Accumulation Analysis

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- Accumulation typestate automata include **important problems** like resource leaks, security vulnerabilities, and initialization
- For accumulation typestate problems, an accumulation analysis is **sound, precise, and fast**

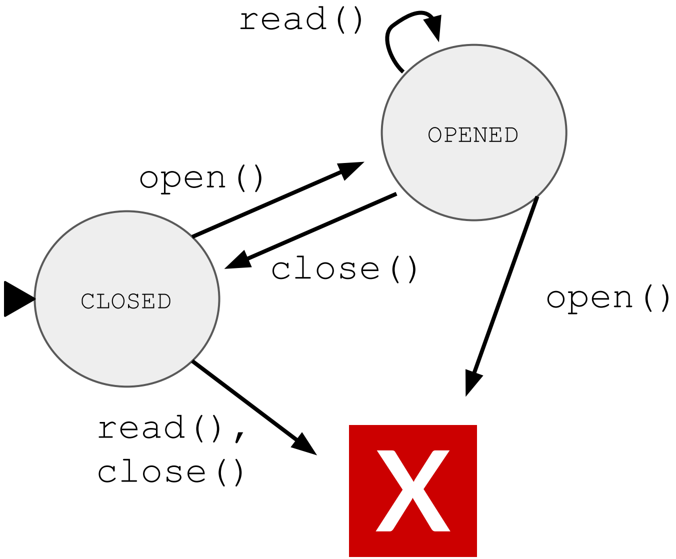
Talk outline

- Background on typestate
- Accumulation analysis
  - definitions & examples
  - proofs
- Literature survey
- Implications for practicality

Typestate analysis

- Classic static program analysis technique (Strom & Yemeni, 1986)
- Extensive literature: **over 18,000** hits on Google Scholar

Typestate specification via FSM



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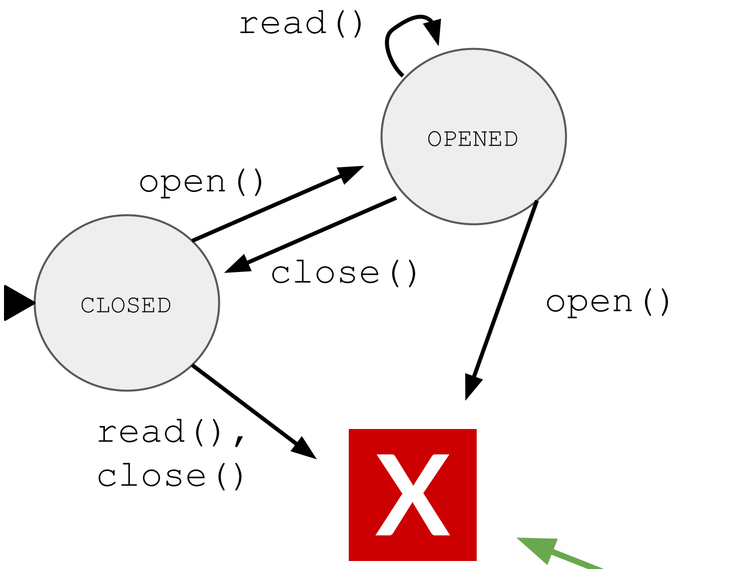

Our goal: ***prove*** that no File ever enters this state

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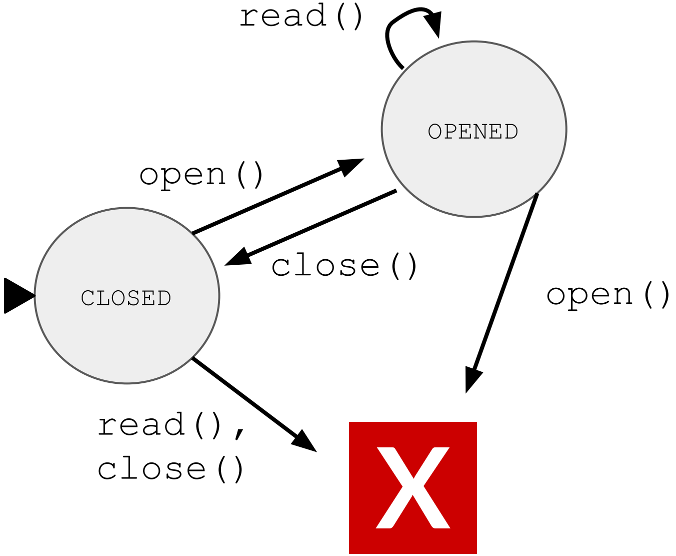


