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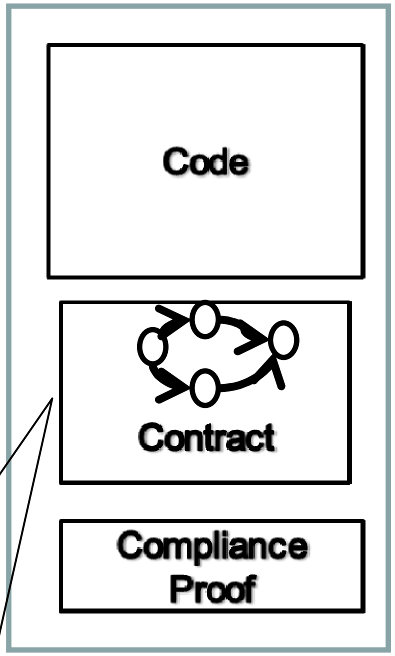
Security-by-Contract using Automata Modulo Theory (AMT)

Ida S.R. Siahaan

Is an application trustworthy ?

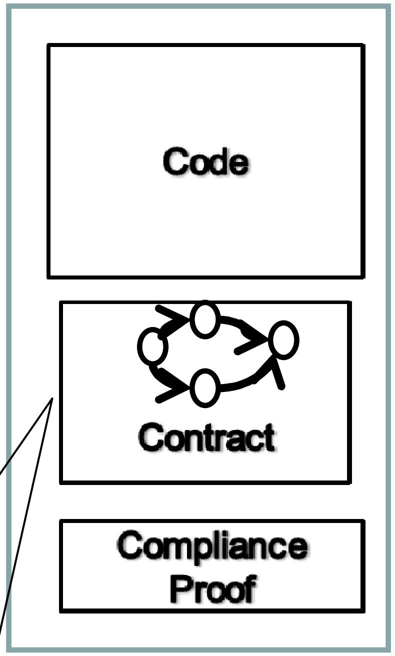


Contract:

specification of application's behavior concerning security-relevant actions

Is an application trustworthy ?

- **Reveal what it does**
  - Design software with security claims
- **Demonstrate its evidence**
  - Check that the application fulfills its claims
- **Verify its compliance**
  - Compliance of Contracts with Policies
- **Assurance for trustworthiness**
  - Inline security policy into the application
  - Run-time monitor the services



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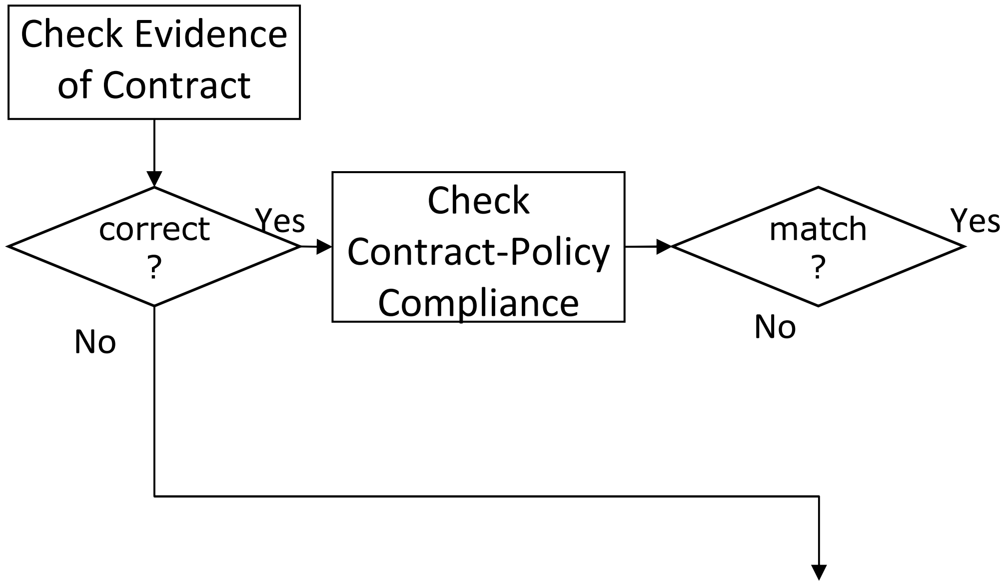

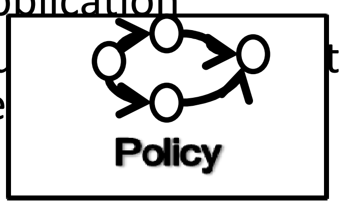

Policy:
specification of application's acceptable behavior to be executed on a platform concerning security-relevant actions

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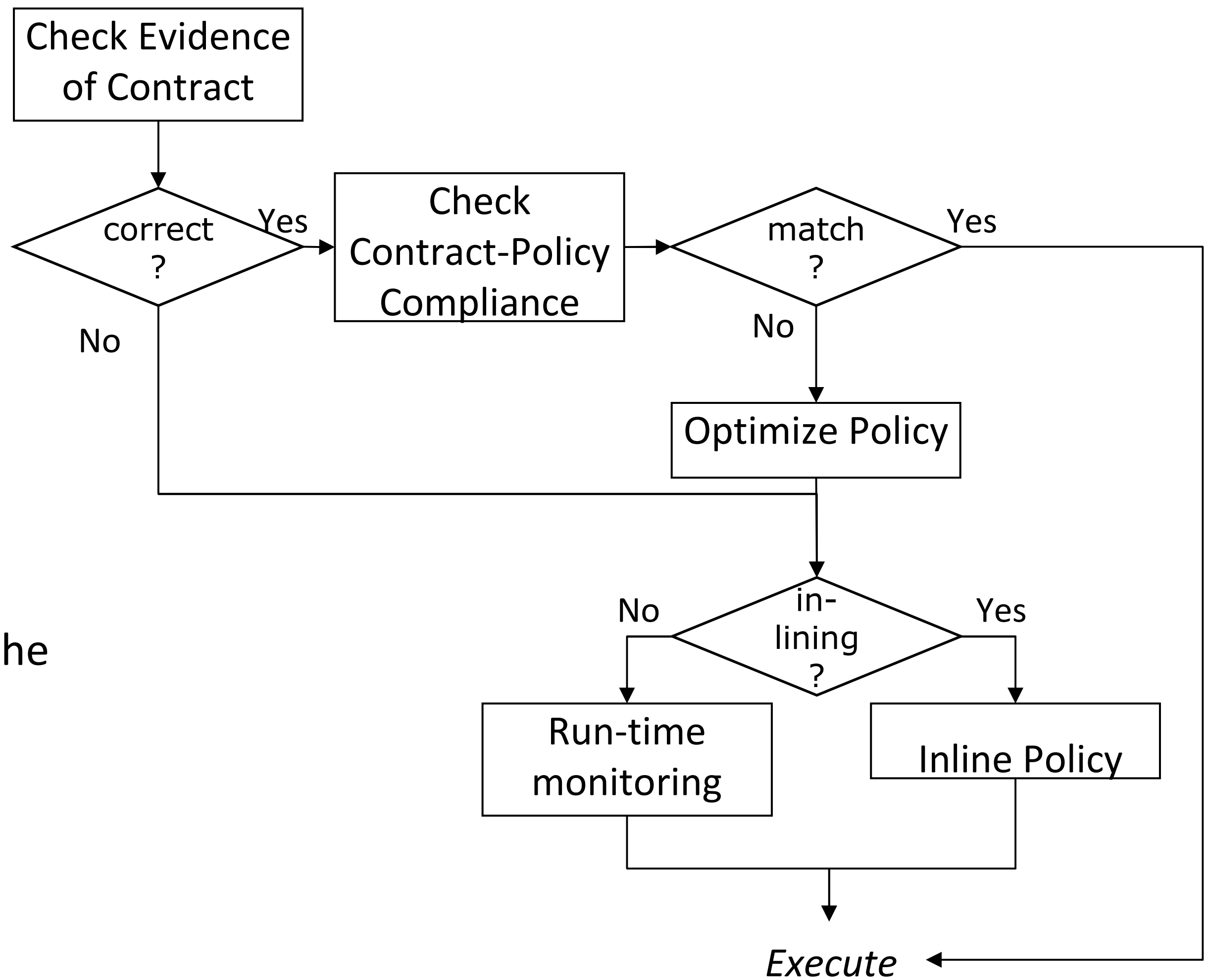


Road Map

Security-by-Contract

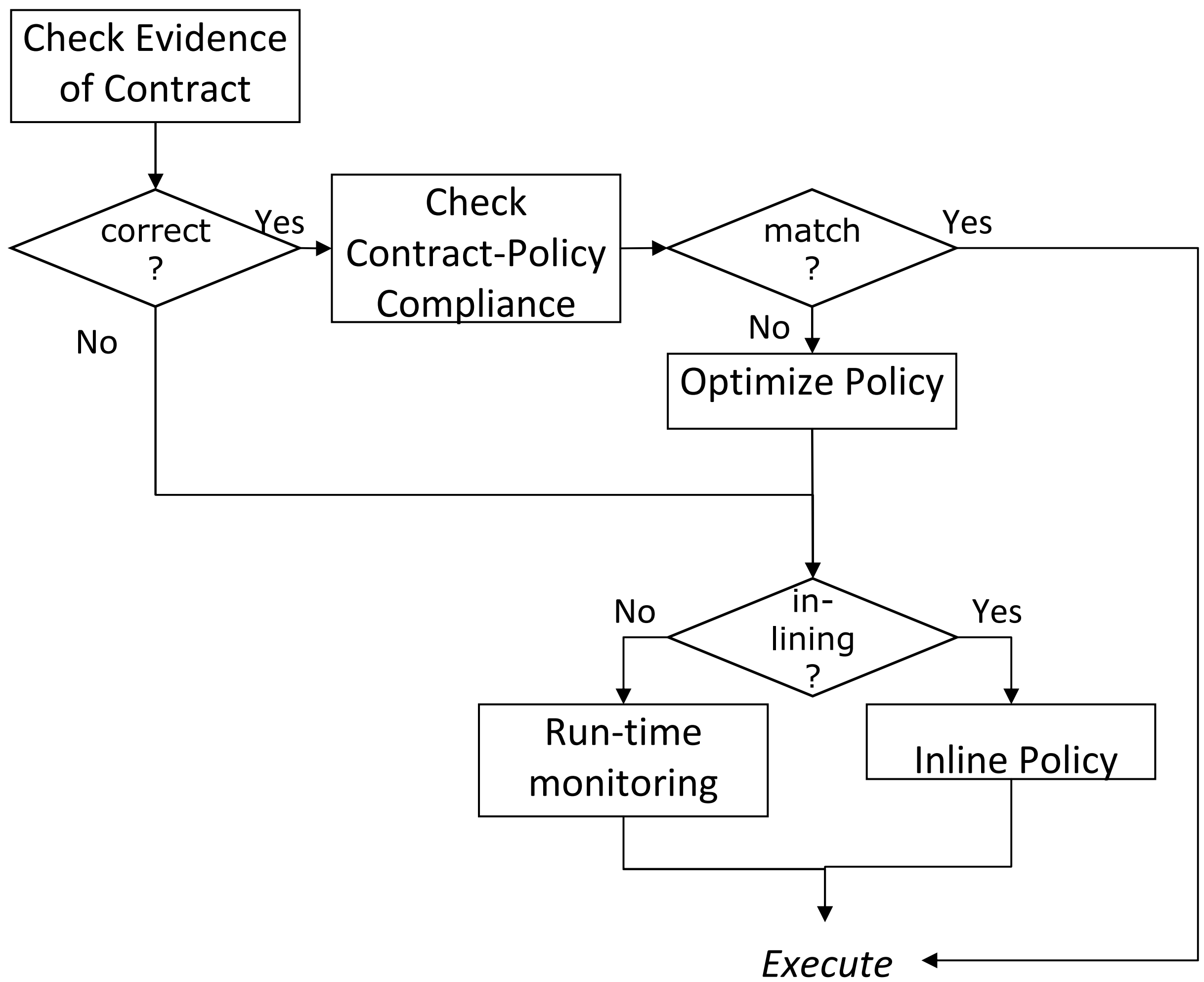
Automata Modulo Theory

On-the-fly Matching

Simulation Matching

IRM Optimization

Thesis Works



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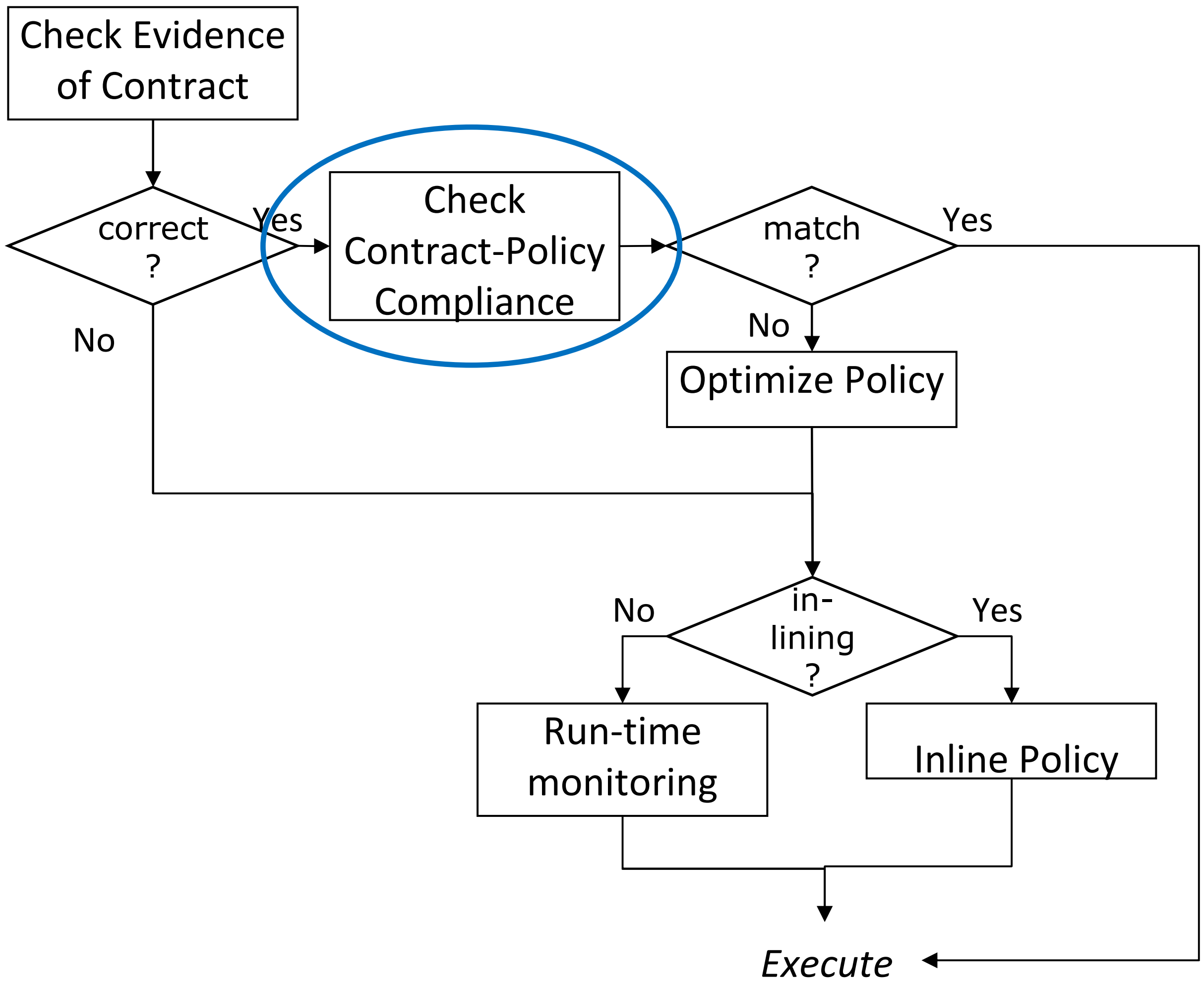

