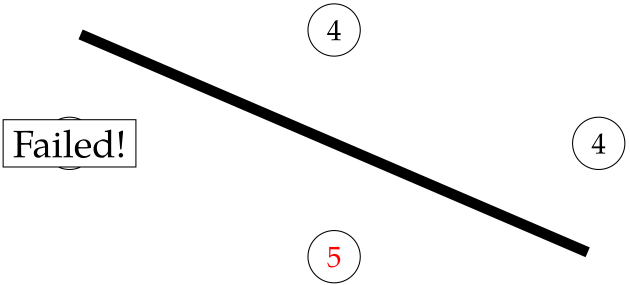

Availability

PRE- AND POST-CONDITION REASONING

Given some input to a program, what is its output?

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Consistency

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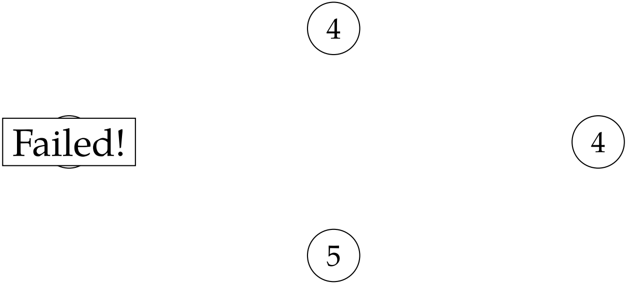

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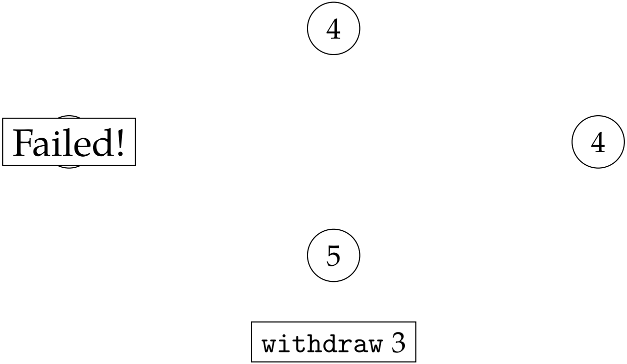


4

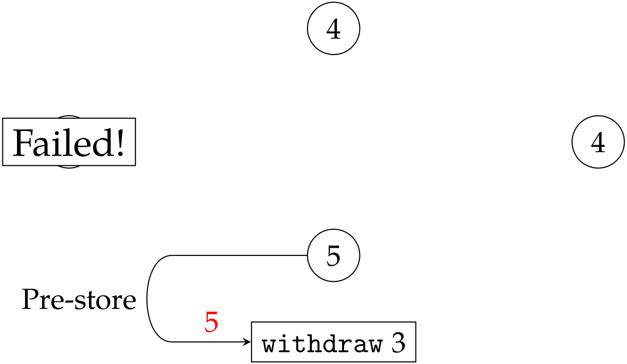
Failed!

4

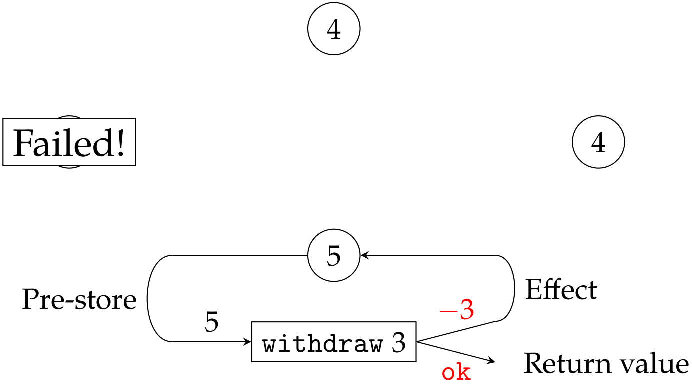
5

withdraw 3

REPLICATED DATA STORES



Replicated Data Stores



Pre-stores of `withdraw 3`: 5✓

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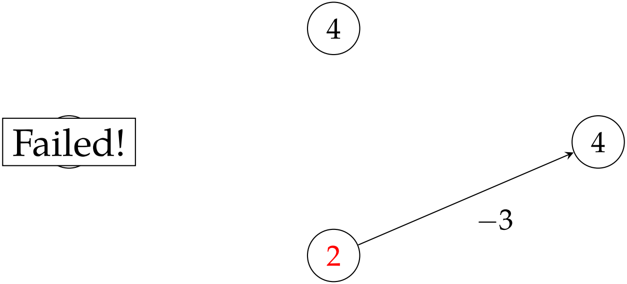