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f.read();
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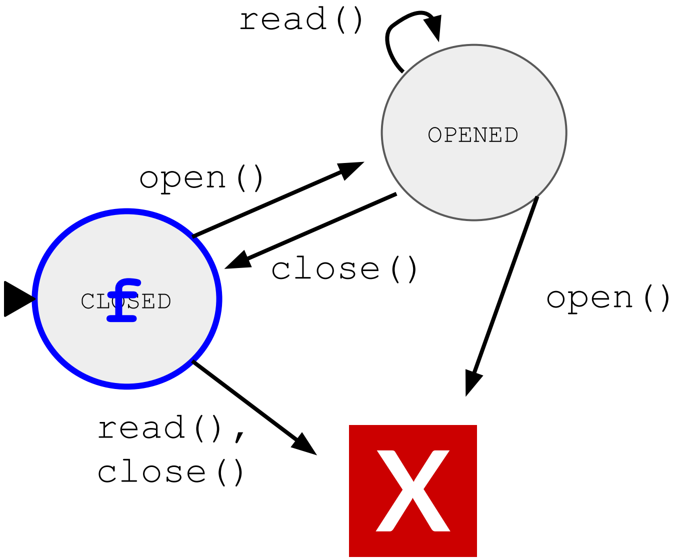


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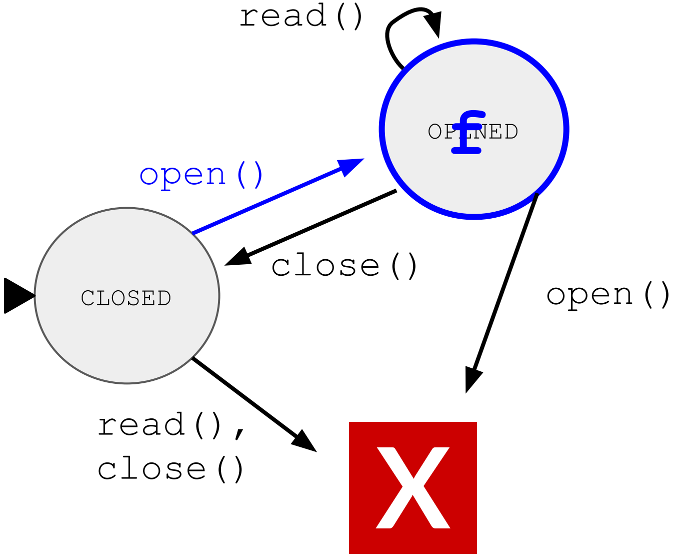


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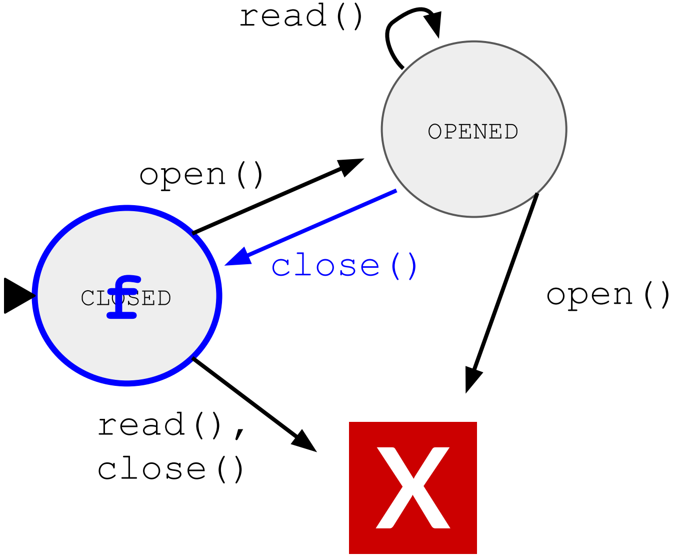


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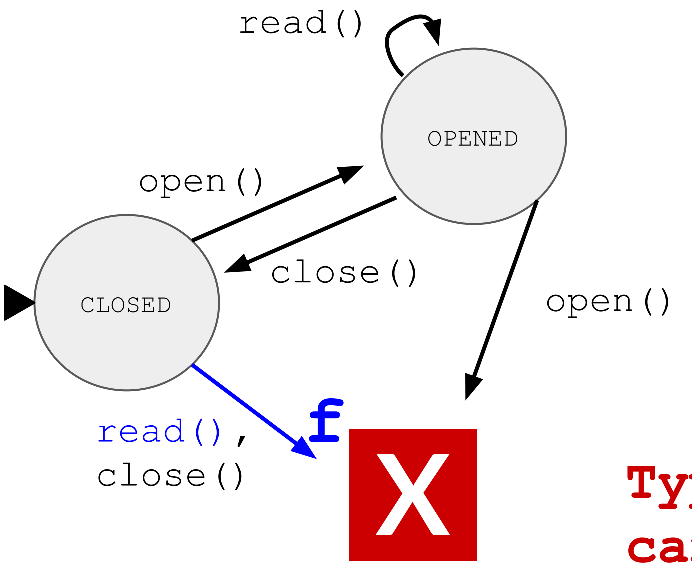


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Typestate error: f cannot read() in state CLOSED

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Soundness is **important**:
- enables verification vs. bug finding
- mission-critical domains

