Outline

Lecture 1, part 1

- Motivation
- Model Checking

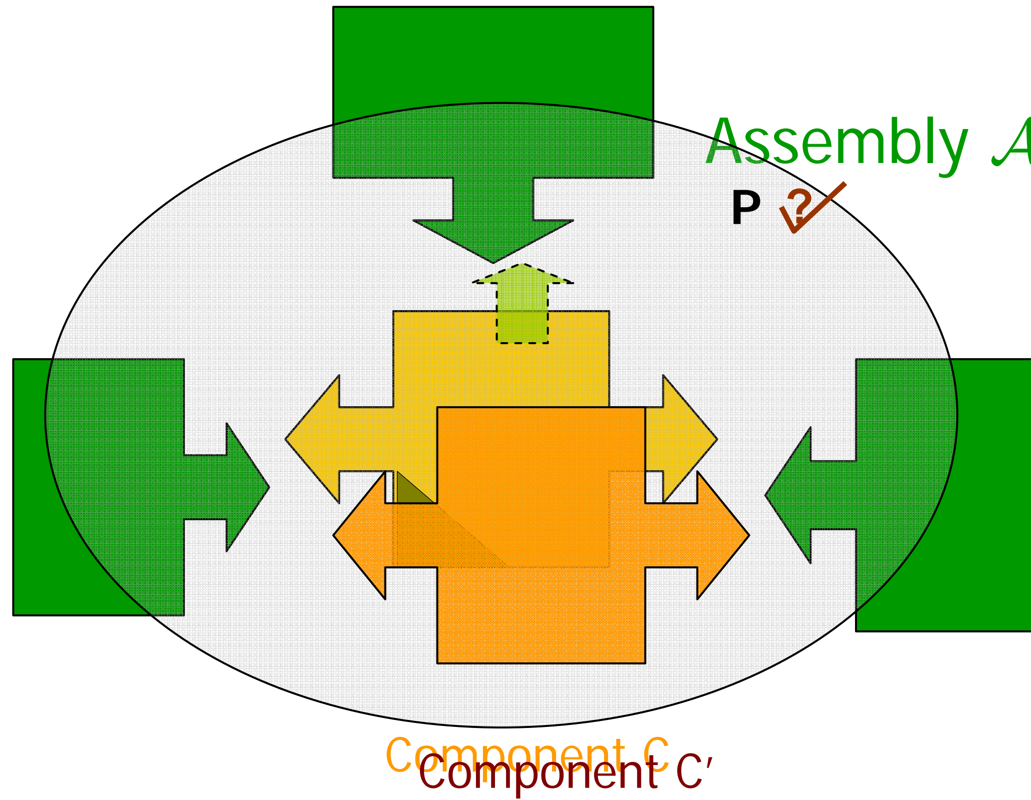
Lecture 1, part 2

- State/Event-based software model checking

Lecture 2

- Component Substitutability

Substitutability Check



Motivation

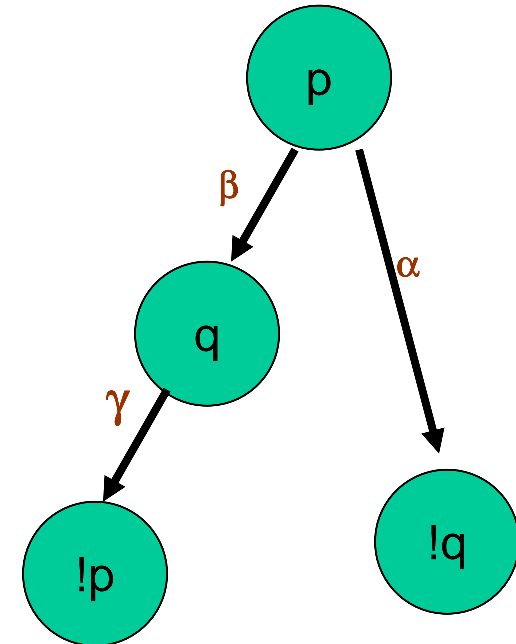
- Component-based Software
  - Software modules shipped by separate developers
  - An assembly consists of several components
  - Undergo several updates/bug-fixes during their lifecycle
- Component assembly verification
  - Necessary on update of any component
  - High verification costs of global properties
  - Instead check for substitutability of new component

