Monitoring Off-the-Shelf Components

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joint work with Prasad Sistla and Lenore Zuck

Problem Description

C: off-the-shelf component

Φ_C: spec of C Φ_G : goal/user spec

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- M monitors the executions of C for violations of Φ_M

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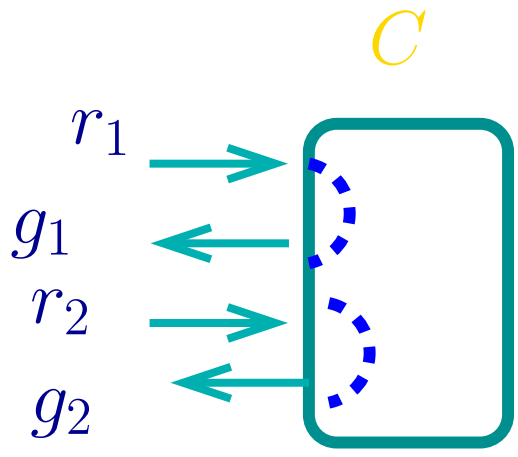
- Φ_M: as "general" as possible

Example: Permission Manager



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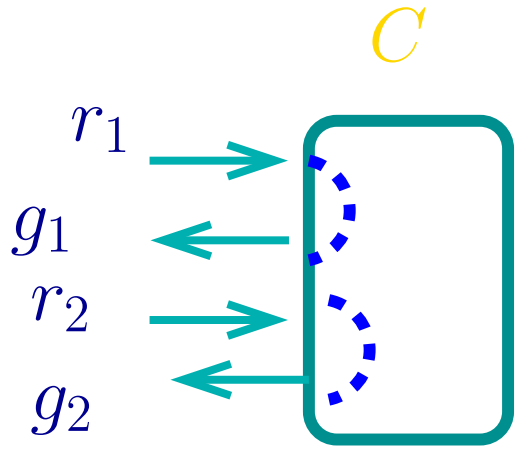

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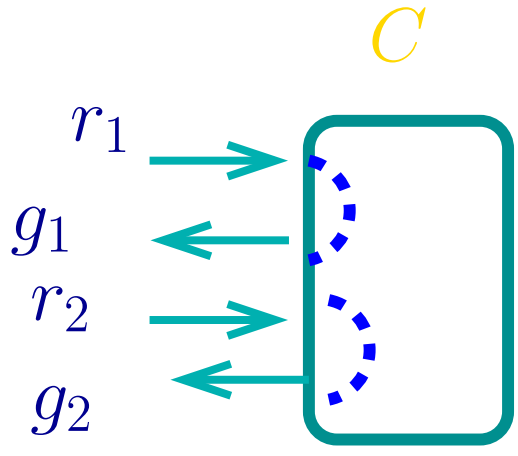

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Previous Results

- Theorem [MSSZ05]: Let $\mathcal{A}$ be a Büchi, assume $L(\mathcal{A})$ is not a safety. Then for every safety $L' \subset L(\mathcal{A})$, there exists a safety L'' s.t.

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- Generally, there is no maximal Φ_M s.t.

$$\Phi_M \rightarrow (\neg\Phi_C \vee \Phi_G)$$

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- Soundness and Completeness

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- Given: $\mathcal{A}$ - Büchi automaton (NBA)

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- For transitions from non-accepting states, decrement the counter
- For transitions from accepting states, reset the counter

Sound but Incomplete

- $L(\mathcal{A}) = \Box \Diamond P$
- $S = (P, \bar{P}, P, (\bar{P})^2, P, (\bar{P})^3, \cdots)$
- No $\mathcal{B}_k$ recognizes S

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- For transitions from non-accepting states, decrease the counter or set it to ∞ (where it remains)