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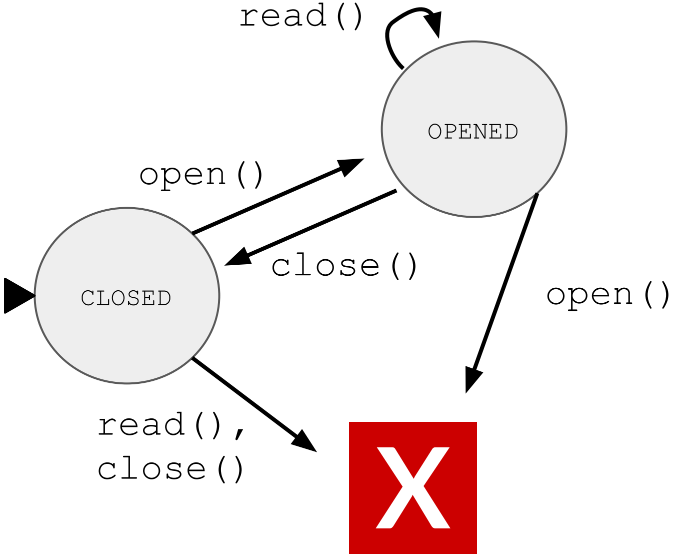


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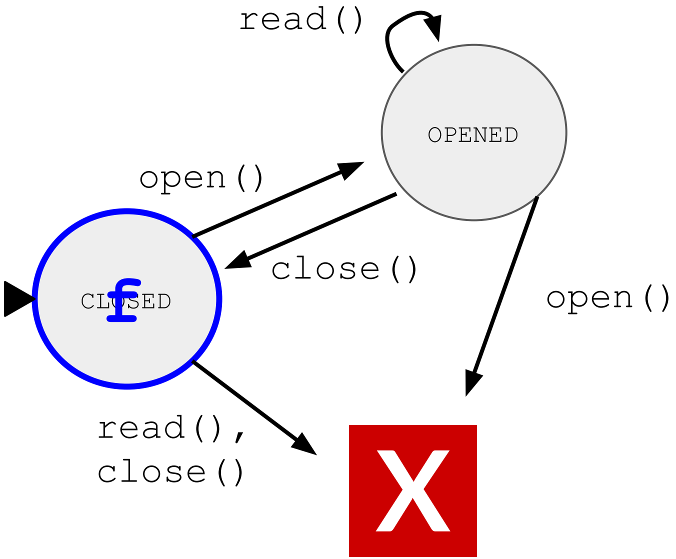


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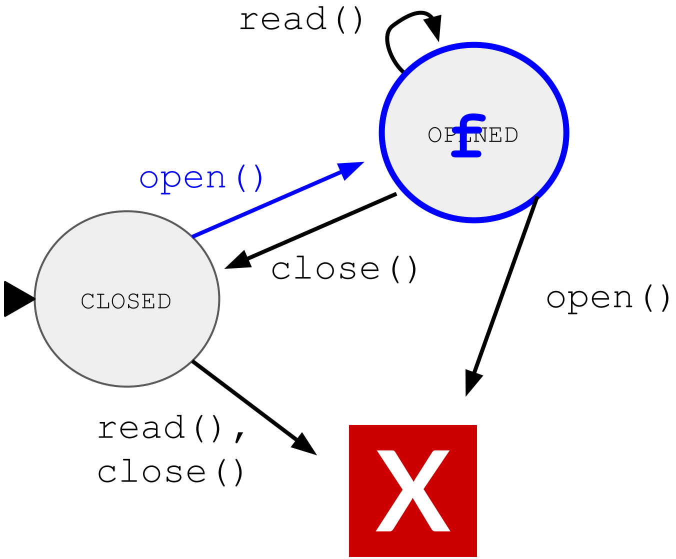


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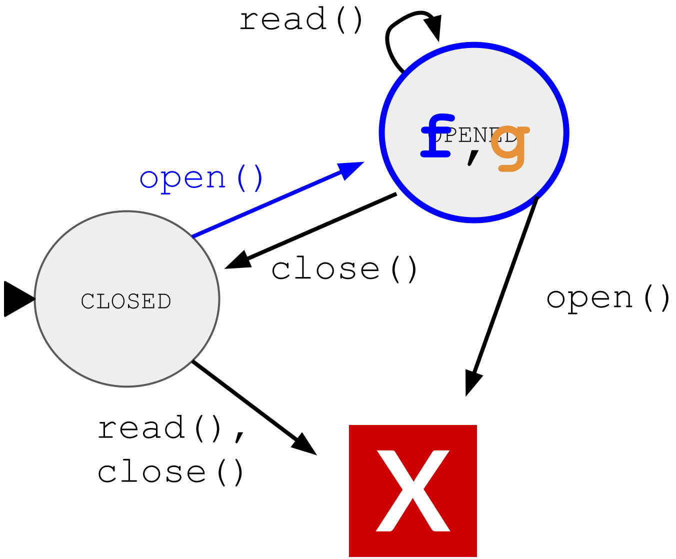