Substitutability Check

- Given old and new components C, C' and assembly $\mathcal{A}$
  - Check if C' is substitutable for C in $\mathcal{A}$
- Two phases:
  - Containment check
    - All behaviors of the previous component contained in new one
  - Compatibility check
    - Safety with respect to other components in assembly: all global specifications satisfied
- Formulation
  - Obtain a finite behavioral model of all components by abstraction: labeled kripke structures
  - Use regular language inference in combination with a model checker

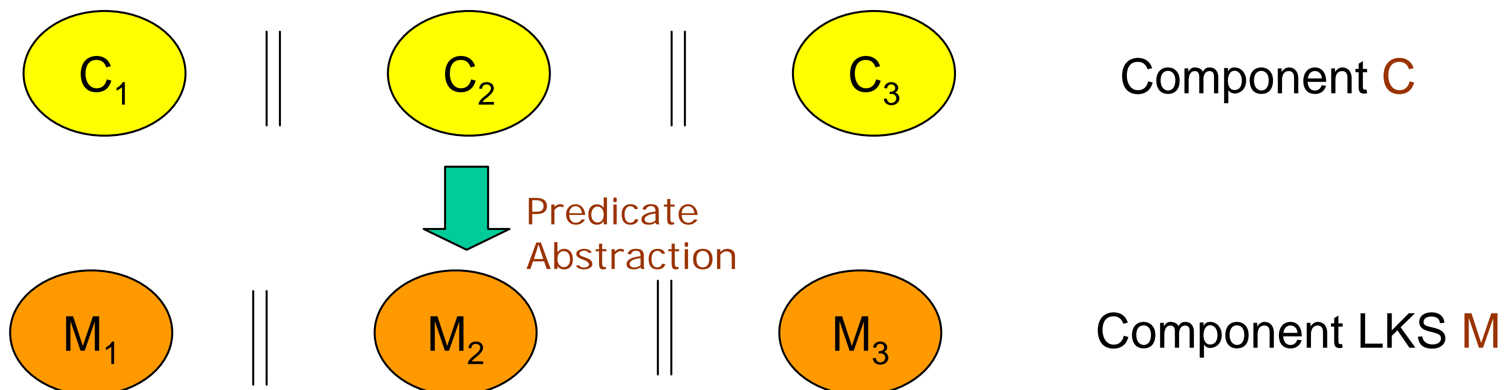
Predicate Abstraction into LKS

- Labeled Kripke Structures
  - <Q,Σ,T,P,$\mathcal{L}$>
- Composition semantics
  - Synchronize on shared actions
- Represents abstractions
- State-event traces
  - <p,β,q,γ, …..>