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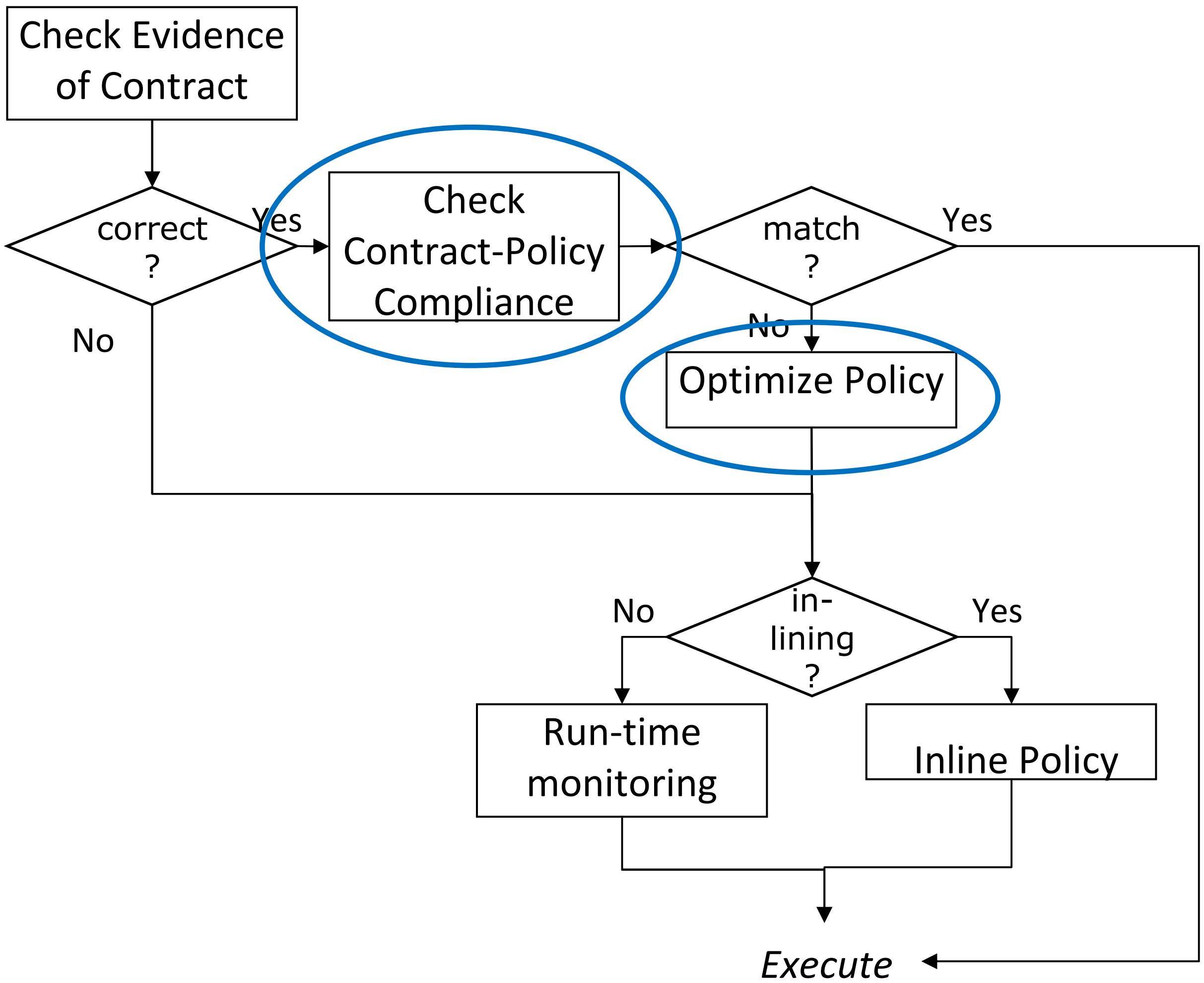
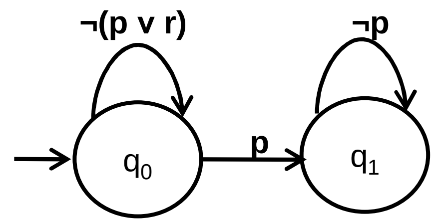


Why not Security Automata ?



- **Class of Büchi automata accepting safety properties (recognizers) [Schneider-TISSec'00]**
  - a countable set Q of *automaton states,*
  - a countable set I of *input symbols*
  - a *transition function* $\delta : (Q \times Q) \rightarrow 2^Q$, and
  - a countable set $Q_0 \subseteq Q$ of *initial automaton states*

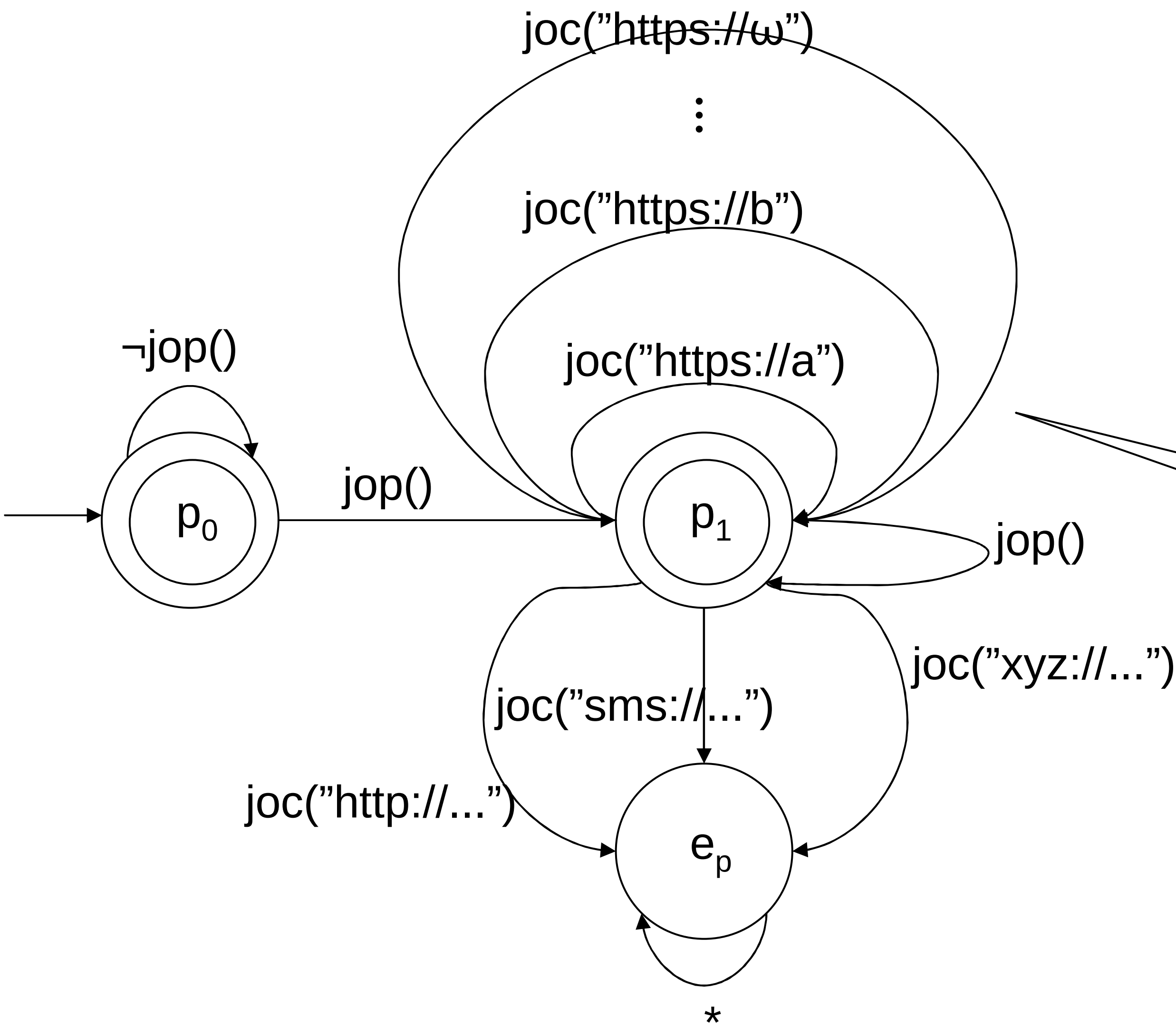
Liveness Property

- **It is rare, but it exists**
  - Example: A security requirement for banking applets
    - an application should use all the permissions it requires
    - to avoid over-entitlement which can be the source of potential (and possibly unknown) attacks

Infinite Transitions

Example of a Policy:
"After PIM is accessed only secure connections can be opened''

Infinite Transitions



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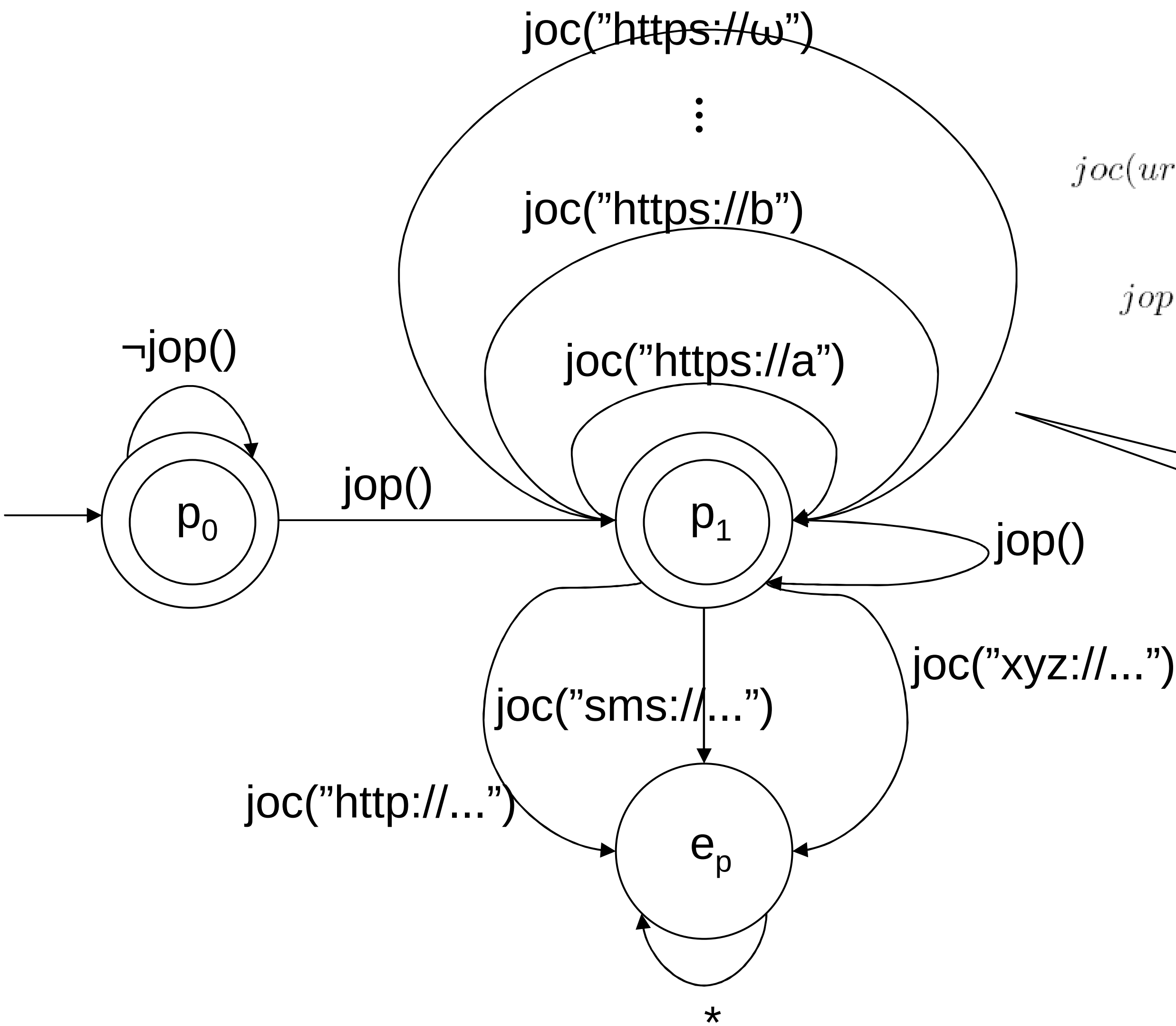

$$joc(url) \doteq \texttt{javax.microedition.io.Connector.open}(url)$$

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Example of a Policy:
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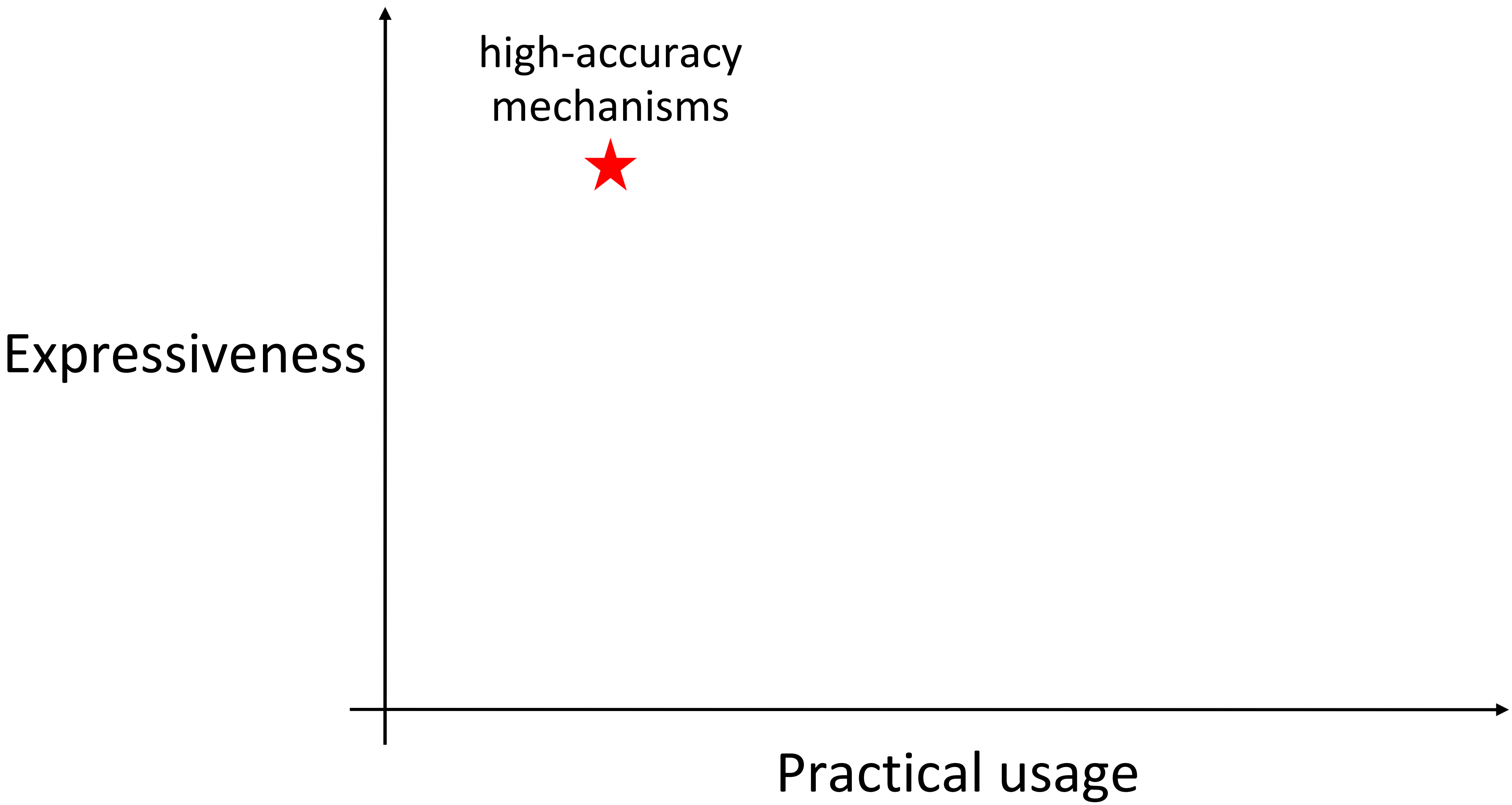
Security Policies Enforcement Mechanisms



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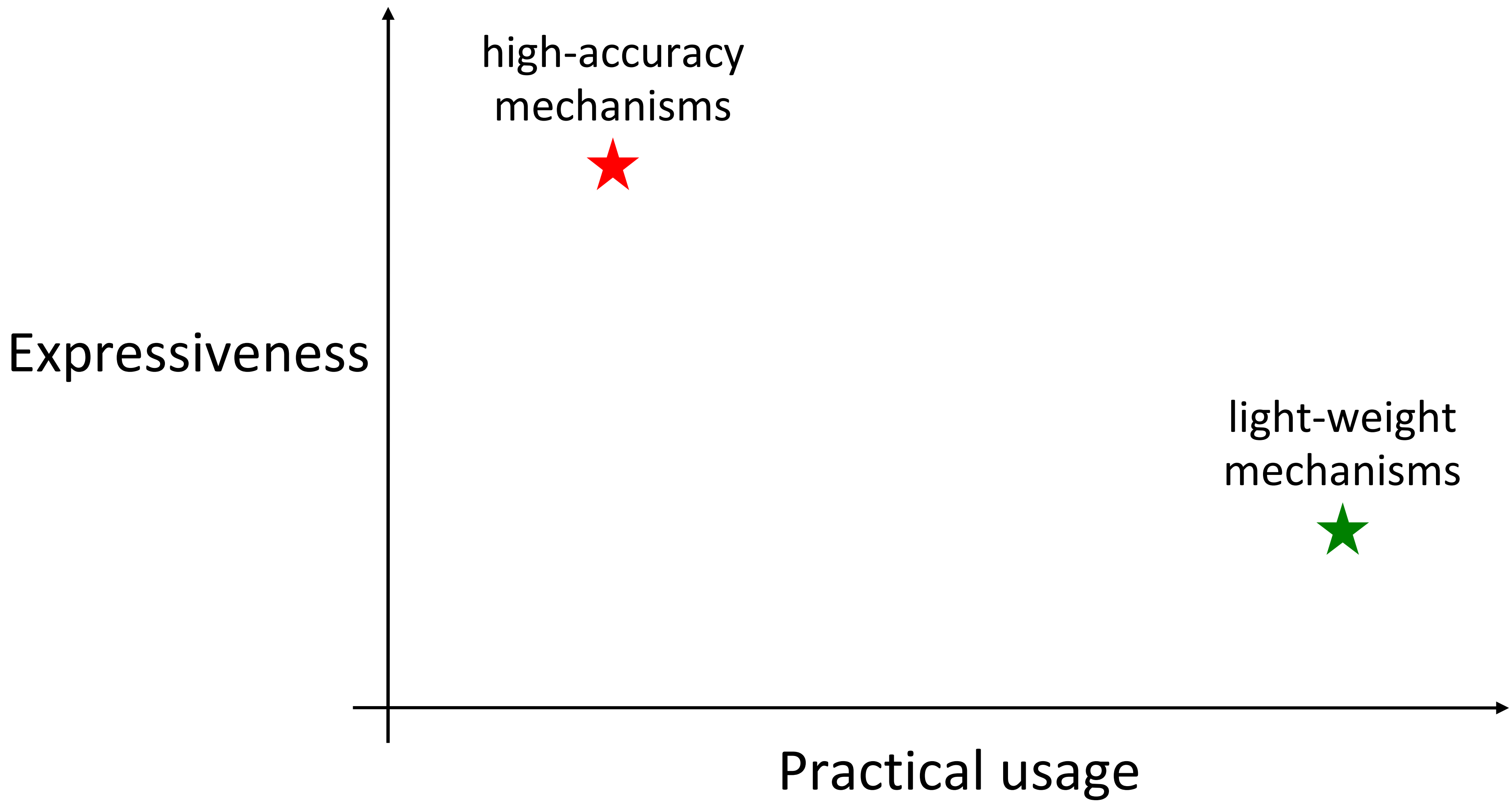