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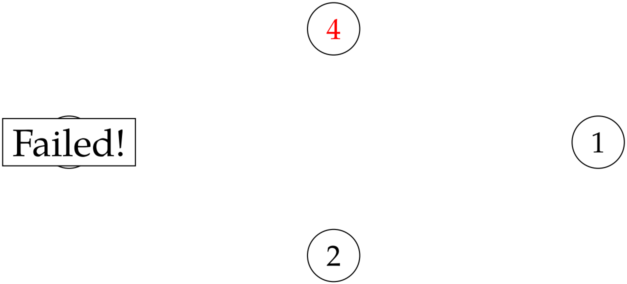

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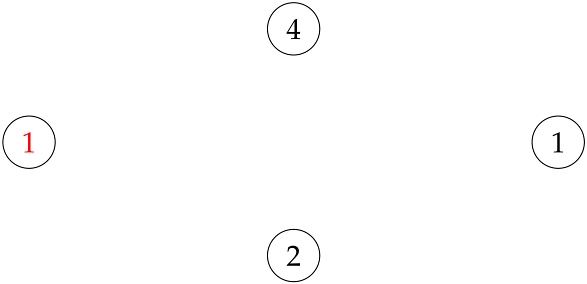

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AN UNFORTUNATE CONFLICT

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We don't…

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- Consistency: pre/post logic can be enforced
- Availability: a called operation always returns a response
- Partitions: the network may drop arbitrary messages

CAP Theorem: You can only have two.

AN UNFORTUNATE CONFLICT

So how do we maintain both consistency and availability?

We don't…

- Consistency: output depends on complete input
- Availability: output must eventually be returned
- Partitions: complete input might never arrive

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Partitions are unavoidable for a distributed system.

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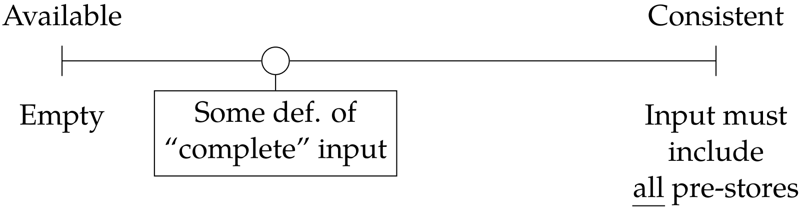

Available

Consistent

Empty

Some def. of “complete” input

Input must include all pre-stores

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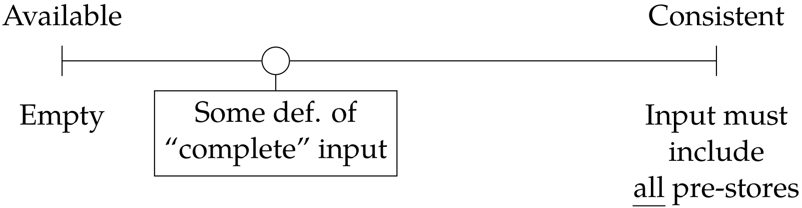

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Made possible by a novel replicated store runtime.

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First, let's deposit money.

$$\texttt{deposit} := \lambda n.\ \textbf{issue}\ (\texttt{Add}\ n)\ \textbf{in}\ n$$

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A **query** term can be annotated with a consistency guard, which the runtime enforces until termination of the operation.

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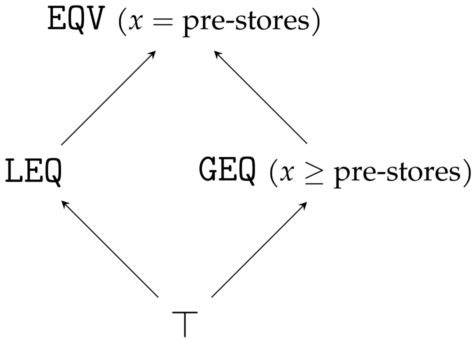

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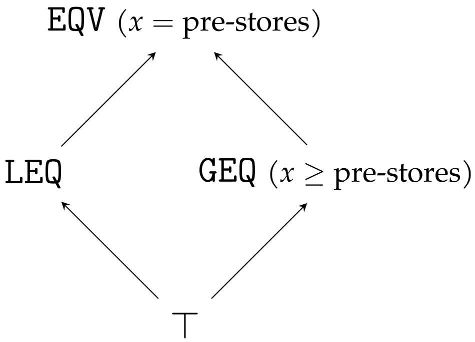
`LEQ`

`GEQ` ($x \geq$ pre-stores)

$\top$

Guards: consistency level domain based on data refinements.