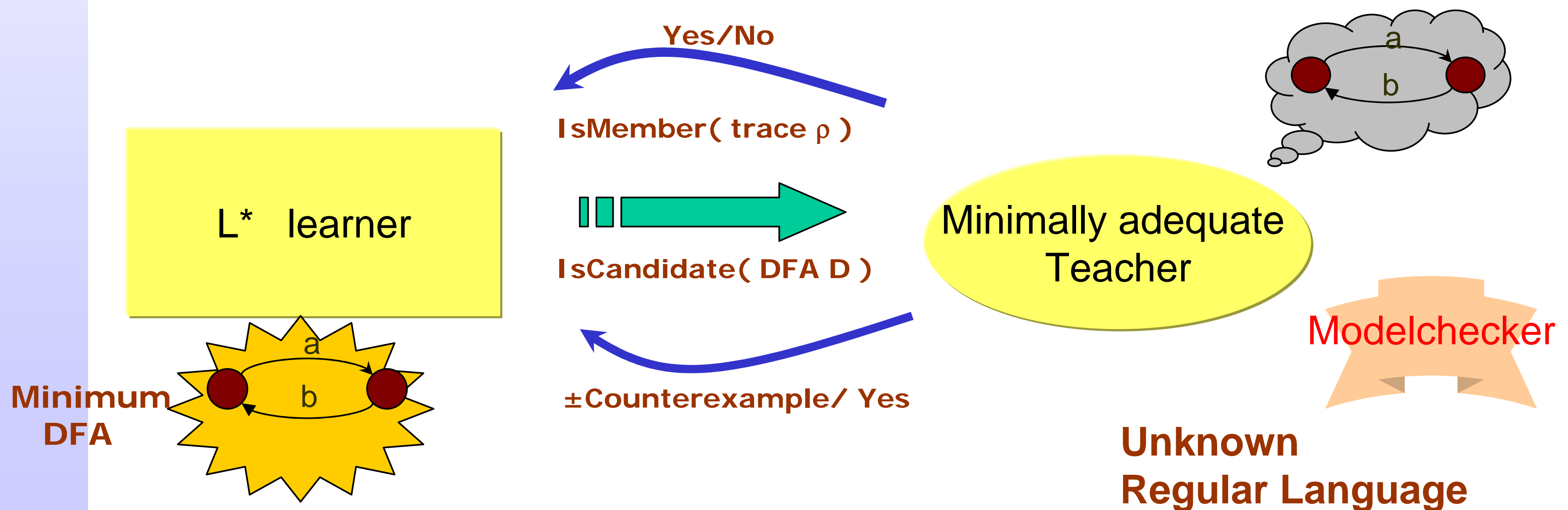
Component Interface LKS

- Component
  - A set of communicating concurrent C programs or libraries
    - No recursion, inlined procedures
  - Abstracted into a Component Interface LKS
  - Communication between components is abstracted into interface actions



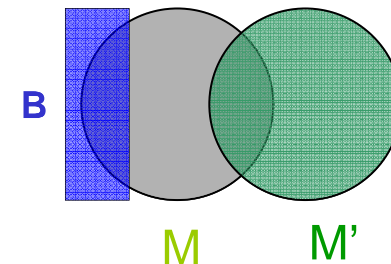
Learning Regular languages: L*

- Forms the basis of containment and compatibility checks
- L* proposed by D. Angluin