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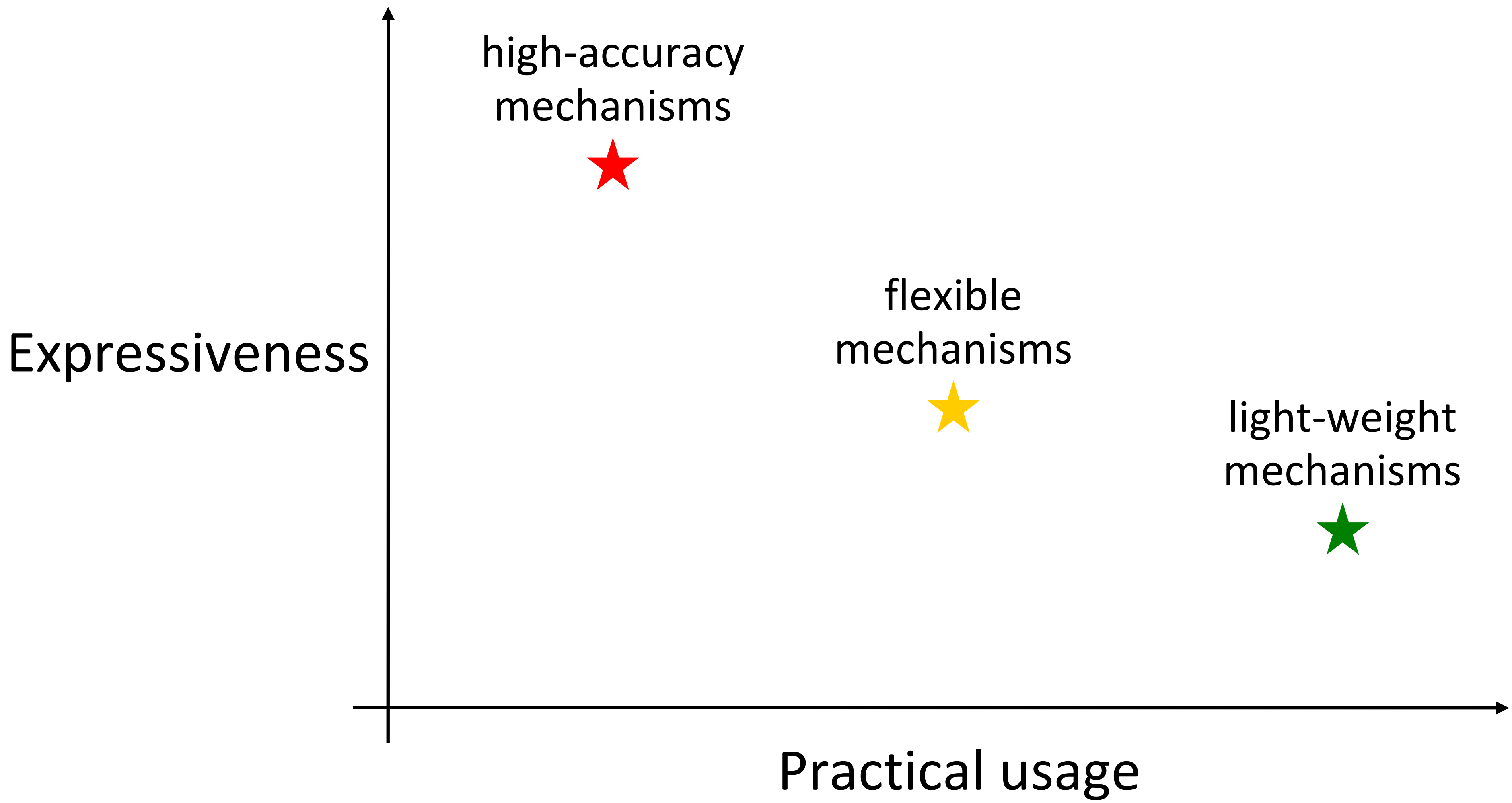

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Automata Modulo Theory (AMT)
as flexible mechanism

AMT = Büchi automata + Satisability Modulo Theories

Satisability Modulo Theories (SMT) [Sebastiani-JSAT'07]

- The problem of deciding the satisfiability of a first-order formula with respect to some decidable first-order theory T (SMT(T))
  - **A Σ-theory is a set of first-order sentences with signature Σ**
- Examples of theories of interest:
  - **Equality and Uninterpreted Functions (EUF),**
  - **Linear Arithmetic (LA): both over the reals (LA(Q)) and the integers (LA(Z))**
  - **Combination of two or more theories $T_1,\ldots,T_n$.**
- Examples of SMT tools:
  - **Z3, MathSAT**

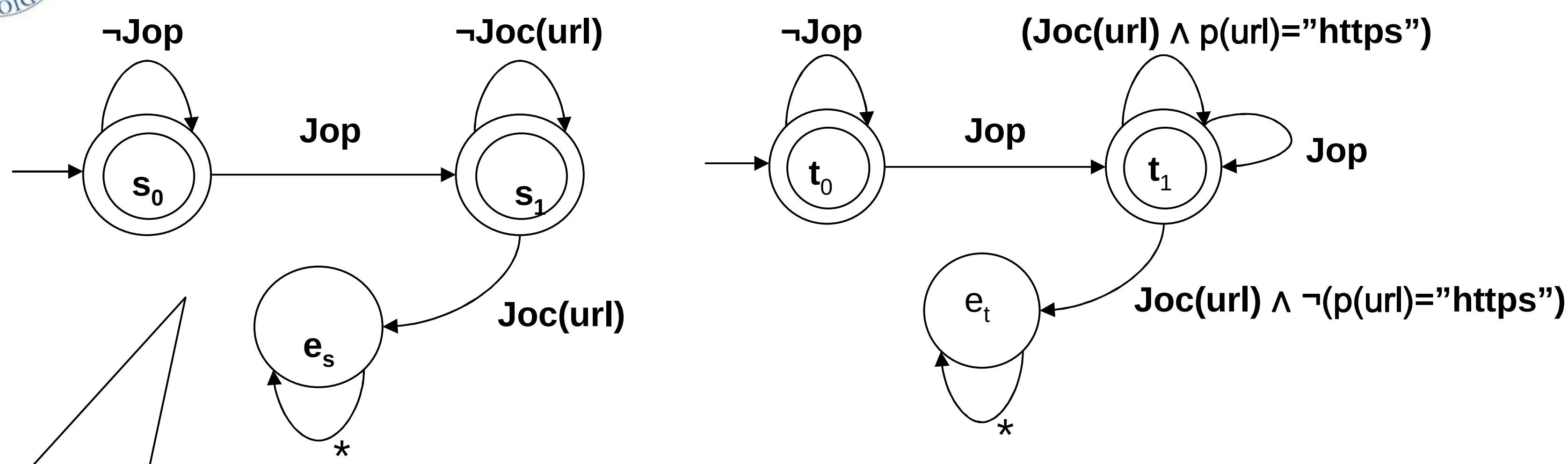
Automata Modulo Theory (AMT)

- **Let A = < S, Σ, $\mathcal{T}$, $\mathcal{E}$, Δ, s_0, F> be an AMT [MS-NordSec'07]**
  - a finite set S of *automaton states*,
  - a set $\mathcal{E}$ of formulae in the language of the Σ-Theory $\mathcal{T}$ as *input symbols,*
  - an *initial state* $s_0 \in S$,
  - a set $F \subseteq S$ of *accepting states*, and
  - a *labeled transition relation* $\Delta \subseteq S \times \mathcal{E} \times S$

Examples of AMT

Example of a Contract
"After PIM is opened no connections are allowed"

Examples of AMT



Example of a Contract
"After PIM is opened no connections are allowed"

$$
\begin{aligned}
Joc(url) &\doteq \texttt{Joc(joc,url)} \\
Jop &\doteq \texttt{Jop(jop,}x_1,\ldots,x_n\texttt{)} \\
p(url) = type &\doteq url.\texttt{startsWith}(type) \\
joc &\doteq \texttt{javax.microedition.io.Connector.open} \\
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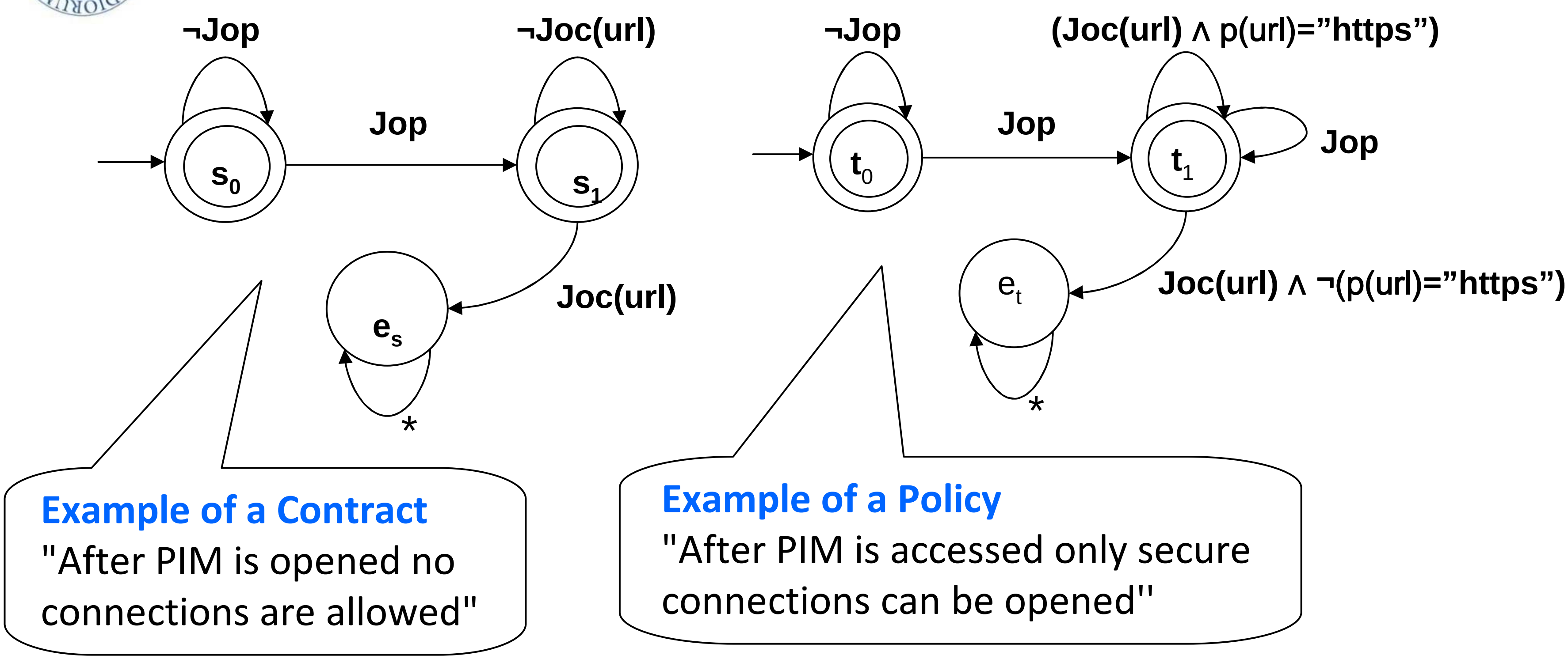

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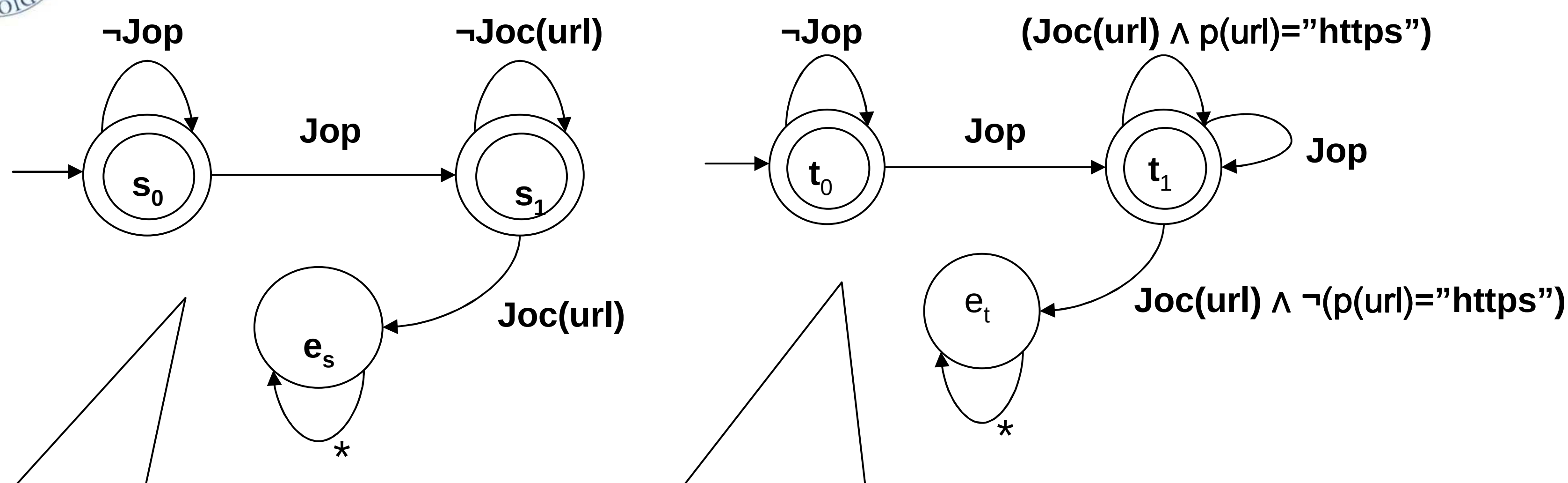

Example of a Contract

"After PIM is opened no connections are allowed"

Example of a Policy

"After PIM is accessed only secure connections can be opened"

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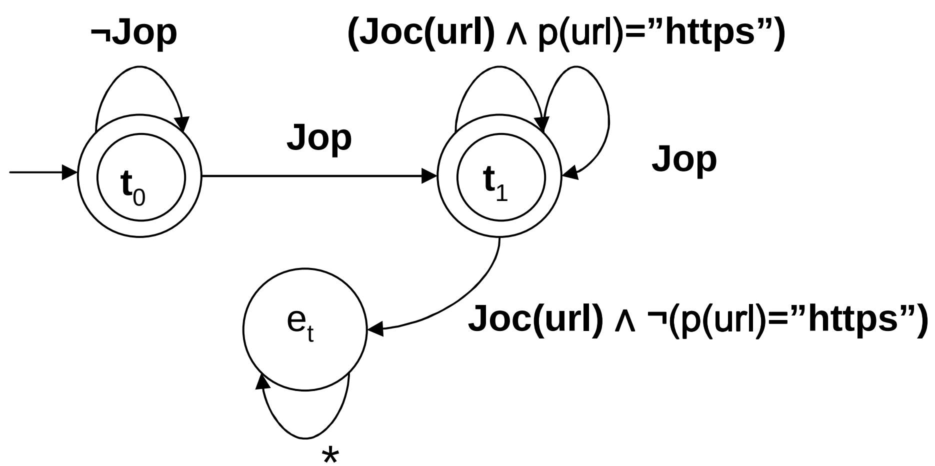
Symbolic Run in AMT