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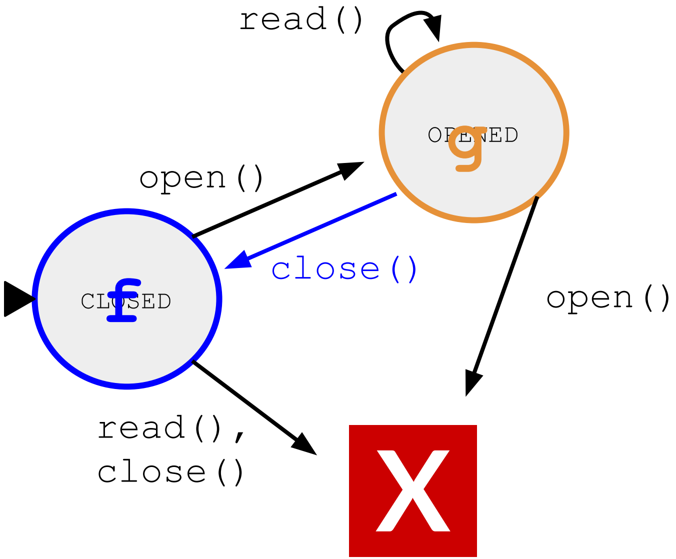


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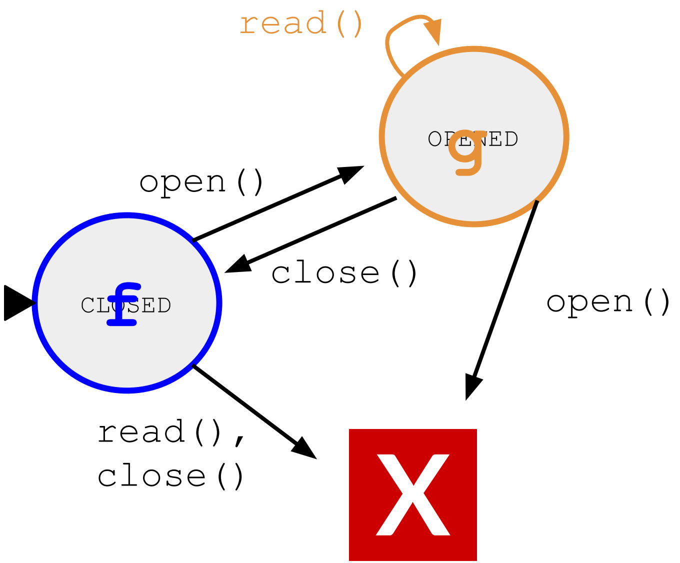


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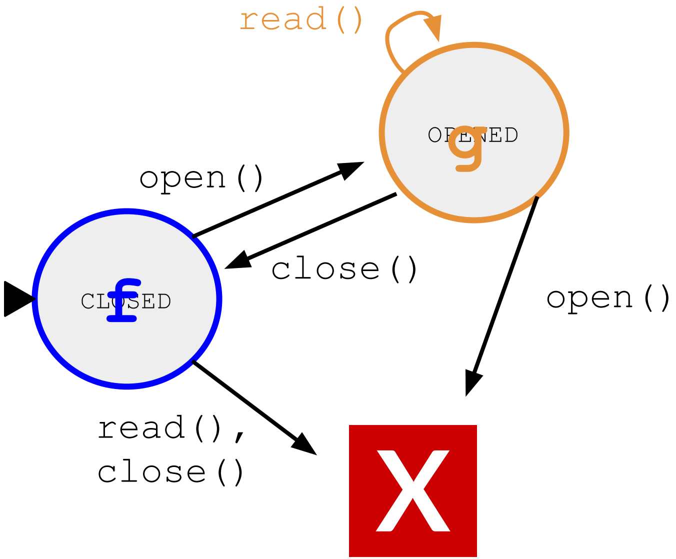


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“false negative”

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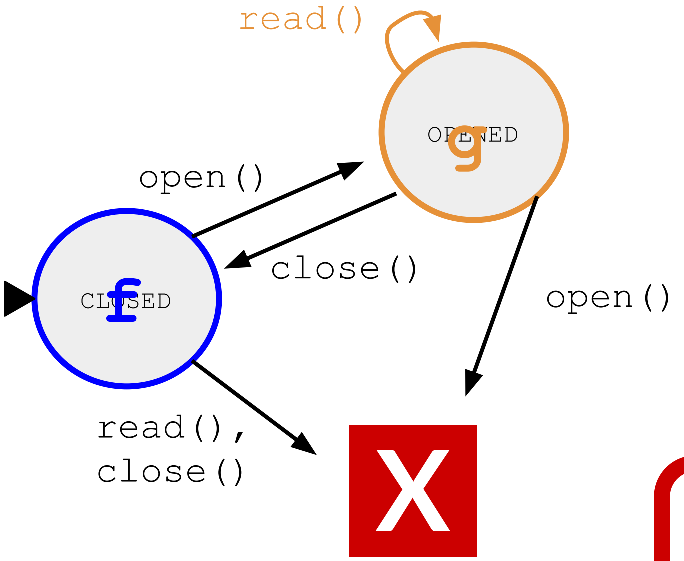


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"false negative" = <u>unsound</u>!