- Polynomial in the number of states and length of counterexample



Containment

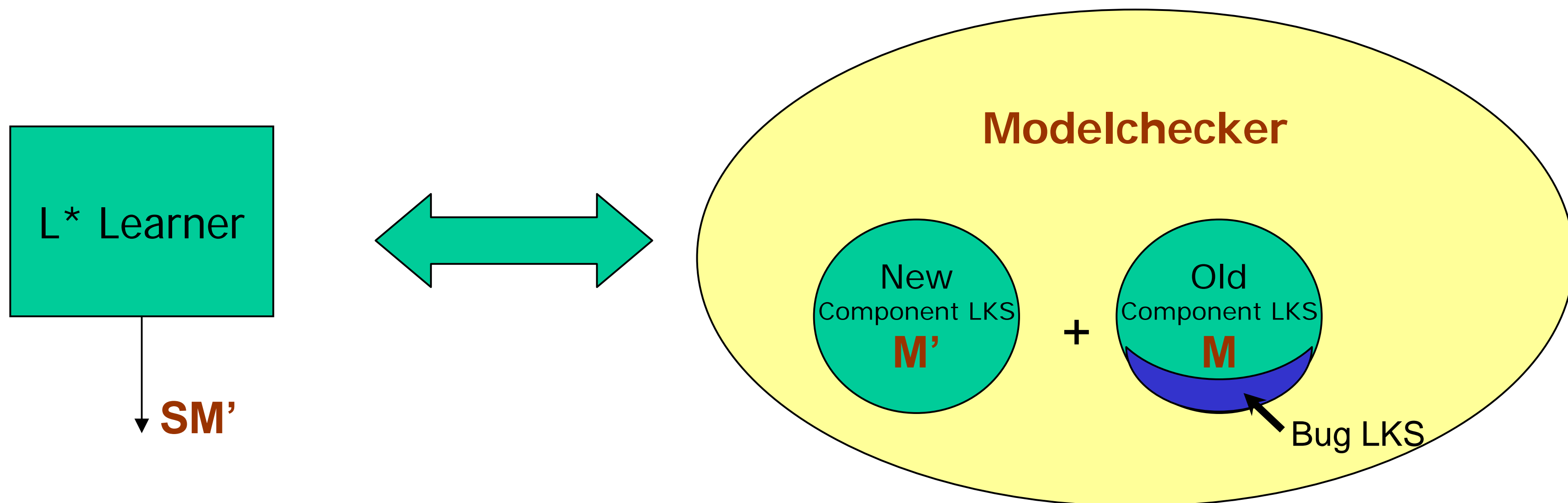
- Goal:
  - Learn useful behaviors from previous component into the new one
- Given Component LKSs: M, M' and Bug LKS B
  - Unknown $U = L(M') \cup (L(M) \setminus L(B))$
  - Iteratively learn the DFA SM'_i using L*
- Model checker
  - IsMember Query: $\rho \in U$
  - IsCandidate Query: $U \equiv L(SM'_i)$