- **Let A = < S, Σ, $\mathcal{T}$, $\mathcal{E}$, Δ, s_0, F> be an AMT**
- **A *symbolic run* of A is a sequence of states alternating with expressions σ = < $q_0e_1q_1e_2q_2$ ... >:**
  - $q_0 = s_0$
  - $(q_i, e_{i+1}, q_{i+1}) \in \Delta$ and e_{i+1} is $\mathcal{T}$-satisfiable:
    - that is there exists some valuation v over Σ and $\mathcal{T}$ s.t. $v \models e_{i+1}$
    - valuation v is a pair $(\mathfrak{M}, \alpha)$: $\mathfrak{M}$ a model of $\mathcal{T}$ and α an assignment
  - *Finite symbolic run* σ = < $q_0e_1q_1e_2q_2 \ldots q_n$>
  - *Infinite symbolic run* σ = < $q_0e_1q_1e_2q_2 \ldots$ >
- ***Accepting symbolic run:***
  - Finite run: $q_n \in F$
  - Infinite run: there exists some k s.t. $q_k \in F$ and q_k is visited infinitely often

Concrete Run in AMT

- **Let $A = < S, \Sigma, \mathcal{T}, \mathcal{E}, \Delta, s_0, F>$ be an AMT**
- **A *concrete run* of *A* is a sequence of states alternating with valuations σ = < $q_0 v_1 q_1 v_2 q_2$ ... >:**
  - $q_0 = s_0$
  - there exists $e_{i+1} \in \mathcal{E}$:
    - $(q_i, e_{i+1}, q_{i+1}) \in \Delta$
    - there exists some valuation v over Σ and $\mathcal{T}$ *s.t.* $v \models e_{i+1}$
  - *Finite concrete run* σ = < $q_0 v_1 q_1 v_2 q_2$ ... q_n>
  - *Infinite concrete run* σ = < $q_0 v_1 q_1 v_2 q_2$ ... >
- ***Acceptance condition as symbolic run***

Example of an Accepting Run in AMT



Symbolic Run

t0 Jop(jop,file,permission) t1 Joc(joc,url)^p(url)=“https”

t1 Jop(jop,file,permission) t1 Joc(joc,url)^p(url)=“https” …

Concrete Run

t0 (jop,PIM.CONTACT_LIST,PIM.READ_WRITE)

t1 (joc,“https://www.esse3.unitn.it/”)

t1 (jop,PIM.CONTACT_LIST,PIM.READ_ONLY)

t1 (joc,“https://online.unicreditbanca.it/login.htm”) …

Deterministic AMT

- **A = < S, Σ, $\mathcal{T}$, $\mathcal{E}$, Δ, s_0, F> is a deterministic AMT**
  - S, Σ, $\mathcal{T}$, $\mathcal{E}$, s_0, F as before
  - a *labeled transition function* $\Delta \subseteq S \times \mathcal{E} \times S$:
    - for every $s, s_1, s_2 \in S$ and every $e_1, e_2 \in \mathcal{E}$
    - if $(s, e_1, s_1) \in \Delta$ and $(s, e_2, s_2) \in \Delta$ where $s_1 \neq s_2$
    - then $(e_1 \wedge e_2)$ is unsatisfiable in the Σ-Theory $\mathcal{T}$
- **Why determinism matters ?**
  - nondeterministic complementation is complex and exponential blow-up
- **Why considering only the complementation of deterministic automata ?**
  - security policies are naturally deterministic
    - a platform owner should have a clear idea on what to allow or disallow

AMT Complementation and Intersection

- **Complementation:**
  - For each deterministic AMT automaton A there exists a (possibly nondeterministic) AMT that accepts all the words which are not accepted by automaton A.
- **Intersection: Let < S^a, Σ^a, $\mathcal{T}^a$, $\mathcal{E}^a$, Δ^a, s_0^a, F^a> and < S^b, Σ^b, $\mathcal{T}^b$, $\mathcal{E}^b$, Δ^b, s_0^b, F^b> be AMT, the *intersection* automaton *A* = < S, Σ, $\mathcal{T}$, $\mathcal{E}$, Δ, s_0, F> :**
  - $\Sigma = \Sigma^a \cup \Sigma^b$, $\mathcal{T} = \mathcal{T}^a \cup \mathcal{T}^b$, $\mathcal{E} = \mathcal{E}^a \cup \mathcal{E}^b$,
  - $S = S^a \times S^b\ S \times \{1,2\}$, $s_0 = (s_0^a, s_0^b, 1)$, $F = F^a \times S^b \times \{1\}$,
  - for every s ∈ S and for every e ∈ $\mathcal{E}$:

$\Delta = \{<(s^a, s^b, x), (e^a \wedge e^b), (t^a, t^b, y)> \mid (s^a, e^a, t^a) \in \Delta^a$ and $(s^b, e^b, t^b) \in \Delta^b$ and $DecisionProcedure(e^a \wedge e^b) = SAT\}$

$$y = \begin{cases} 2 \text{ if } x = 1 \text{ and } s^a \in F^a \text{ or if } x = 2 \text{ and } s^b \notin F^b \\ 1 \text{ if } x = 1 \text{ and } s^a \notin F^a \text{ or if } x = 2 \text{ and } s^b \in F^b \end{cases}$$

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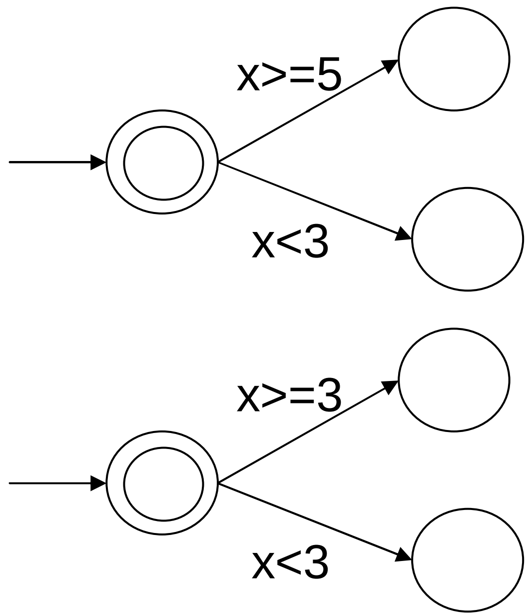
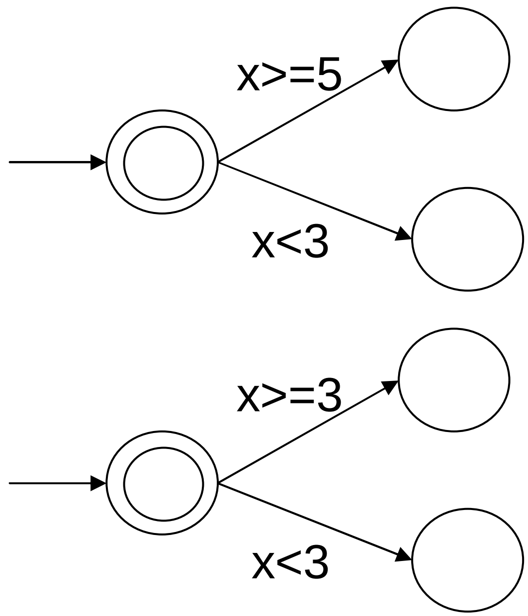
AMT Intersection



(a) Example of Automata

AMT Intersection



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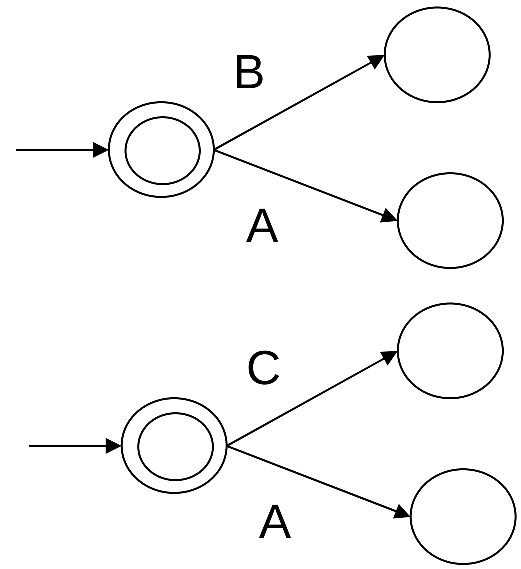

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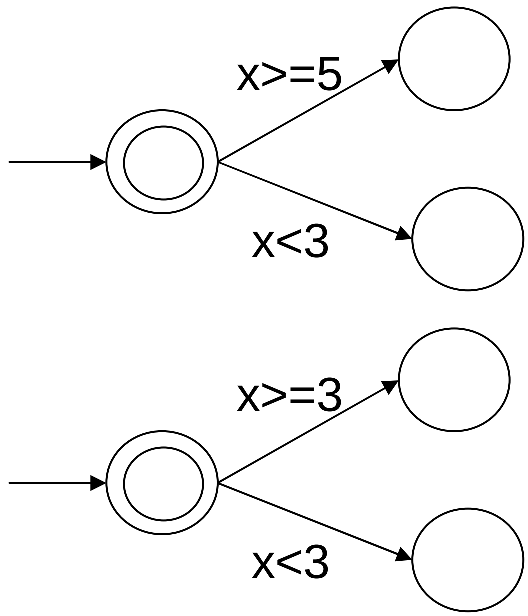

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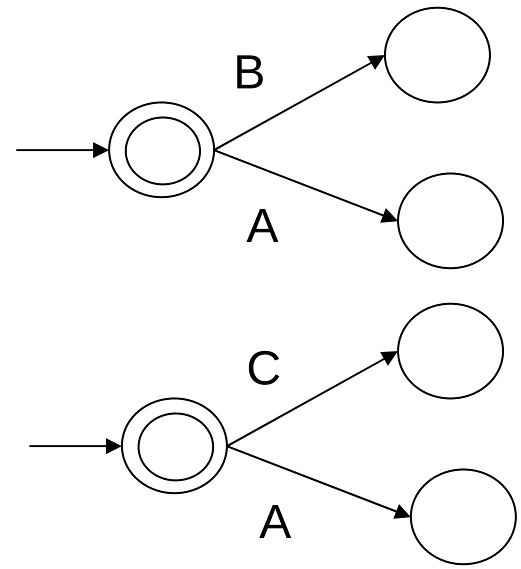
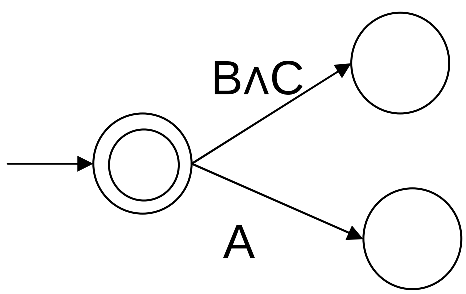


(b) Boolean Abstraction



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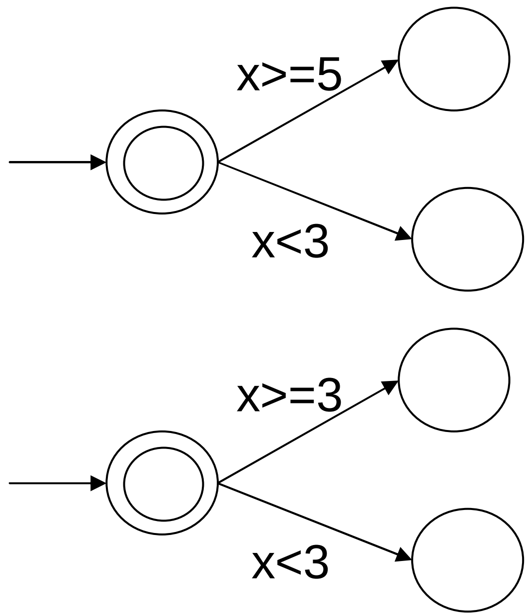

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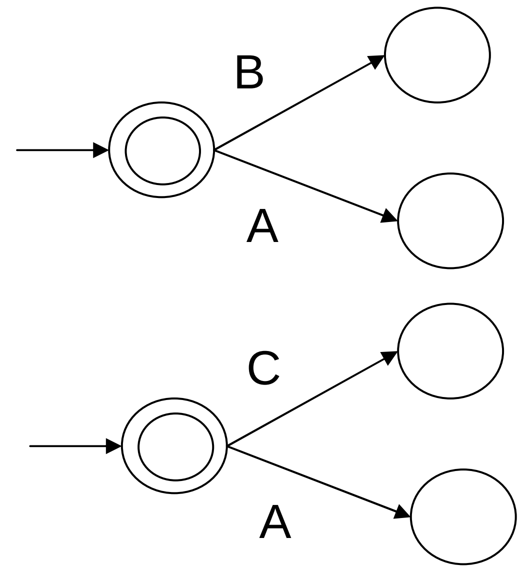

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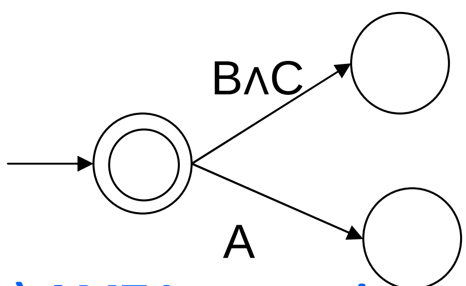
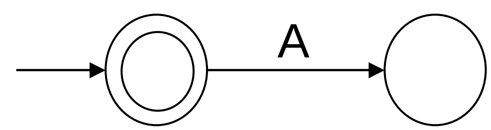


(c) AMT Intersection



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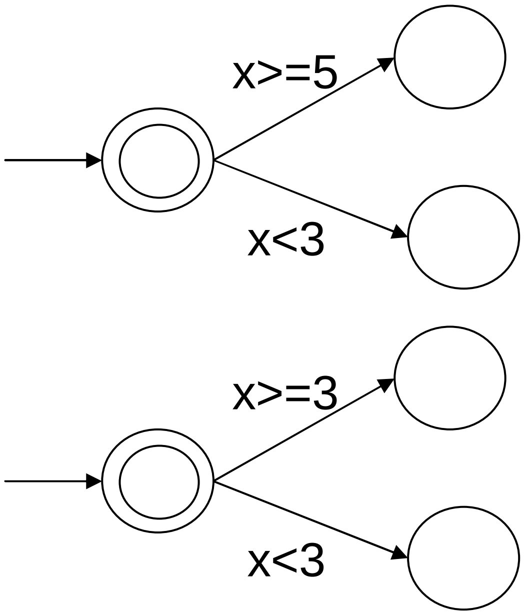

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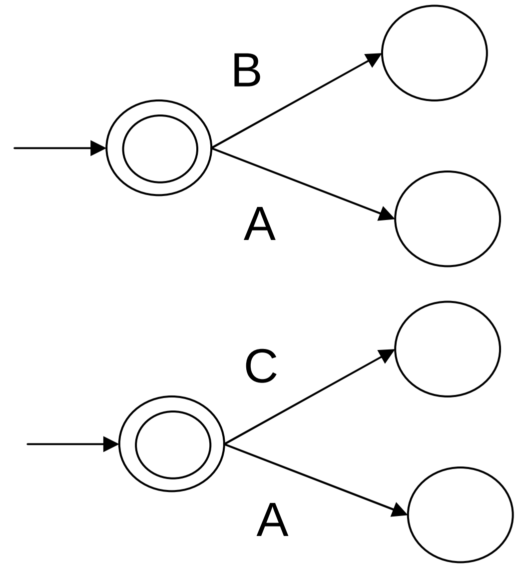

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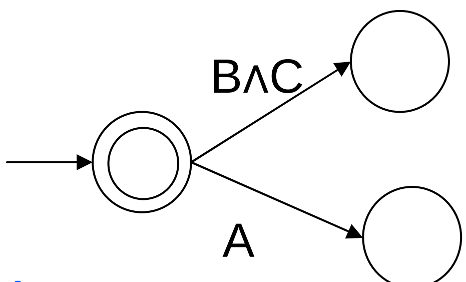

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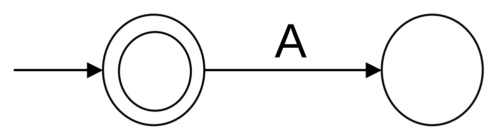

(d) Normal Intersection

So, What is Contract-Policy Compliance Check ?

- **Security policies as AMT**
- **Matching:**
  - Language Inclusion:
    - Given two automata A^c and A^p representing respectively a contract and a policy, we have a match when the set execution traces of the A^c is a subset of the set of acceptable traces of A^p.
  - Simulation:
    - every security-relevant action invoked by A^c can also be invoked by A^p

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Automata Modulo Theory

On-the-fly Matching

Simulation Matching

IRM Optimization

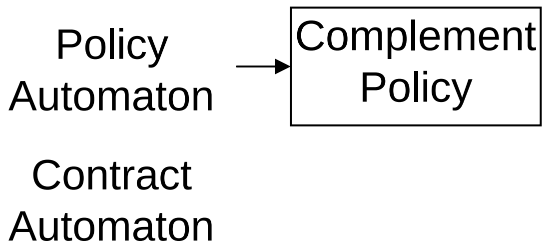
Contract-Policy Matching

Policy
Automaton

Contract
Automaton

- Matching between a contract with a security policy problem can be reduced to an emptiness test of the product automaton between a contract with a complement of policy.