Soundness and Partial Completeness

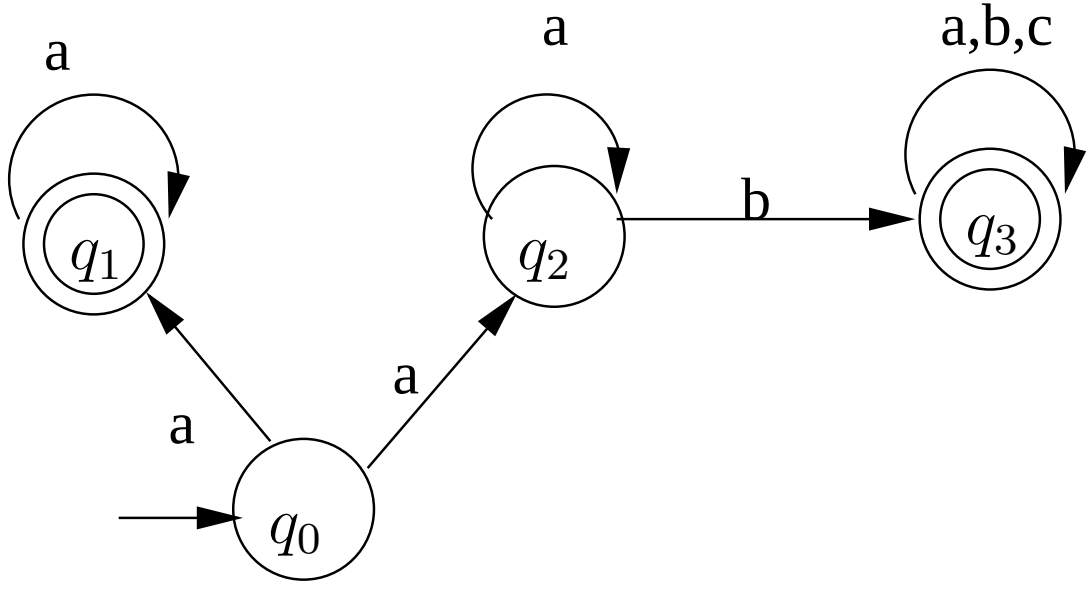
Given an automaton $\mathcal{A}$, a bounded automaton $\mathcal{N}$ over it:

- $L(\mathcal{N}) \subseteq L(\mathcal{A})$
- $L(\mathcal{N})$ is a safety
- If $\mathcal{A}$ is deterministic Büchi, $S \subseteq L(\mathcal{A})$ is safety, then there exists some bounded automaton $\mathcal{N}$ that accepts S

Why partial

$L = \{a^i b \Sigma^\omega \ : i > 0\} \cup \{a^\omega\}$

Cannot get L, only $\{a^i b \Sigma^\omega \ : 0 < i \leq k\} \cup \{a^\omega\}$ where k is the initial value of counter