Containment (contd.)

IsMember Query: $\rho \in U$

IsCandidate Query: $U \equiv L(SM'_i)$



Containment (contd.)

- In contrast to known Refinement-based approaches
  - Containment allows adding new behaviors in M'
    e.g. M, M' have different interleavings of same interface actions
  - Erroneous new behavior detected in Compatibility check
- Finally SM'
  - substitutable candidate
  - may not be safe with respect to other components
  - must verify the global behavioral specifications

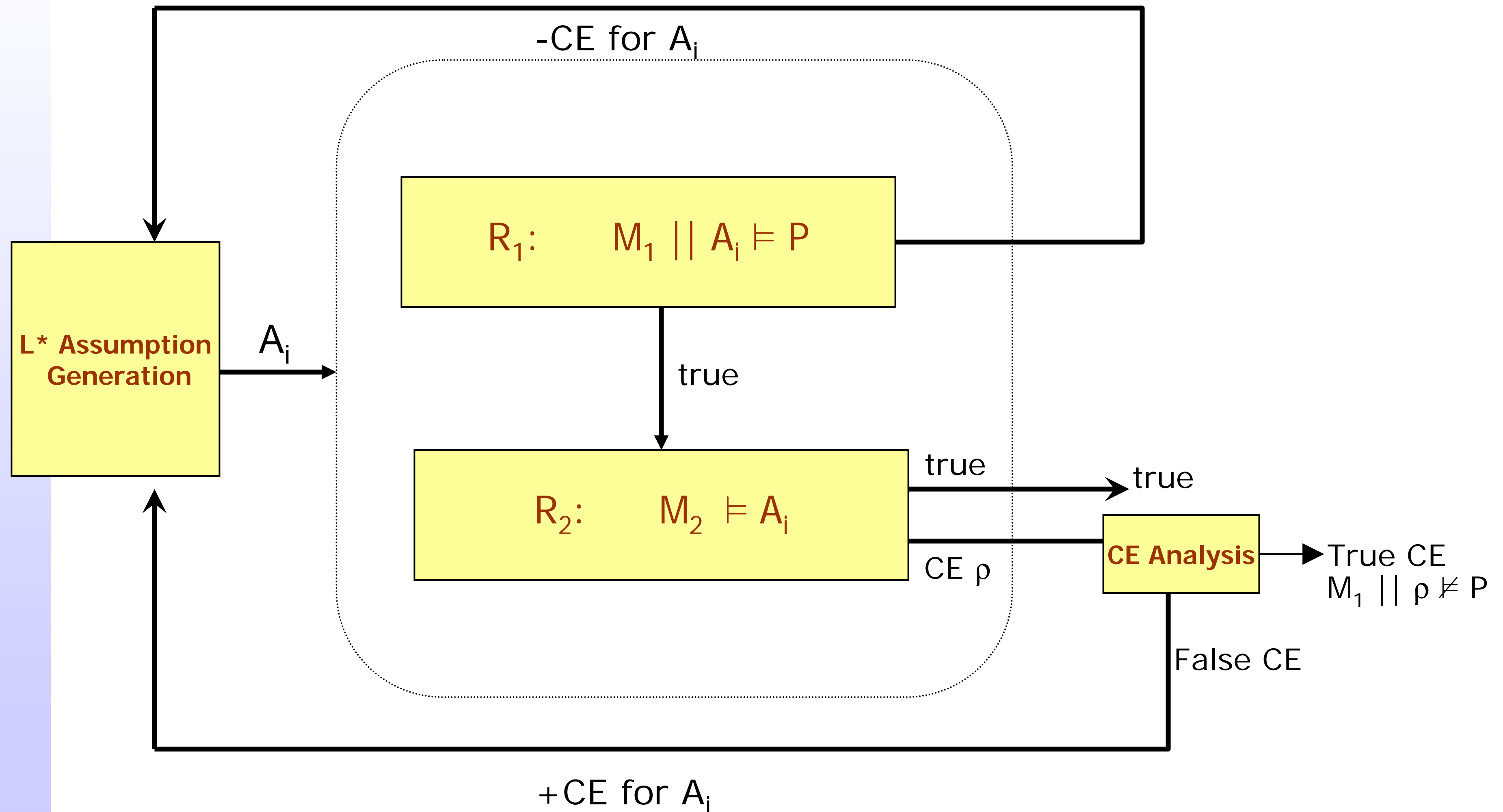
Compatibility check

- Assume-guarantee to verify assembly properties

$$
\begin{array}{ll}
R_1: & M_1 \parallel A \vDash P \\
R_2: & M_2 \vDash A \\
\hline
 & M_1 \parallel M_2 \vDash P
\end{array}
$$

- Generate a (smaller) environment assumption **A**
  - **A:** most general environment so that P holds
  - Constructed iteratively using L* and R_1, R_2