Contract-Policy Matching



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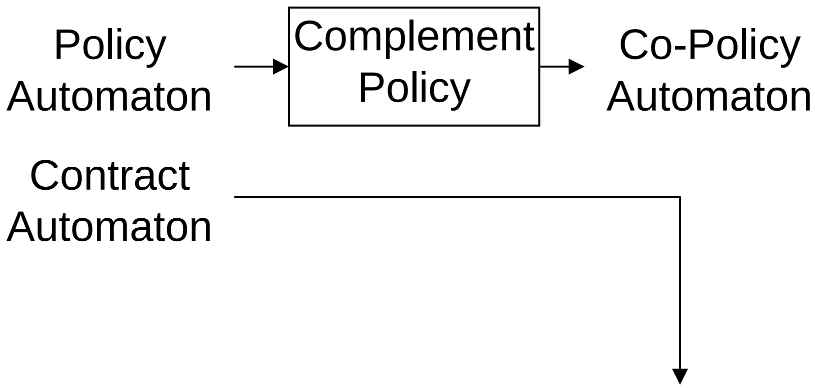

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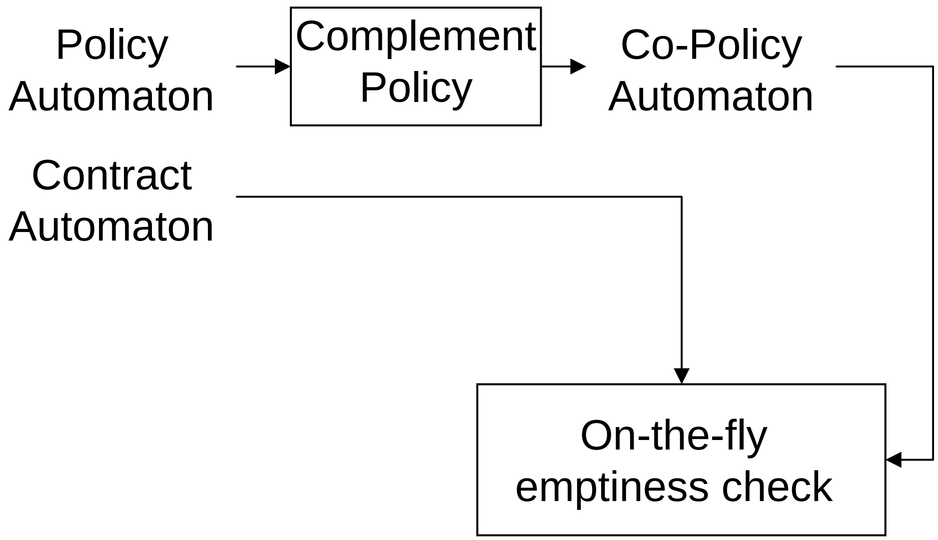

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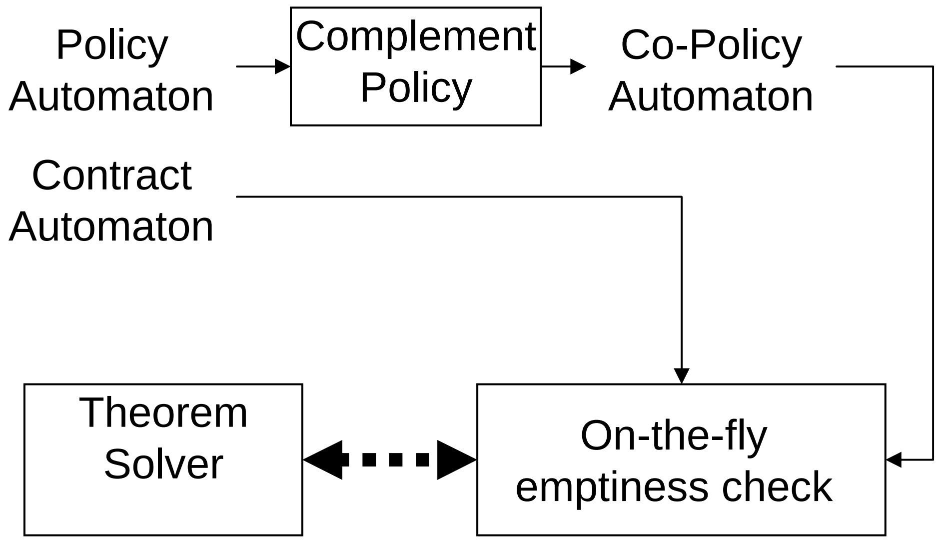
Contract-Policy Matching



- Matching between a contract with a security policy problem can be reduced to an emptiness test of the product automaton between a contract with a complement of policy.

Contract-Policy Matching Algorithm

- Input: a contract and a complement policy
- Output: fail or succeed
- Process:
  - **starts a depth first search procedure check_safety from initial state**
  - **IF an accepting state in AMT is reached:**
    - **IF the state contains an error state of complemented policy THEN report a security policy violation without further ado**
    - **IF the state does not contain an error state of complemented policy THEN start a new depth first search check_availability from the candidate state to determine whether it is in a cycle**
    - **IF cycle THEN report an availability violation**

Contract-policy Matching's Result using Language Inclusion

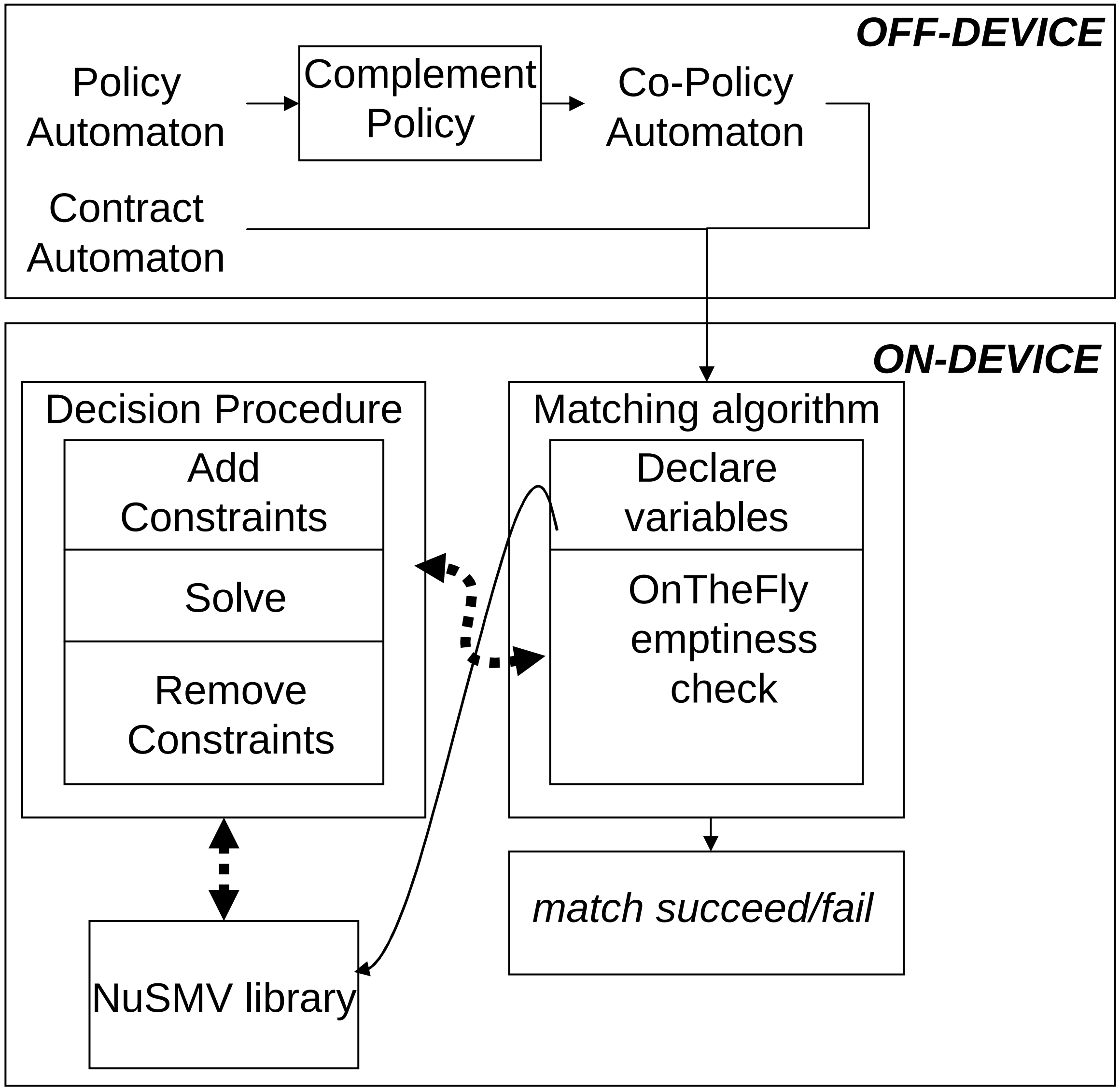
Proposition 4.1.

Let the theory $\mathcal{T}$ be decidable with an oracle for the SMT problem in the complexity class C then:

The contract-policy matching problem for AMT using language inclusion is decidable in

- **time:** $LIN-TIME^{C}$
- **space:** $NLOG-SPACE\text{-}complete^{C}$

Contract-Policy Architecture



Road Map

Security-by-Contract

Automata Modulo Theory

On-the-fly Matching

Simulation Matching

IRM Optimization

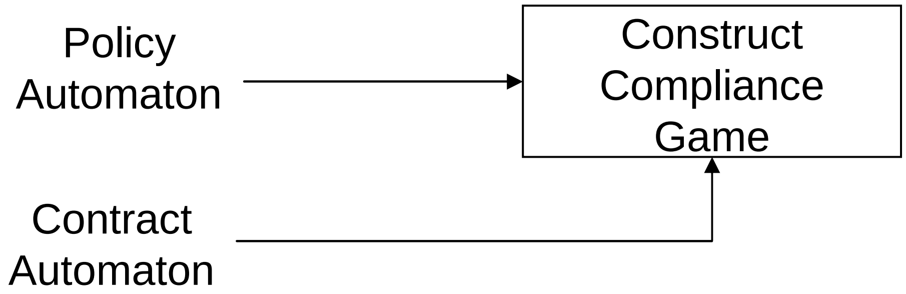
Contract-Policy Matching

Policy
Automaton

Contract
Automaton

- **Matching = Simulation**
  - Every security-relevant action invoked by Contract can also be invoked by Policy
- **Compliance Game**
  - Concrete: Contract tries to make a concrete move and Policy follows accordingly to show that the Contract move is allowed
  - Symbolic: IF expression of Contract implies expression of Policy is VALID (modulo theory) THEN exists a move
  - Adaptation of Jurdzinski's algorithm on parity games (Jurdzinski 2000)

Contract-Policy Matching



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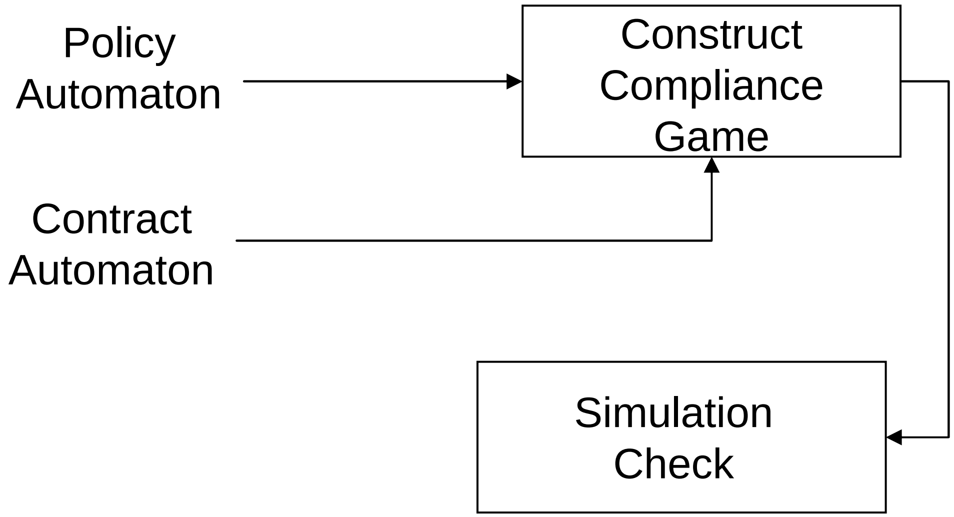
Contract-Policy Matching



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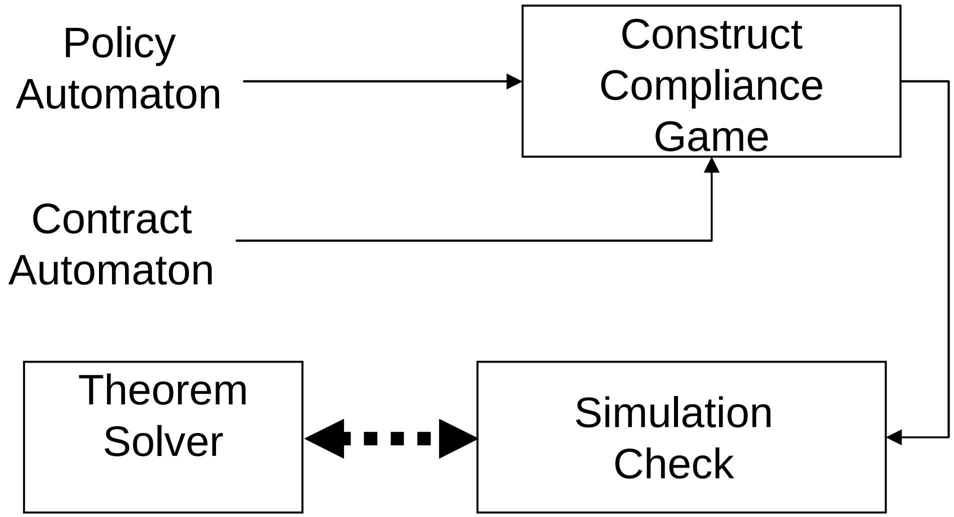

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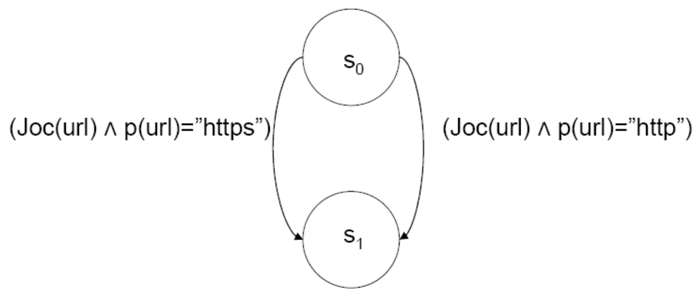
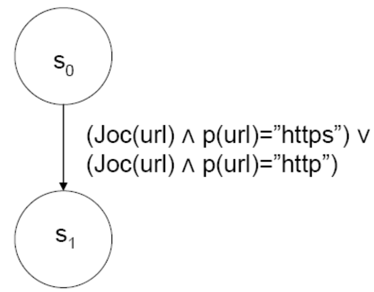
Simulation as Compliance Game

- **Winner of the game:**
  - Contract cannot move: Policy wins.
  - Policy cannot move: Contract wins.
  - Otherwise, two infinite concrete runs *s* and *t* resp. of Contract and Policy:
    - *s* is an accepting concrete run and *t* is not an accepting concrete run: Contract wins.
    - Other cases: Policy wins
- **Failure of Matching**
  - Policy cannot move => Contract is non-compliant

Symbolic vs Concrete Automaton

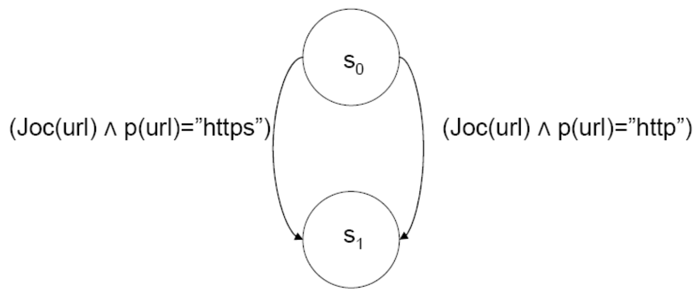


(a) Splitting Edges



(b) Disjuncting Expressions

Symbolic vs Concrete Automaton



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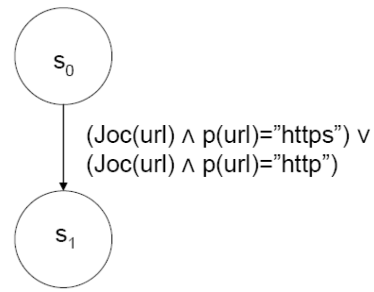
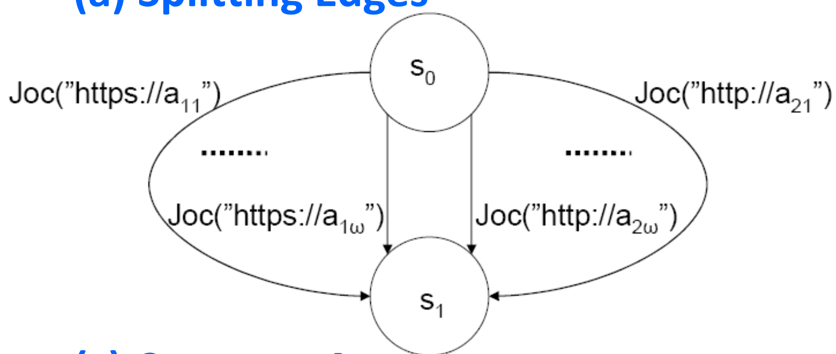


(b) Disjuncting Expressions



(c) Concrete Automaton

$$
\begin{aligned}
e_{11} &\doteq (Joc(url) \wedge p(url) = \text{“https”}) \\
e_{12} &\doteq (Joc(url) \wedge p(url) = \text{“http”}) \\
e_{2} &\doteq (Joc(url) \wedge p(url) = \text{“https”}) \\
&\quad \vee (Joc(url) \wedge p(url) = \text{“http”})
\end{aligned}
$$

(d) Abbreviations

- **IF A^c *complies* with A^p THEN A^c *concretely complies* with A^p**
  - The converse does not hold in general.
  - Contrast to the simulation notions of (Hennessy and Lin 1995)
- **AMT fair simulation is stronger than AMT language inclusion**

Normalized AMT

- **For every q, q_1 in set of states S there is at most one expression e_1 in set of expressions $\mathscr{E}$ s.t. (q, e_1, q_1) is in set of transitions Δ**
  - Example: from previous figure (a) is NOT normalized, (b) is normalized
- **Normalization is possible when:**
  - theory $\mathcal{T}$ is convex and closed under disjunction.
- **Normalization preserves AMT determinism**
- **For normalized AMT: A^c *concretely complies* with A^p IFF A^c *complies* with A^p**

Simulation Policy-Contract Algorithm

- Matching between a contract with a security policy problem can be reduced to compliance game between a contract with a policy.
- Input: a contract and a policy
- Output: fail or succeed
- Process:
  - **Create compliance game graph $G = \langle V, E, l \rangle$**
  - **$\mu(v) := 0$ for all $v \in V$**
  - **WHILE $\mu(v) \neq \mu_{new}(\mu, v)$ for some $v \in V$ DO**
    - $\mu := \mu_{new}(\mu, v)$
  - **IF $\mu(v(s_0^c, s_0^p)) < \infty$ THEN**
    - succeed (Simulation exists)

Contract-policy Matching's Result using Simulation

Proposition 6.2.