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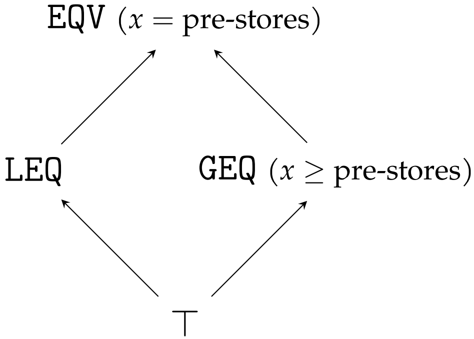

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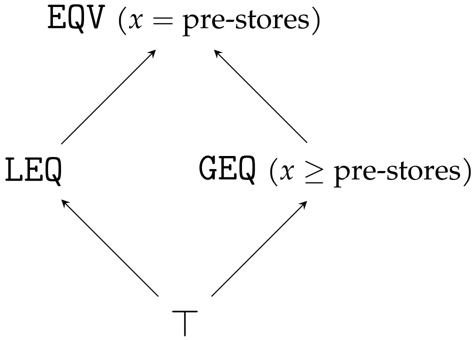

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Special Task 0 ✓

THE CAROL TYPE SYSTEM

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Everything is an operation!

$$\vdash 5 : \{\ \mathbf{Op}\ D\ \texttt{Int} \mid \mathbf{e} = \texttt{id} \wedge \mathbf{r} = 5\ \}$$

VERIFYING WITHDRAW

$$\varphi := (\mathbf{s} \geq 0 \Rightarrow [\![\mathbf{e}]\!](\mathbf{s}) \geq 0) \wedge (\mathbf{r} = \mathbf{s} - [\![\mathbf{e}]\!](\mathbf{s}))$$

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Special Task 2 ✓

SO WHO'S PAYING FOR THIS?

Programmer only needs local, sequential reasoning…

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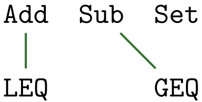

`Add` `Sub` `Set`

`LEQ` `GEQ`

Accords tell the runtime which effects are safe during a query.

Theorem: If {guard} is in accord with {effect}, then a query using {guard} can safely return without including {effect}.

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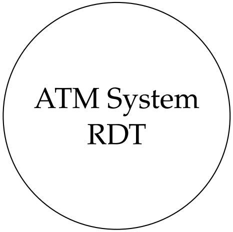

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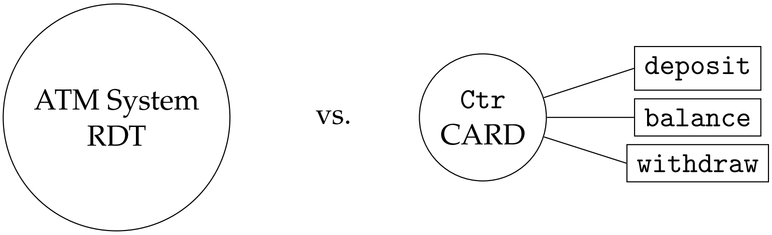

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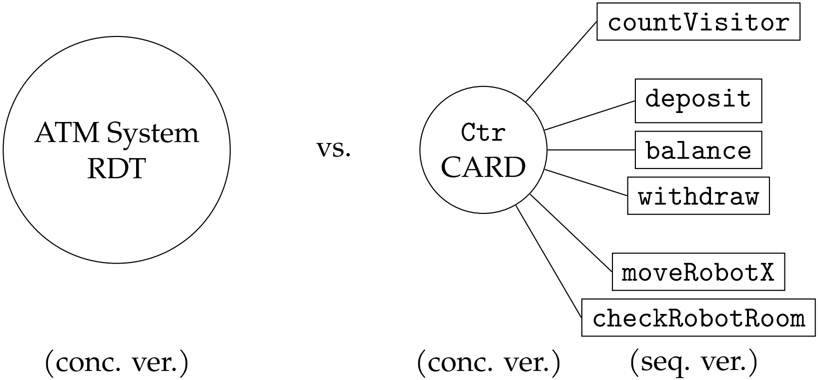

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Extending semantics/language

- Direct messages for safety-preserving side deals.

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- Haskell DSL and runtime implementation: `https://github.com/cuplv/discard`