Compatibility check

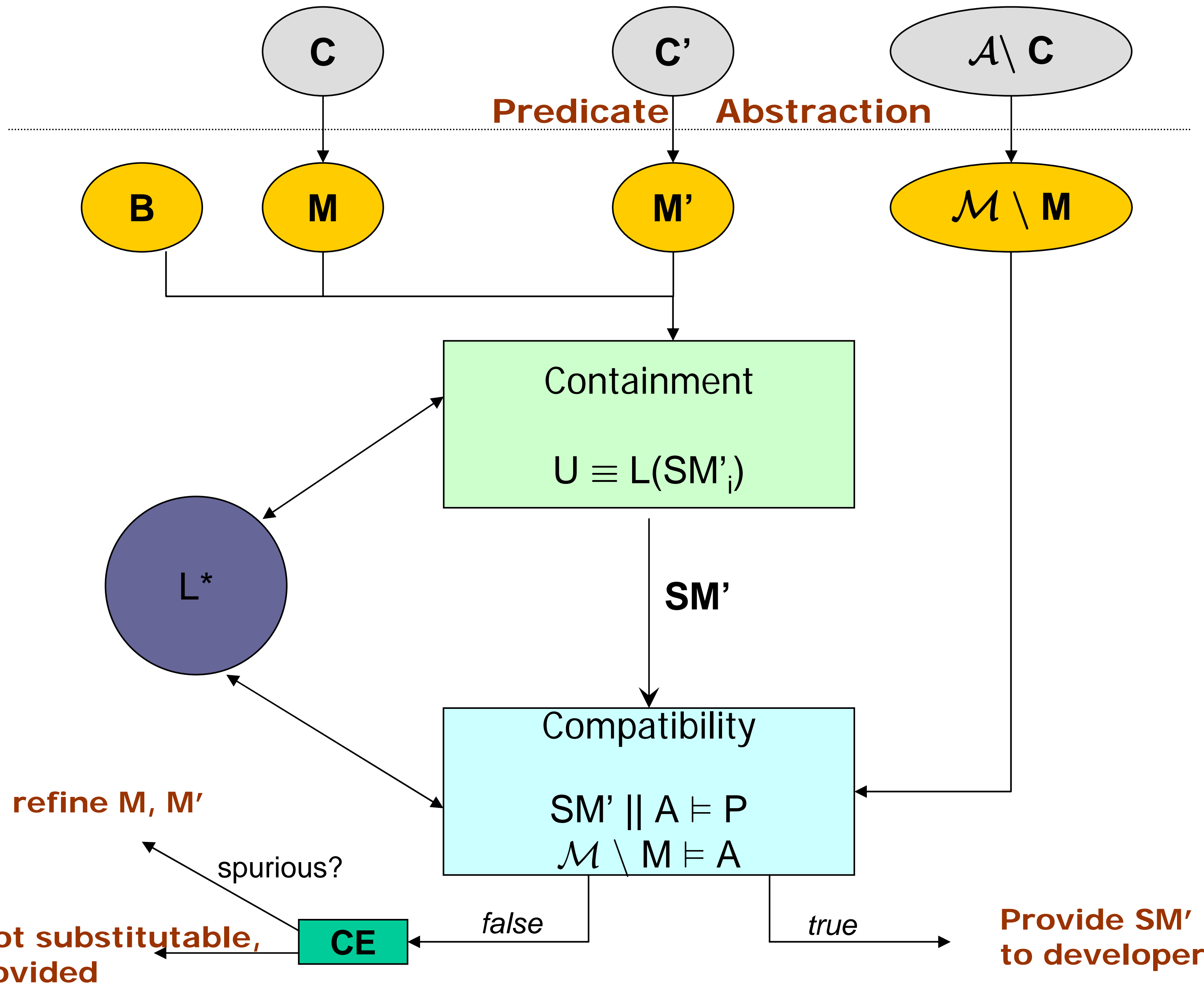


Compatibility check (contd.)

- Generate a most general assumption for SM’
  - M_1 = SM’
  - $M_2 = \mathcal{M} \setminus M$ (all other component LKSs)
- Membership queries:
  - SM’ || $\rho \subseteq$ P
- Candidate queries:
  - SM’ || A $\subseteq$ P
  - $M_2 \subseteq A$
- CE analysis: SM’ || CE $\subseteq$ P
  - Yes $\Rightarrow$ False CE
  - No $\Rightarrow$ True CE

CEGAR

- Compatibility check infers
  - Either SM’ is substitutable
  - Or counterexample CE
- CE may be spurious wrt C, C’
  - CE is present in component LKS M or M’
  - Must refine M, M’
  - Repeat substitutability check


C
C'
$\mathcal{A}\setminus$ C
Predicate Abstraction
B
M
M'
$\mathcal{M}\setminus$ M
Containment
$U \equiv L(SM'_i)$
L*
SM'
Compatibility
SM' || A ⊨ P
$\mathcal{M}\setminus$ M ⊨ A
refine M, M′
spurious?
false
true
CE
SM′ not substitutable,
CE provided
Provide SM′
to developer

Feedback to the Developer

- If SM' is substitutable
  - LKS showing how SM' differs from M'
- If SM' is not substitutable
  - counterexample showing the erroneous behavior in M'

Related Work

- Learning Assumptions: Cobleigh. et. al.
  - Do not consider state labeling of abstract models
  - Do not incorporate a CEGAR framework for AG
- Compatibility of Component Upgrades: Ernst et. al.
  - Do not consider temporal sequence of actions in generating invariants
- Interface Automata: Henzinger et. al.
  - Do not have CEGAR, AG
  - No procedure for computing interface automata

Experiments

- Prototype implementation in ComFoRT framework
- ABB IPC component assembly
  - modified WriteMessageToQueue component
  - checked for substitutability inside the assembly of four components (read, write, queue, critical section)

ComFoRT: Component Formal Reasoning Framework