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     → Tan et al. 2021 report hours for real programs

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- Three prior approaches:
    1. **whole-program** may-alias analysis (expensive)
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        → e.g., Bierhoff et al. 2009, Clark et al. 2013, Rust

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  3. **ignore aliasing** and be unsound (due to cost)

     → allows industry deployment, e.g., Emmi et al. 2021

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Key question: does typestate analysis *always* need aliasing information?

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Key intuition: once an operation ***becomes legal***, it ***stays legal***

Accumulation typestates

accumulation typestate automaton:

for any **error-inducing sequence** $S = t_1, \ldots, t_i$,

all **subsequences** of S that end in t_i

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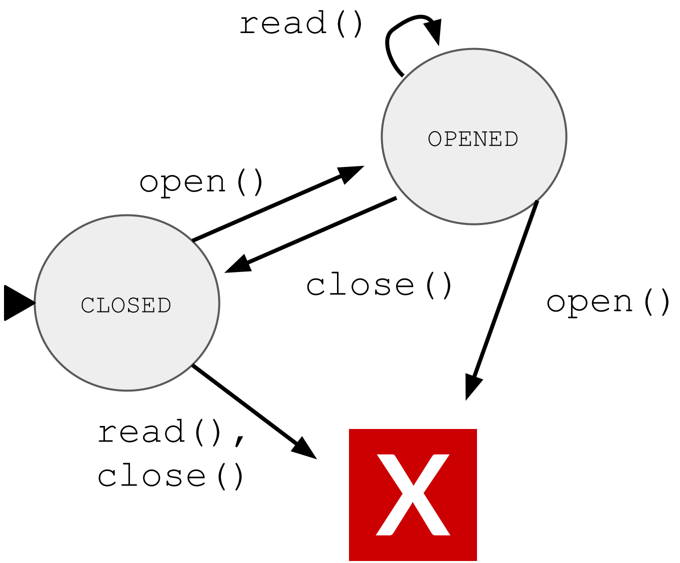

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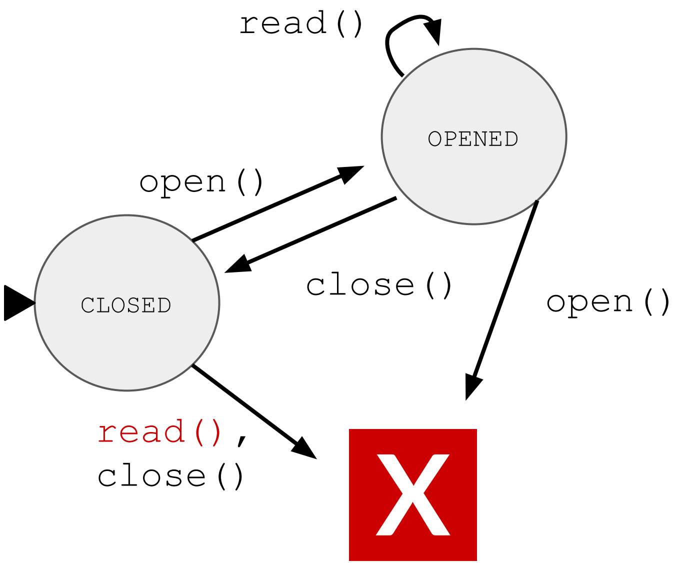

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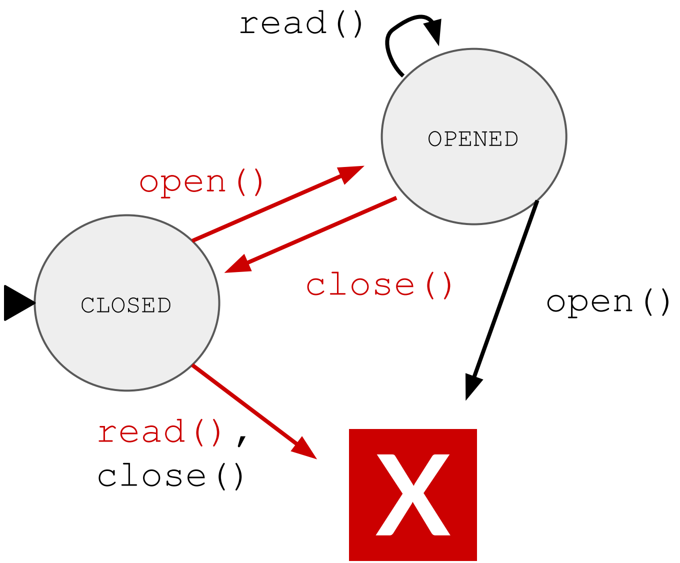