Streett Automata

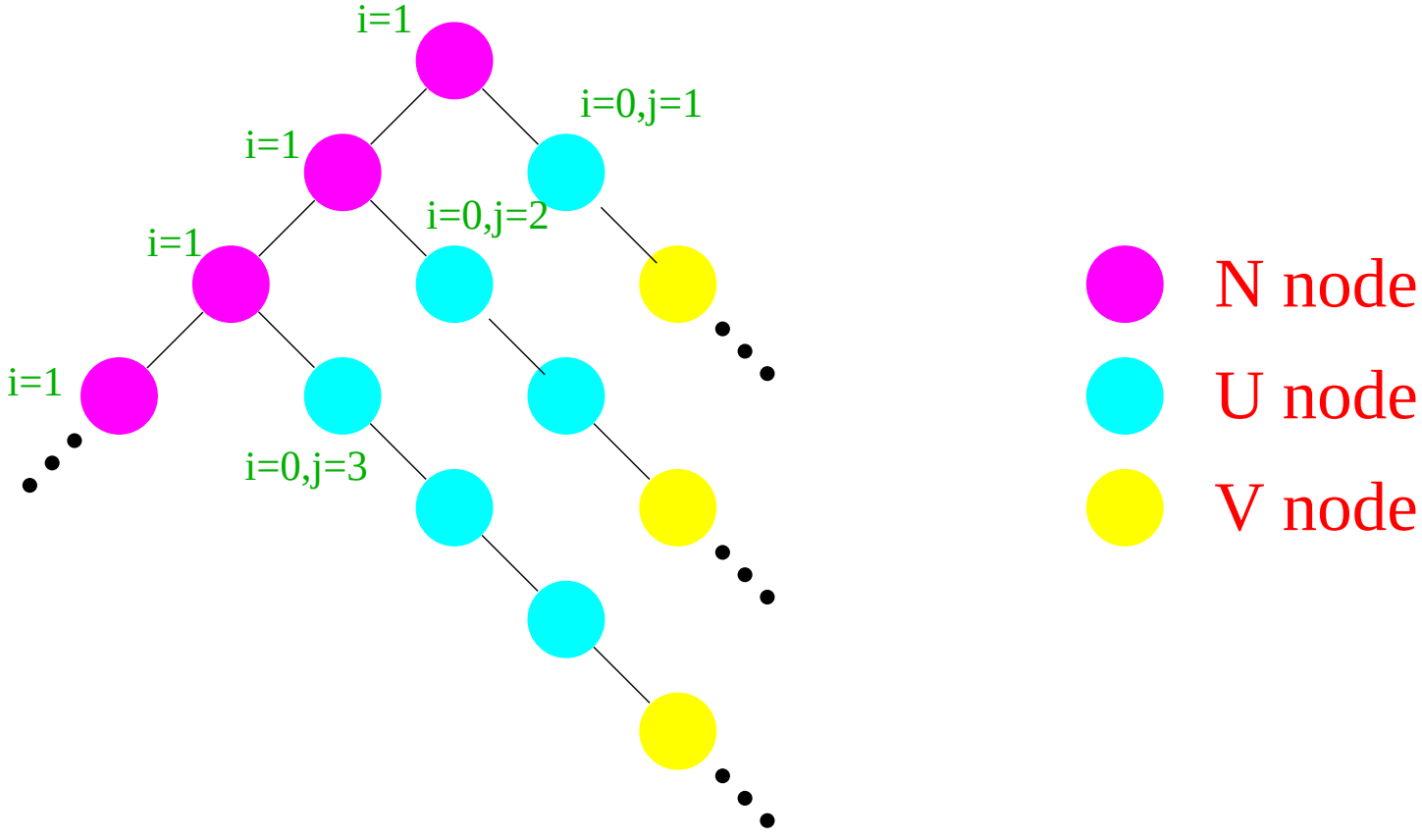
- Accepting condition: set of pairs (U, V), $U, V \subseteq Q$
- A run is accepting if, for every pair (U, V), $\Box\Diamond U \Rightarrow \Box\Diamond V$
- NBAs can be converted into equivalent deterministic Streetts [Safra88]

Extended Bounded Automata(EBA)

- Use 2 counters i, j for every (U, V) pair
- Transitions ending in U nodes
  - $i > 0$: decrease i
  - $i = 0$: i remains 0, decrease j
- Transitions ending in neither U nor V nodes
  - $i > 0$: non-increase i
  - $i = 0$, i remains 0, non-increase j

Why two counters

- N nodes on left path
- Unbounded U nodes on right paths



Soundness and Completeness

- For every EBA $\mathcal{E}$ over $\mathcal{A}$, $L(\mathcal{E})$ is a safety and $L(\mathcal{E}) \subseteq L(\mathcal{A})$
- Let $\mathcal{A}$ be a deterministic Streett, for each safety $S \subseteq L(\mathcal{A})$, there exists an EBA $\mathcal{B}$ that accepts S

Synthesizing from Formulae

- Semantic Approach
  - Associate a counter for each $\mathcal{U}$ subformula in the construction of tableau
  - A counter can be active or inactive
  - A transition is disabled if the counter is 0

Syntactic Approach

- Push negations to propositions
- Replace every $\mathcal{U}$ with $\mathcal{U}_{<k}$

  ($\mathcal{U}_{<k}$: bounded until operator)
- For a temporal formula ϕ and a positive integer k, ϕ_k is a safety property which implies ϕ

Related Work

- Pnueli, Zaks, Zuck 2005(RV05) workshop: use game theoretic approach

- Larsen 90,91: Give methods for synthesizing a safety property with respect to a context

Conclusion and Future Work

- Methods for customizing off-the-shelf components by monitors

- Future work
  - Study the complexity of monitors
  - Develop real-time monitors
  - Construct active monitors
  - Consider more realistic examples