Let the theory $\mathcal{T}$ be decidable with an oracle for the SMT problem in the complexity class *C* then:

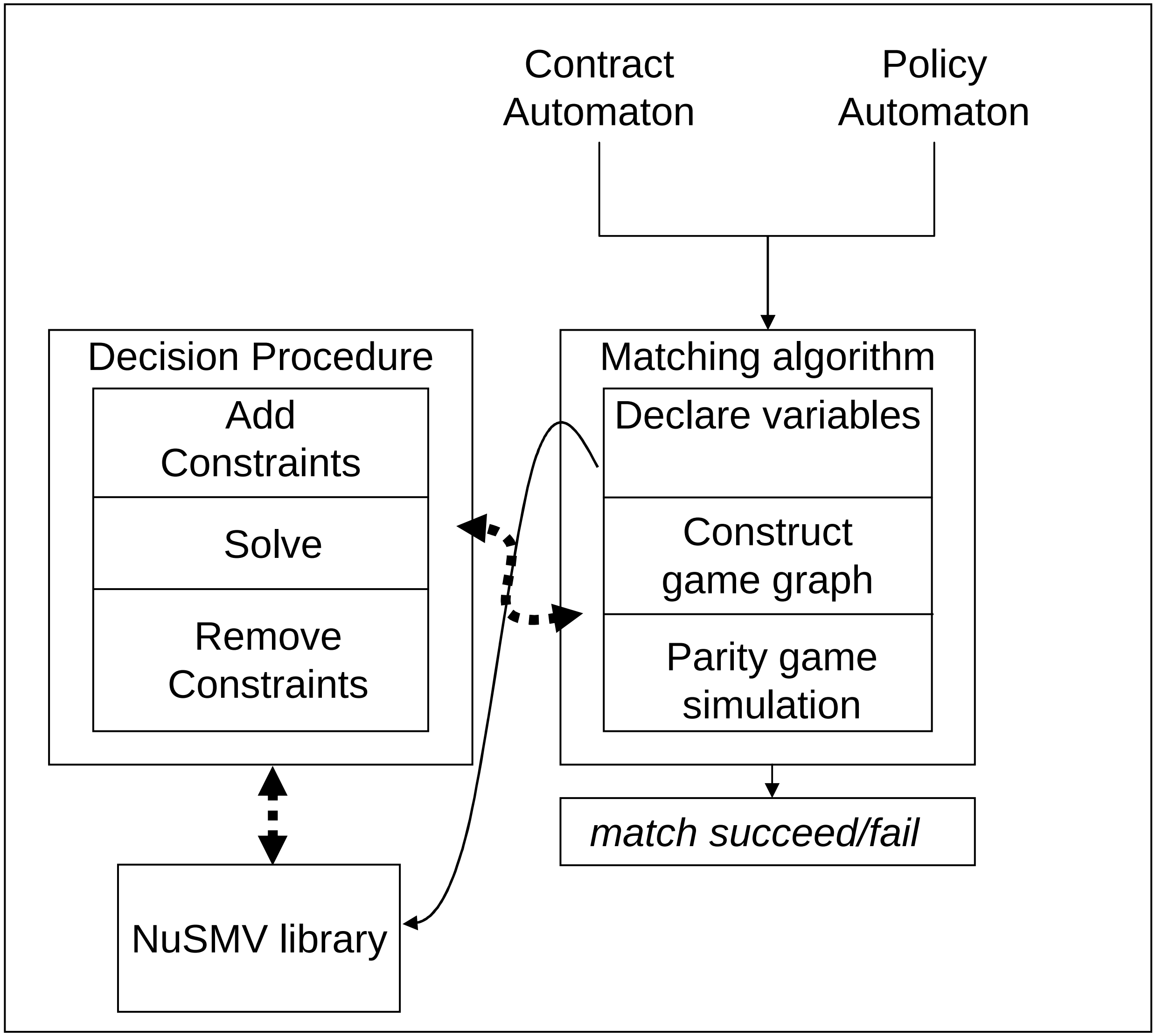
The contract-policy matching problem for AMT using fair simulation is decidable in

- **time: *O(2. |E| .|V1|)***
- **space: *O(|V|)***

– **By Lemma 6.1.**

- **$|V_1|$ is in $O(|S^c| \,.\, |S^p|)$**
- **$|V_0|$ is in $O(|S^c| \,.\, |S^p| \,.\, |\Delta^c|)$**
- **$|E|$ is in $O(|S^c| \,.\, |S^p| \,.\, |\Delta^c|)^C$**

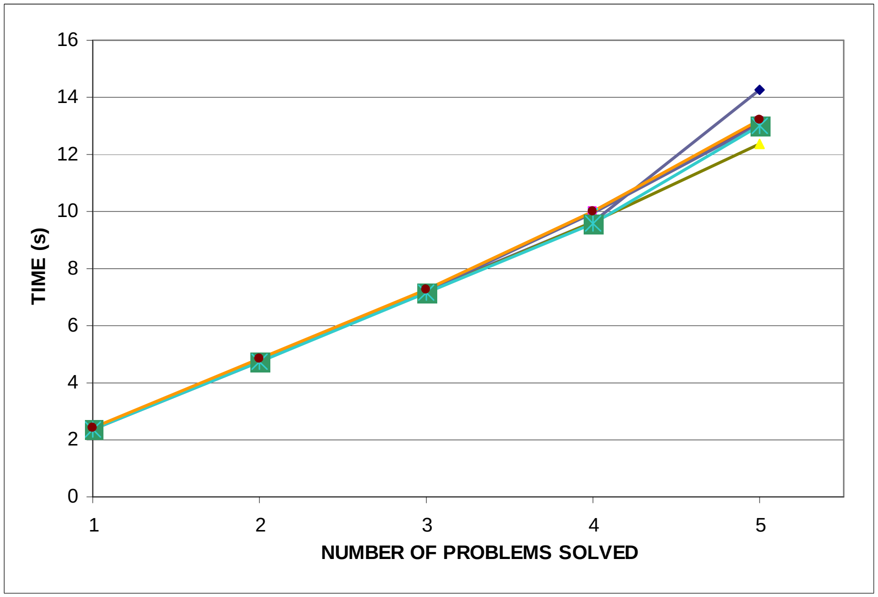
Simulation Contract-Policy Architecture



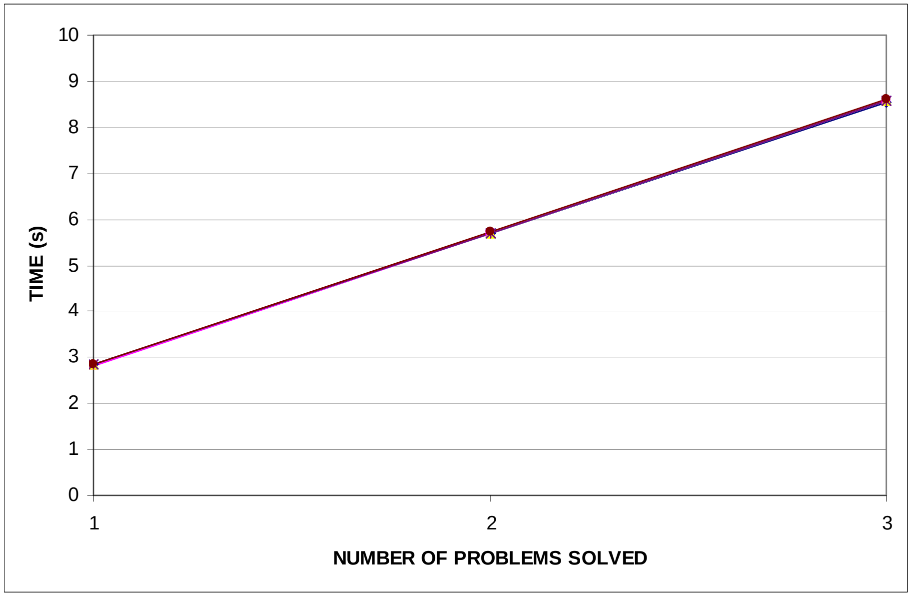
Matching Experiment

- Goal: proof-of-concept and deciding the best configuration of integrating matching algorithm with decision procedure
- Collected data: number of visited states, number of visited transitions, and running time for each problem in each design alternative
- Problem suite:
  - **sample of policy-contract (mis)matching pairs**
  - **artificial problem to mimic large number of states**
- Setup:
  - **Desktop:**
    - **PC (Intel(R) Pentium D CPU 3.40GHz, 3389.442MHz, 1.99GB of RAM, 2048 KB cache)**
    - **On-the-fly: OS Linux version 2.6.20-16-generic, Kubuntu 7.04 (Feisty Fawn)**
    - **Simulation: Microsoft(R) Windows XP Professional Version 2002 Service Pack 3**
  - **Mobile device:**
    - **HTC P3600 (3G PDA phone) with ROM 128MB, RAM 64MB, 400MHz, Samsung(R) SC32442A**
    - **OS Microsoft(R) Windows Mobile 5.0 with Direct Push technology**

On-the-fly Matching Experiment on Desktop

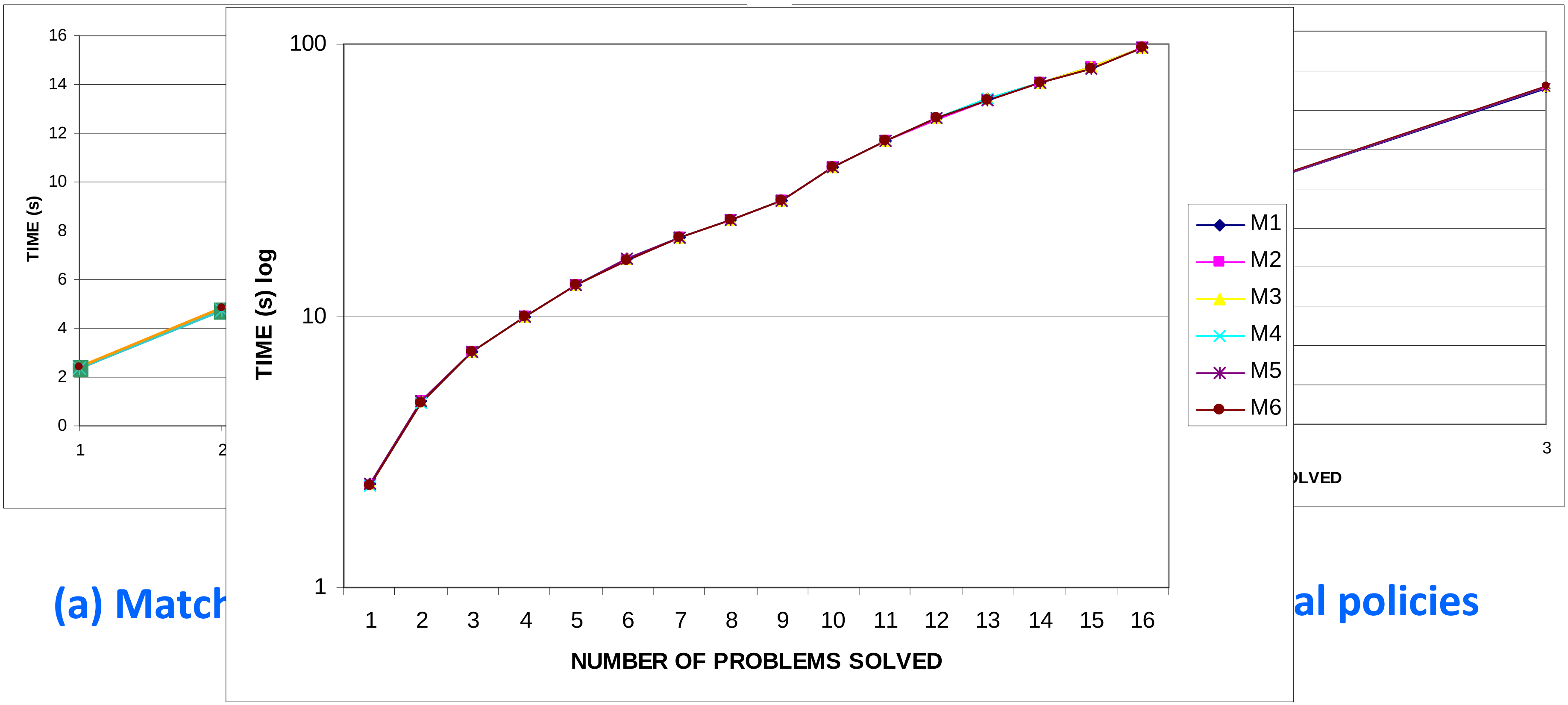


(a) Match succeeds for real policies



(b) Match fails for real policies

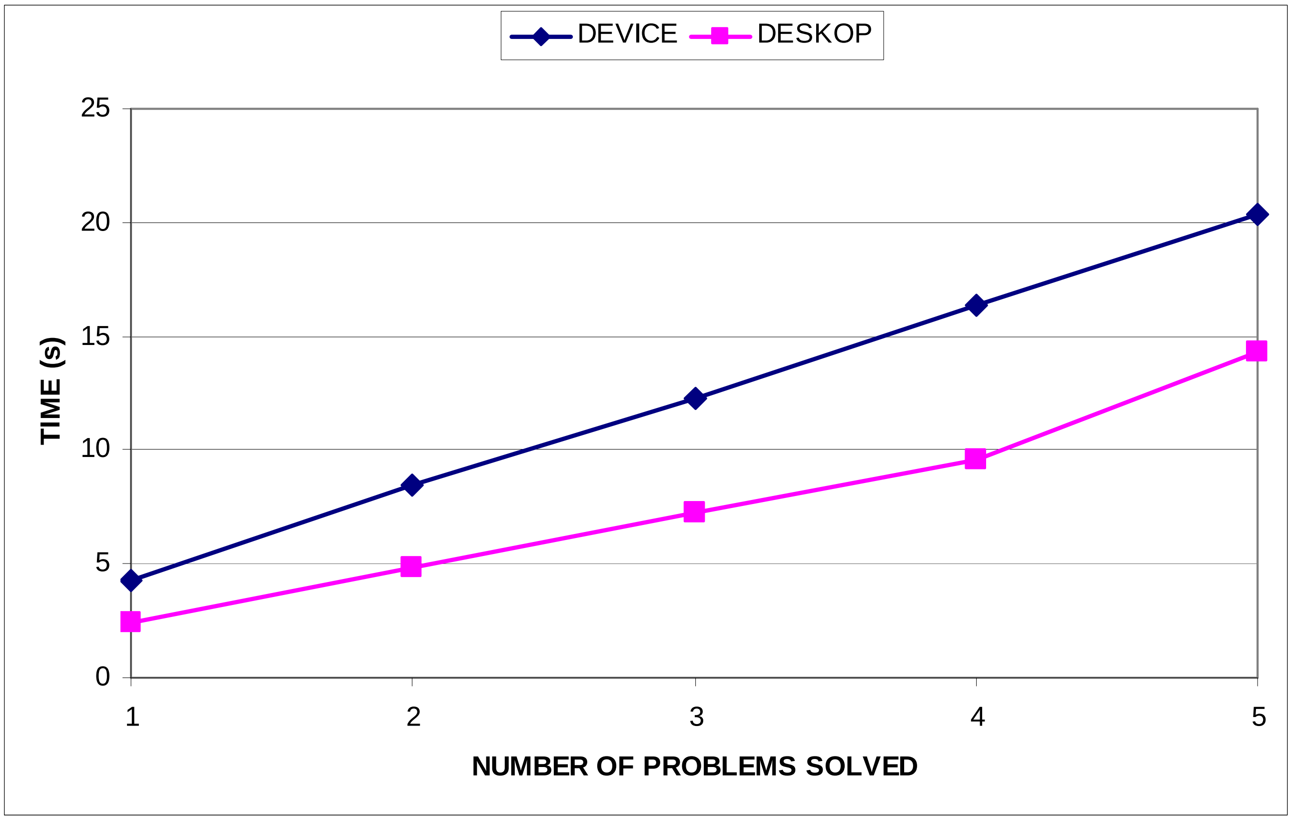
On-the-fly Matching Experiment on Desktop