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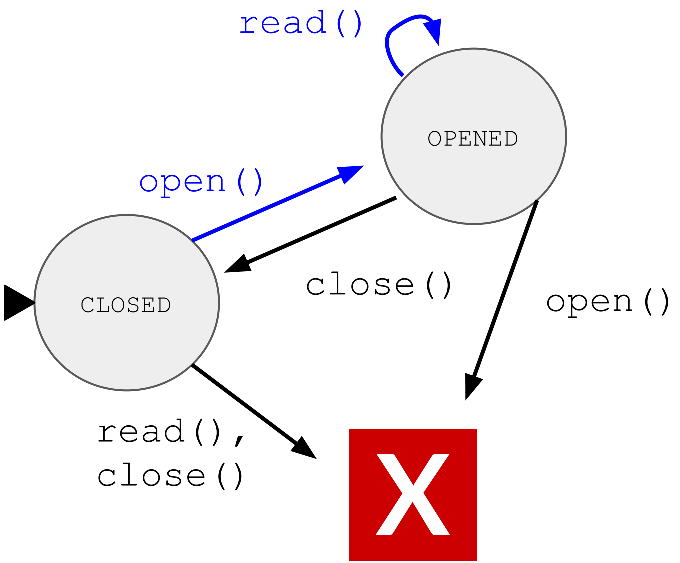

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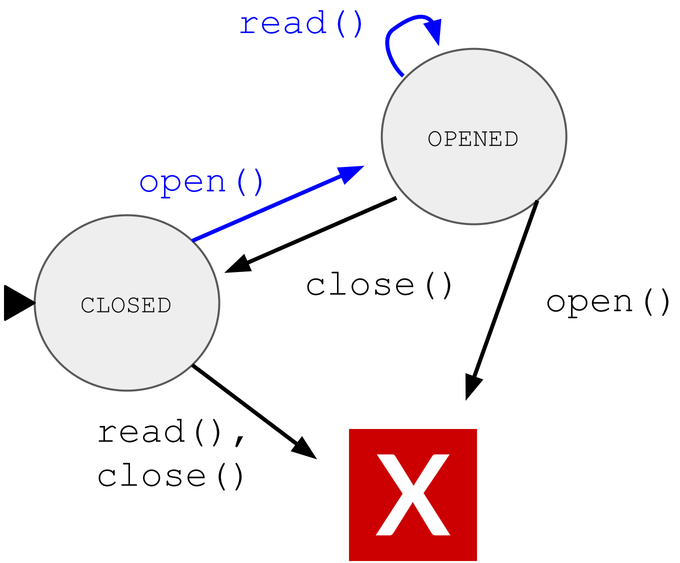

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⇒ **not accumulation**

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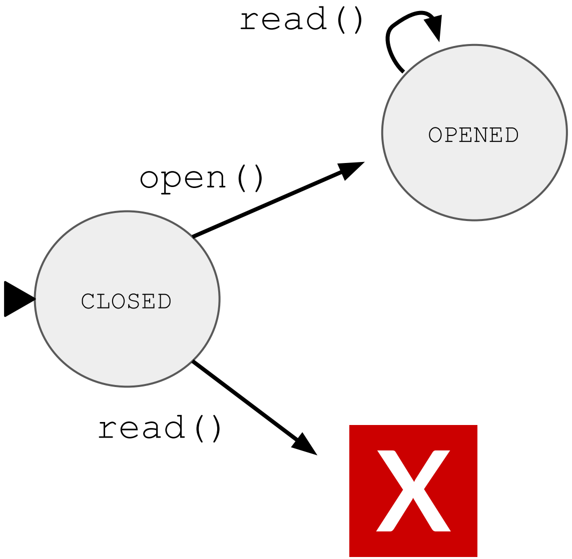

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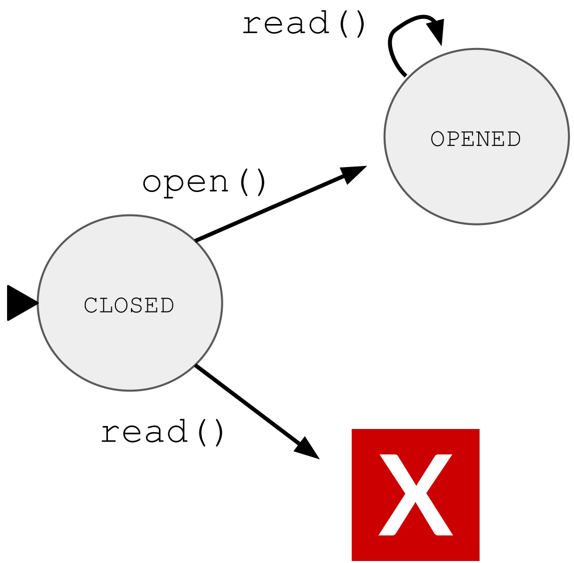

