A Spatio-Temporal Logic for the Specification and Refinement of Mobile Systems

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Motivation

Formal description of systems with mobile code

- WAN computing, agent-based systems
- correctness non-obvious, including security issues

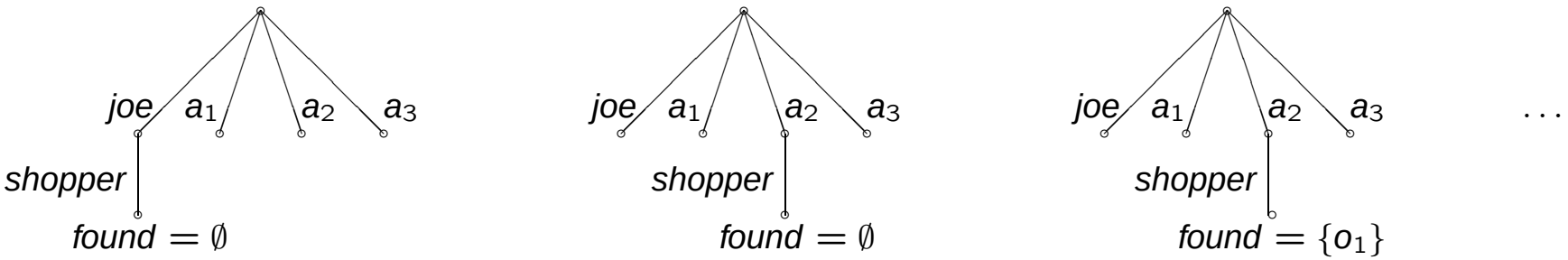
Existing formalisms for mobile systems

- mostly based on “operational” calculi
- some have associated logics: Ambient logic, μ-calculus for Klaim
- “intensional” semantics, reflecting structural equivalence
- no good notions of refinement

Reactive systems

- transition system semantics (next-state relation + fairness)
- well-established refinement notions
- stuttering equivalence: TLA

Basic Idea



Configurations (t, λ)

- t finite tree, edges labelled by unique names
- λ assigns local states to nodes

Computations $\sigma = (t_0, \lambda_0), (t_1, \lambda_1), \ldots$

Formulas

$shopper\langle found = \emptyset\rangle$	location *shopper* exists without found goods
$joe.shopper \gg a_2.shopper$	*shopper* moves from location *joe* to location a_2

MTLA (Mobile Temporal Logic of Actions)

TLA

- Linear Temporal Logic with formulas $\Box[\mathcal{A}]_v$
- Important feature: invariance under finite stuttering

+ Spatial Formulas

- Explicit name references $n[F]$
  - F holds at n ... provided n exists
  - NB: n may be arbitrarily far down the tree
- Structural modification of trees $\alpha.n \gg \beta.n$
  - subtree at αn before transition equals subtree at βn after transition
  - local state at moving subtree preserved

Refinement of mobile systems

Operation refinement

- decompose high-level operations
- represented in TLA by implication, thanks to stuttering invariance

Spatial decomposition

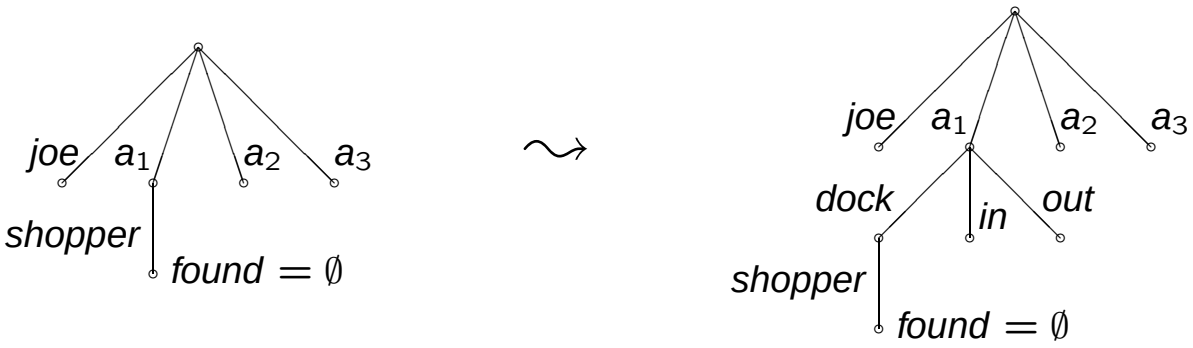
- refine high-level location *n* into a tree (with root named *n*)
- in general also distribute local state of *n*

Virtualisation of locations

- implement high-level location *n* by structurally different hierarchy
- preserve external behavior : *n* hidden from high-level interface

Spatial decomposition

Suppose visiting agents are kept in a “dock” location



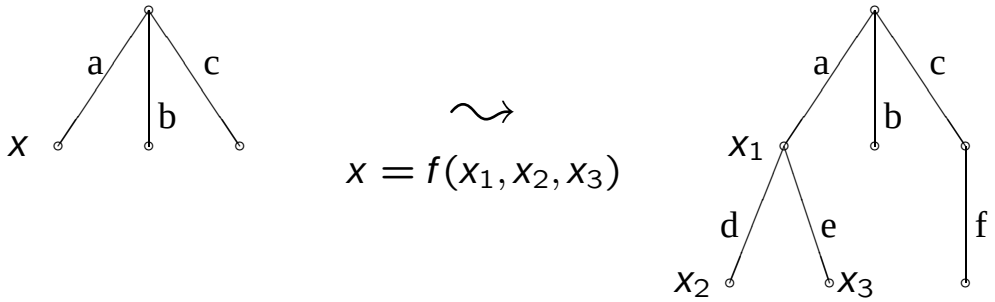
Still conforms to the original specification

- formula *Shopper* doesn’t mention locations *dock*, *in*, *out*
- location *shopper* is still below location a_1

Refinement is expressed as $\quad Impl \;\Rightarrow\; Spec$

Spatial decomposition: general case

Usually, decomposition requires distribution of state



Refinement is then expressed as $\quad Impl \;\Rightarrow\; \exists\, a.x : Spec$

local state variable x hidden from high-level interface

Virtualisation of locations

Hide entire locations, not just local state

External behavior preserved except for location *n*

- formally expressed by quantification over locations
- spatial refinement mappings

Refinement is expressed as $\quad Impl \;\Rightarrow\; \exists\!\!\!\!\!\!\;\; n : Spec$

Summing up

TLA'ish logic for specification of mobile systems

- add (few) spatial operators to describe topology
- concise description of system structure and its evolution

Refinement concepts represented as implication

- stuttering invariance supports operation refinement, as in TLA
- "deep" spatial operators support spatial decomposition

Future work: axiomatization, decidability, model checking