(a) Match ... al policies

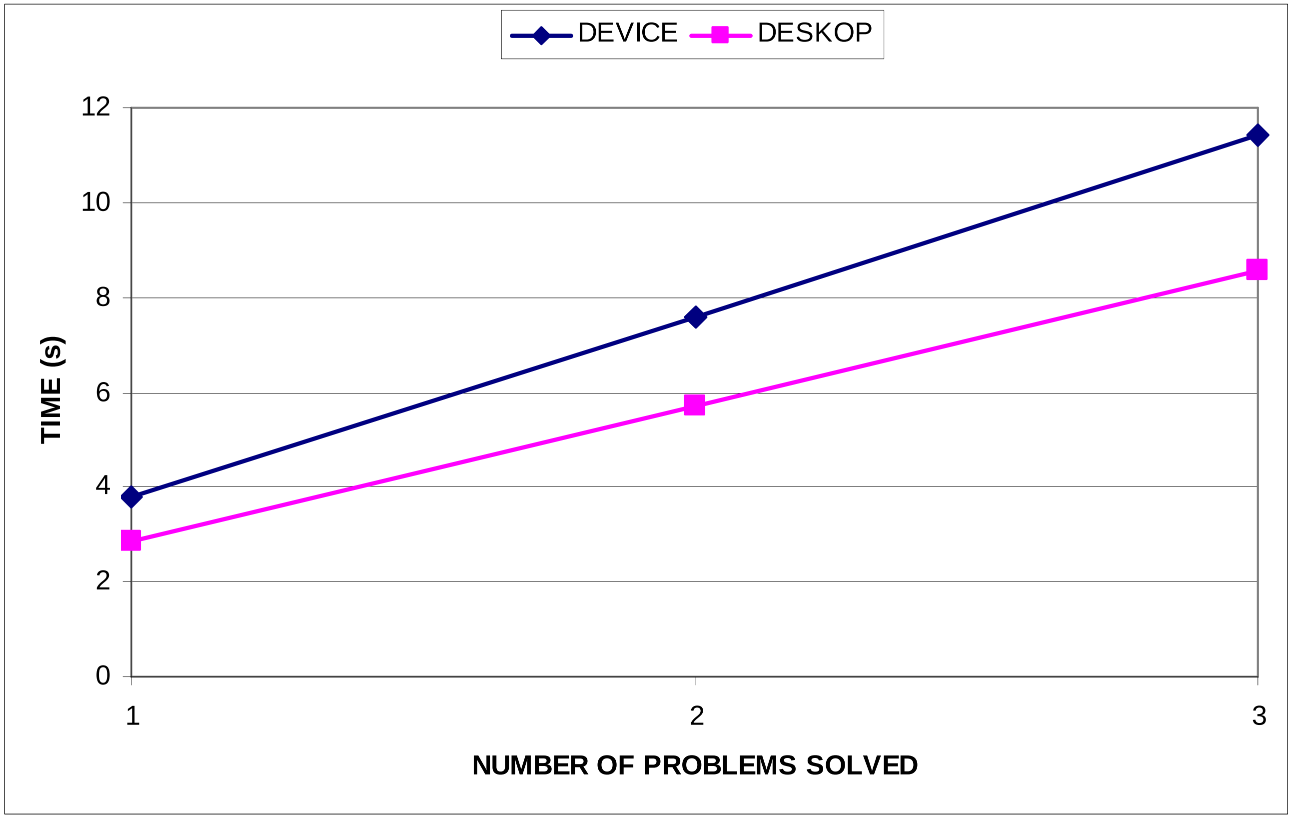
(c) Matches among synthetic contracts and policies

On-the-fly Matching Experiment Device vs Desktop



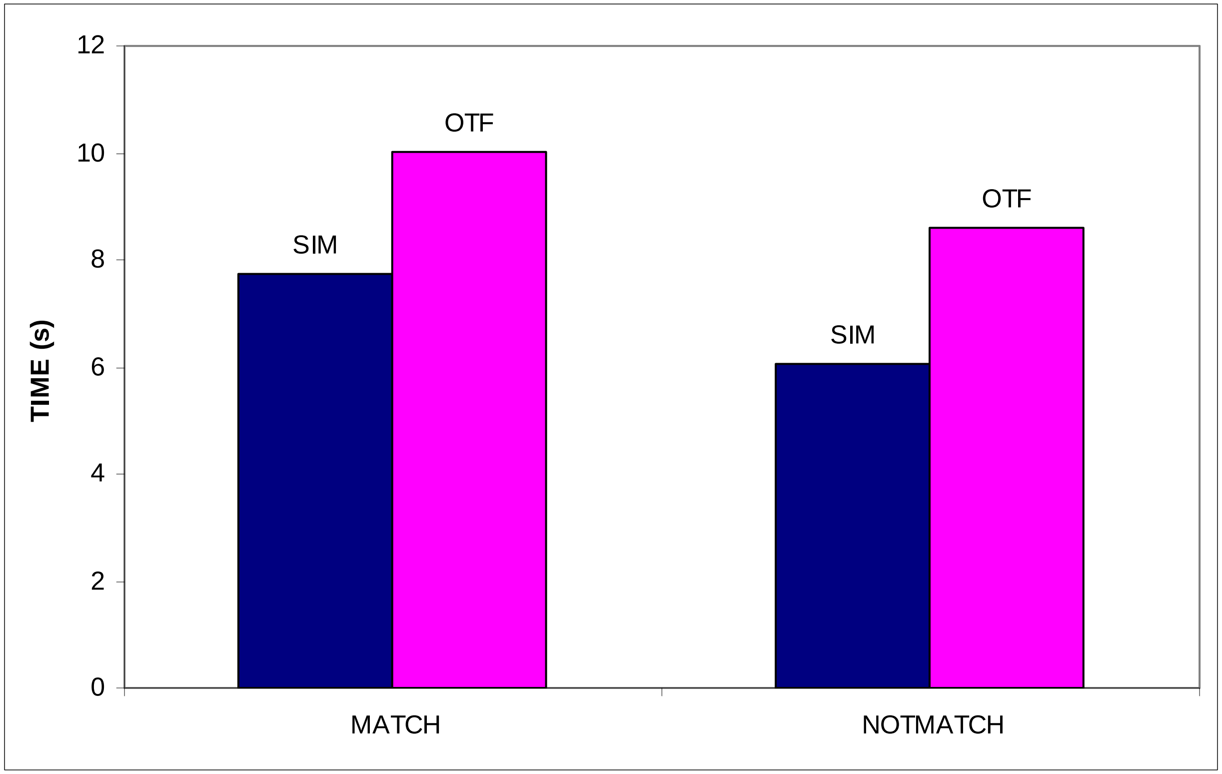
(a) Match succeeds

On-the-fly Matching Experiment Device vs Desktop



(b) Match fails

Matching Experiment
Simulation vs On-the-fly on Desktop



(a) Match succeeds

#SOLVED	SIM (s)	OTF (s)
1	2.014	2.41
2	3.948	4.825
3	5.834	7.263
4	7.72	10.023

(b) Match fails

#SOLVED	SIM (s)	OTF (s)
1	1.998	2.858
2	4.058	5.728
3	6.056	8.602

Road Map

Security-by-Contract

Automata Modulo Theory

On-the-fly Matching

Simulation Matching

IRM Optimization

IRM Optimization Models

Trusted | **Untrusted**

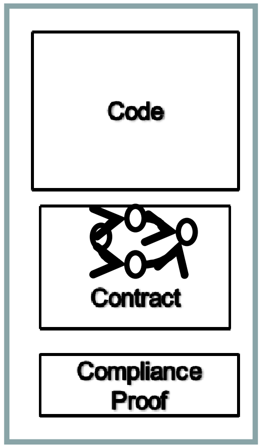
extract security relevant behaviors from code

ContractExtractor

Code

Contract

Model1: Contract Extractor on Trusted part



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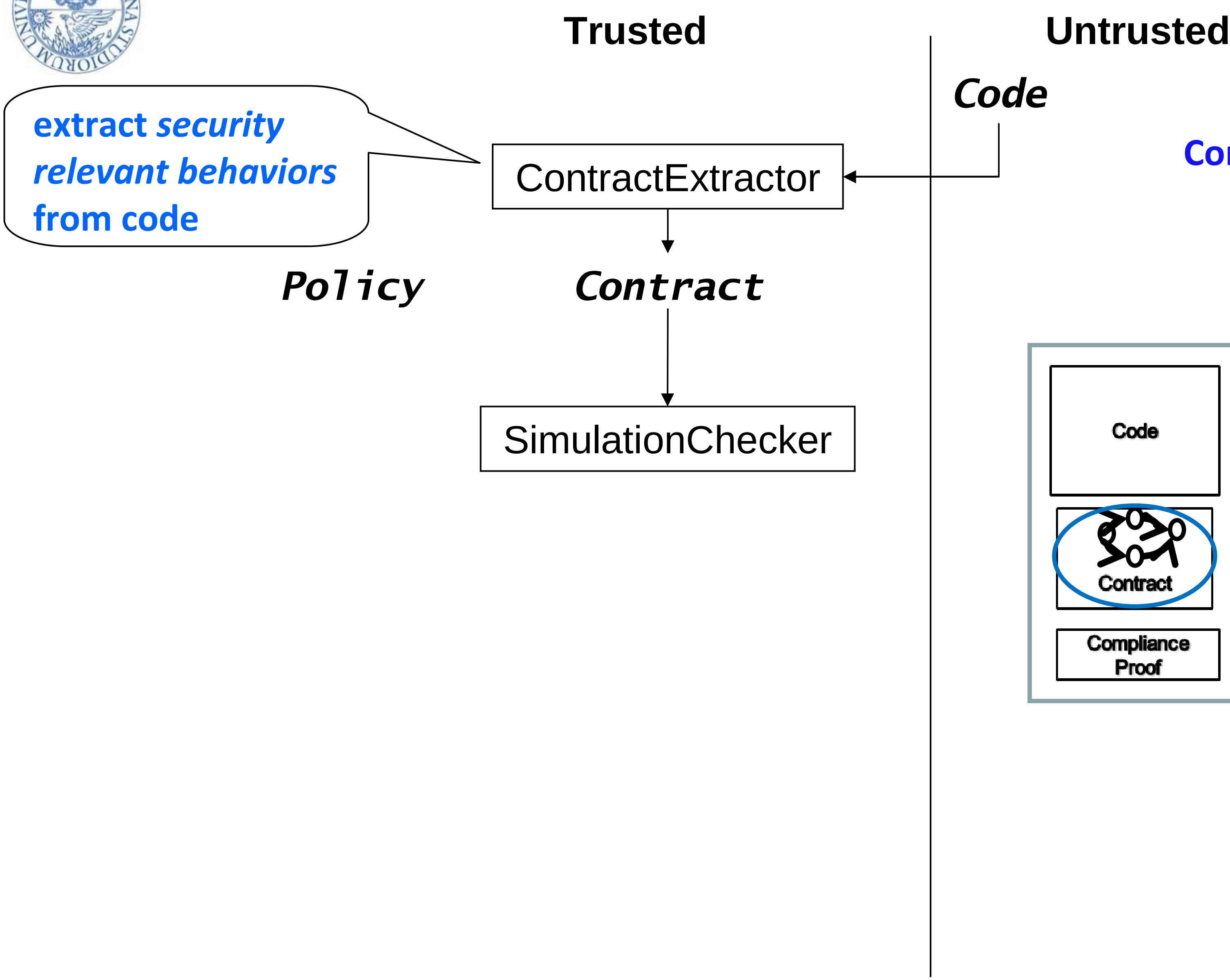
IRM Optimization Models



Model1: Contract Extractor on Trusted part

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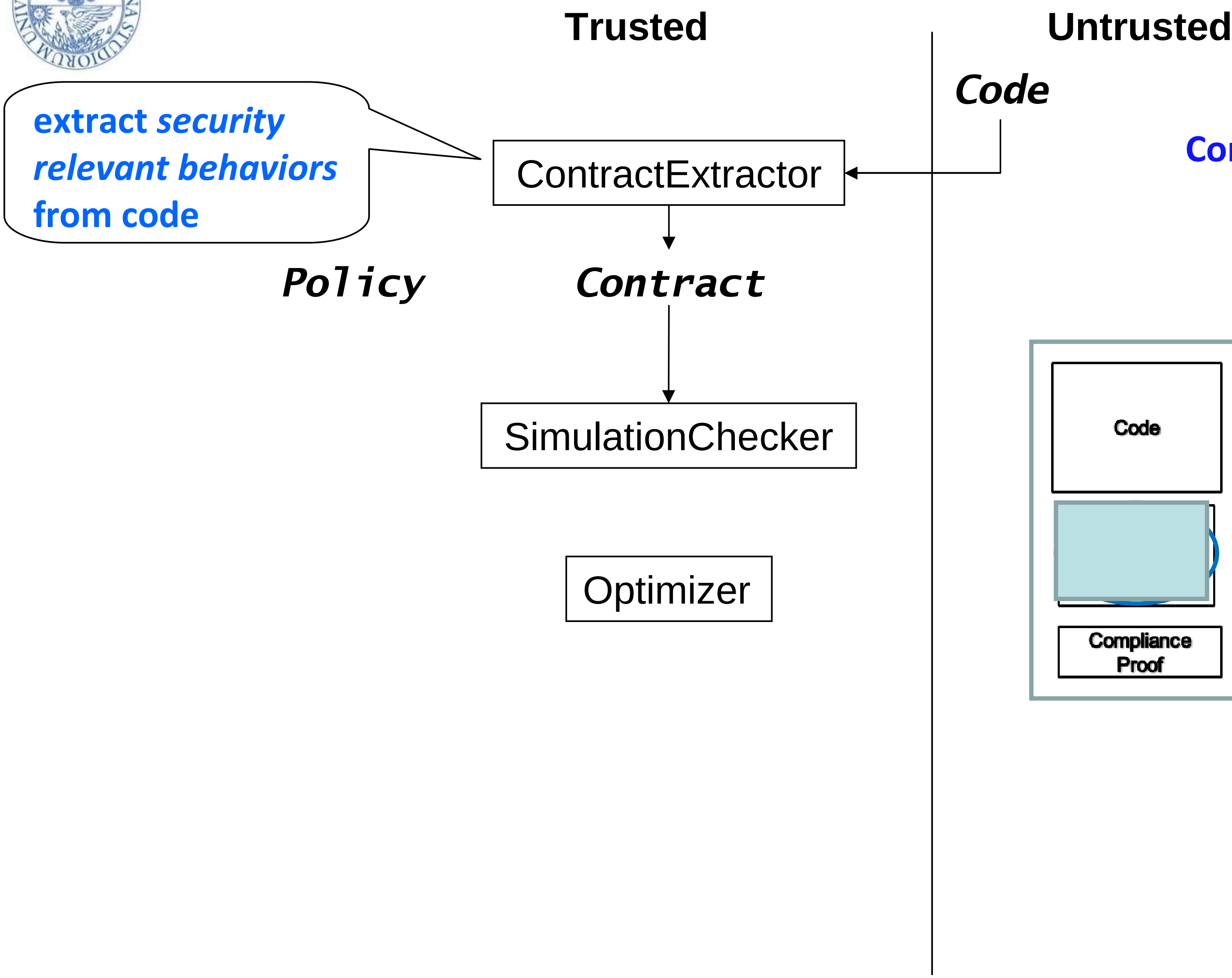
IRM Optimization Models