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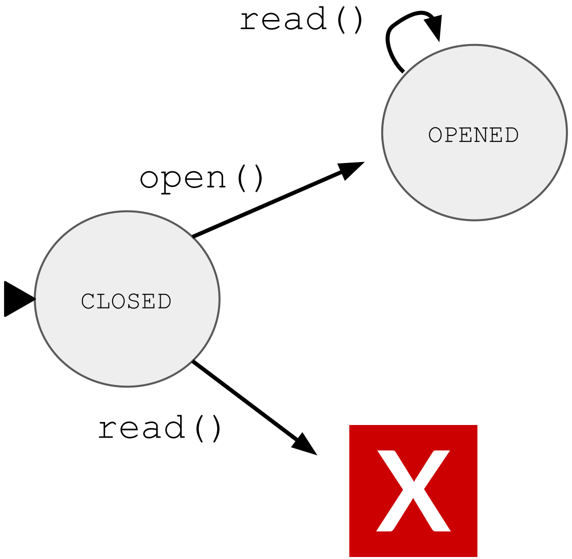

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> "The subsequence language of *any language whatsoever* over a finite alphabet is regular."

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2. this automaton has an **error-inducing sequence S** with a **non-error-inducing subsequence S'**
3. construct a program with two aliased variables: do **S - S' on the first**, and **S' on the second**

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1 $x_1 = x_2$

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the "sound" analysis misses the real error!

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67 / 302

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- Higher proportion of accumulation TSA in large collections: **more common in practice?**
- Our artifact includes all the TSAs we saw

https://doi.org/10.5281/zenodo.5771196

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Source LoC	~9.1M
True positives	16
False positives	3

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100% recall,
82% precision

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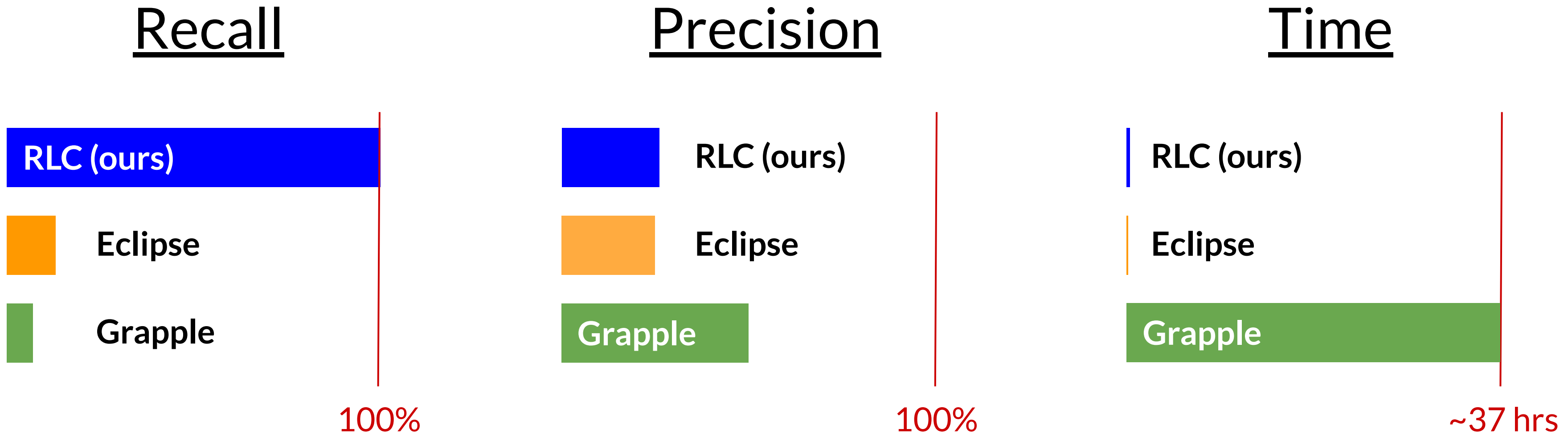

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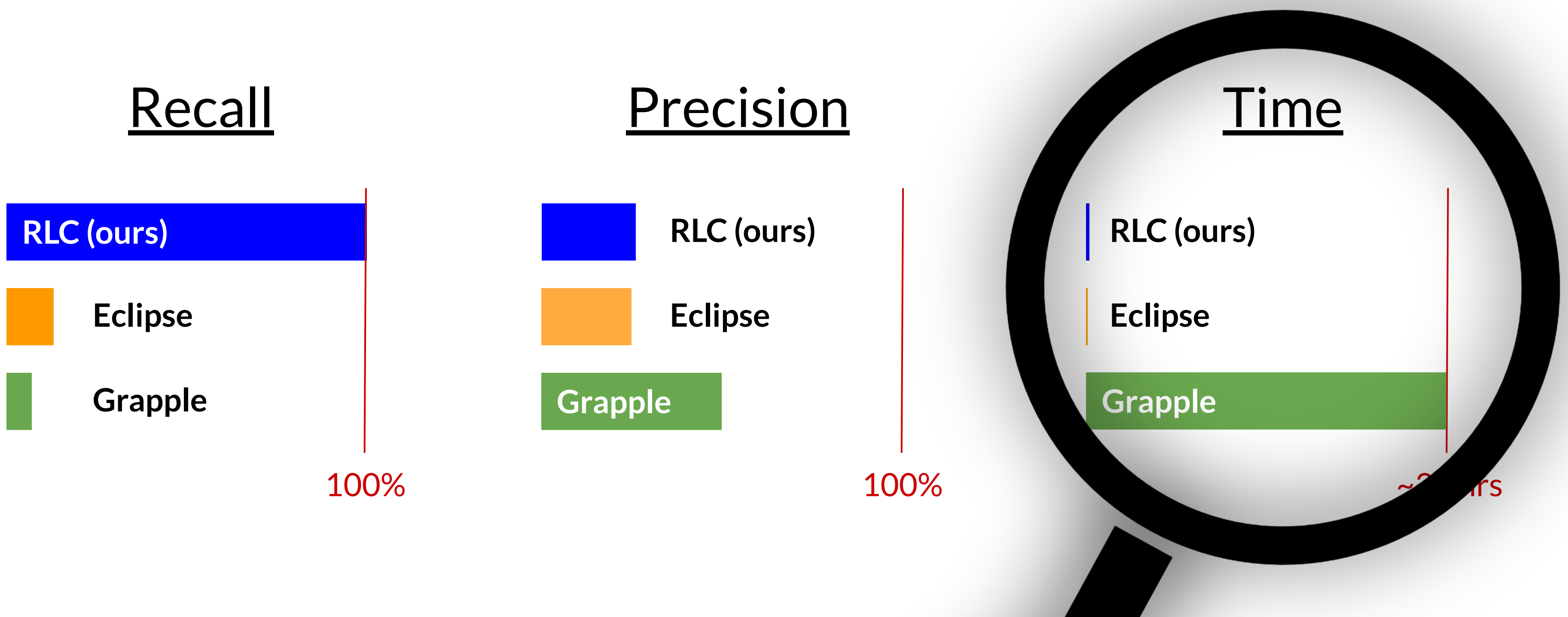

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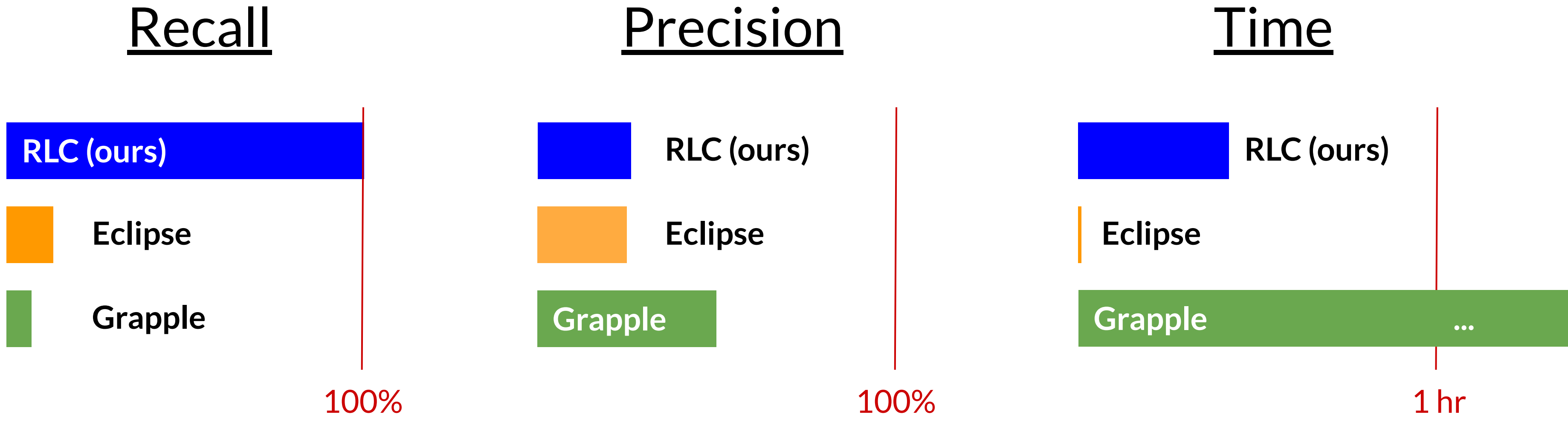

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- Important lessons:
  - when accumulation is **applicable**, it produces analyses that are **sound, precise, and fast**
  - **cheap, local alias reasoning** is always useful for **precision**
  - sound with no aliasing information ⇒ sound with limited aliasing information

Contributions

- Identification of the **accumulation typestate automata**, a new, important subset of typestates
- Proof that accumulation typestates are **exactly** those checkable **without aliasing information**
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