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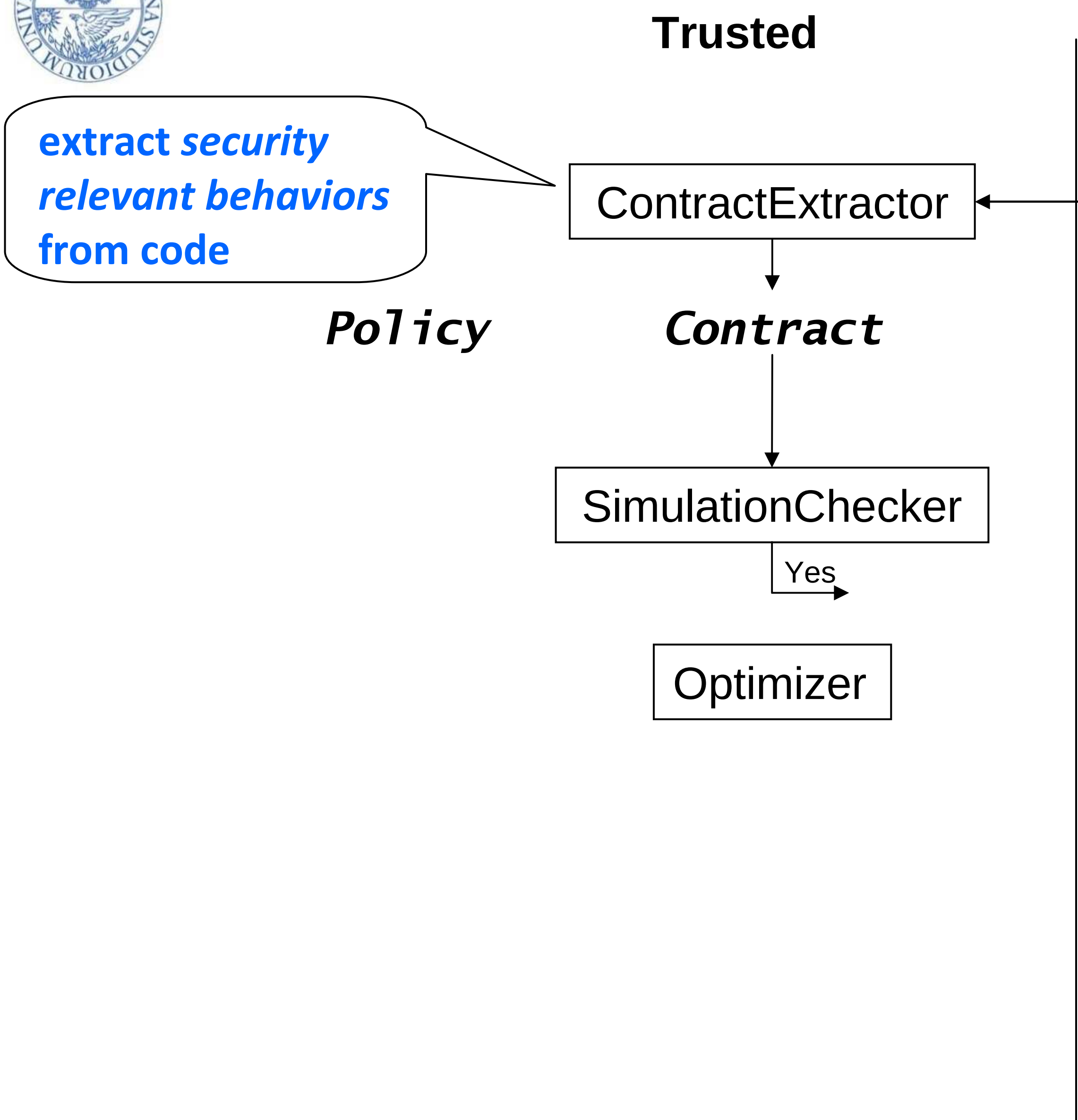
IRM Optimization Models



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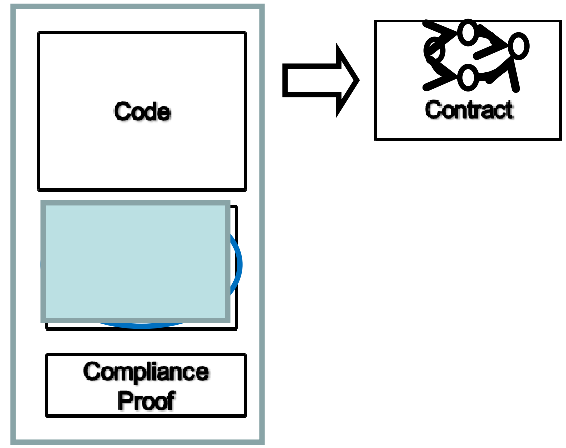

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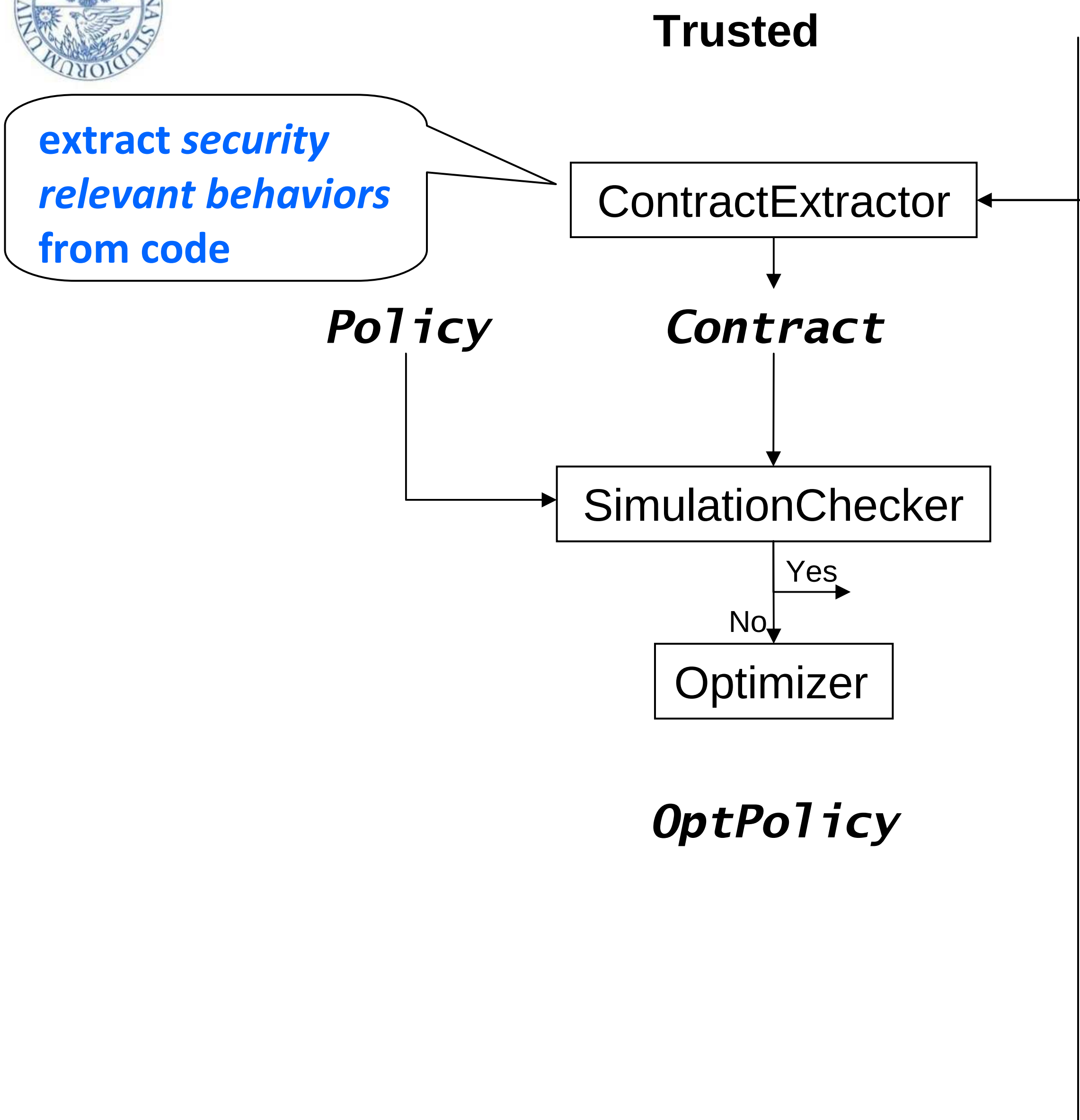
IRM Optimization Models



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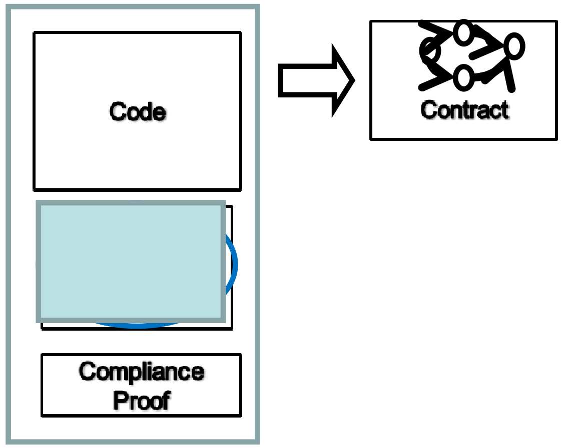
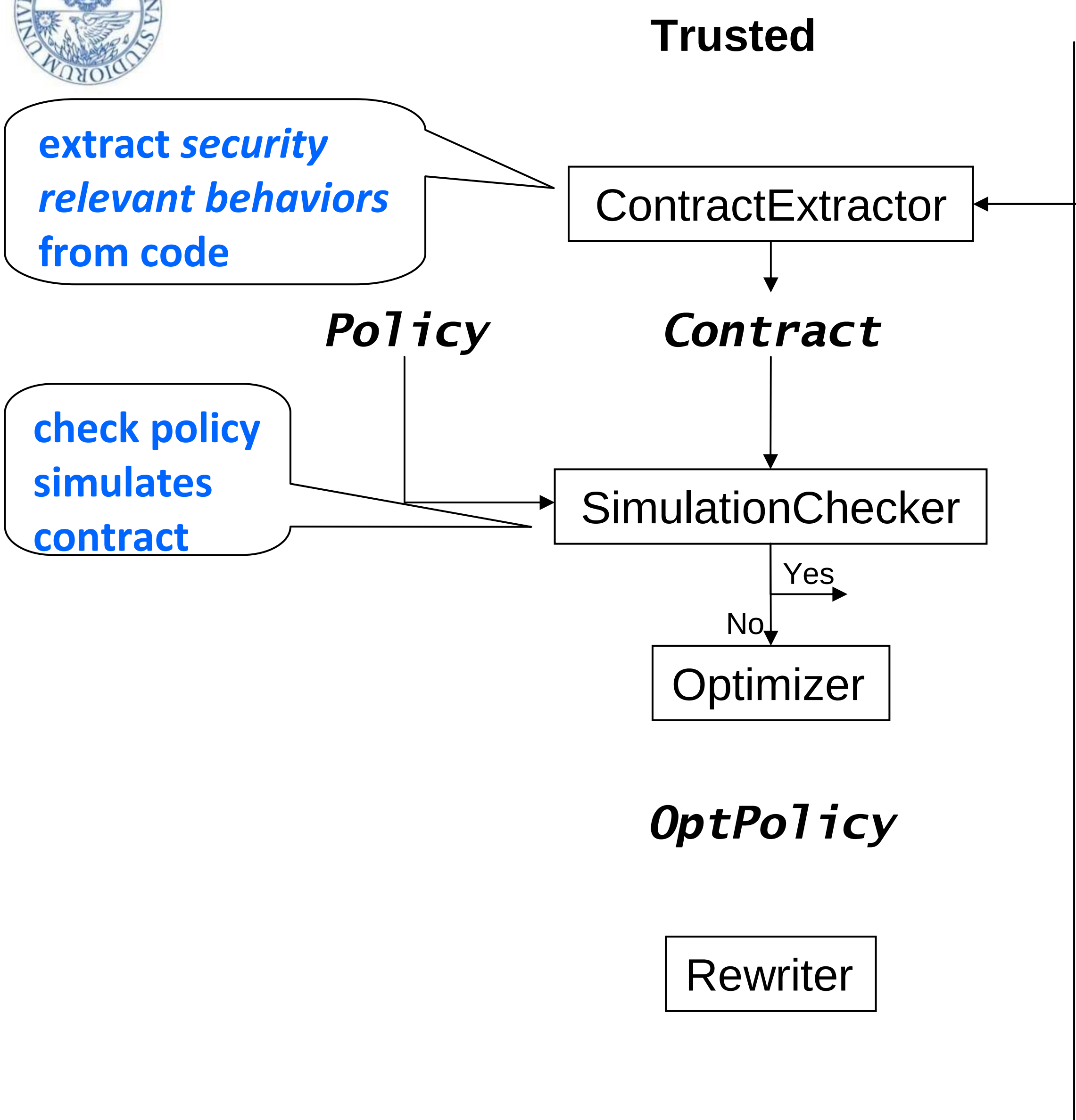


IRM Optimization Models



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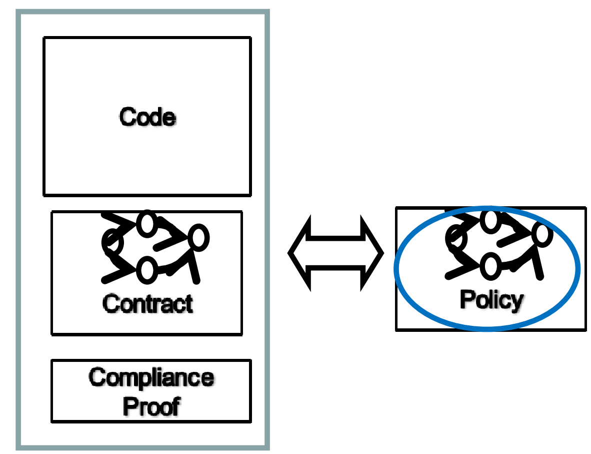

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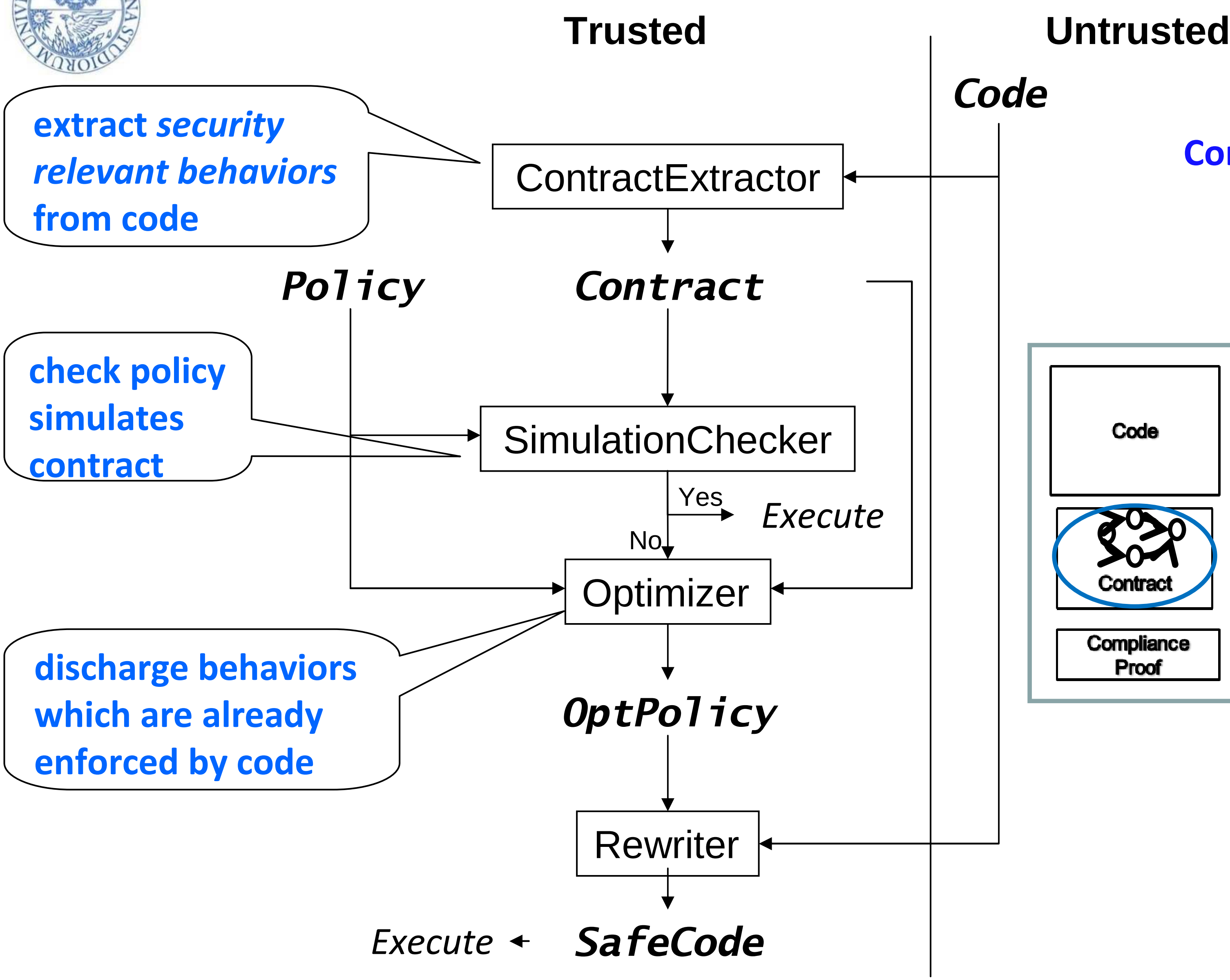

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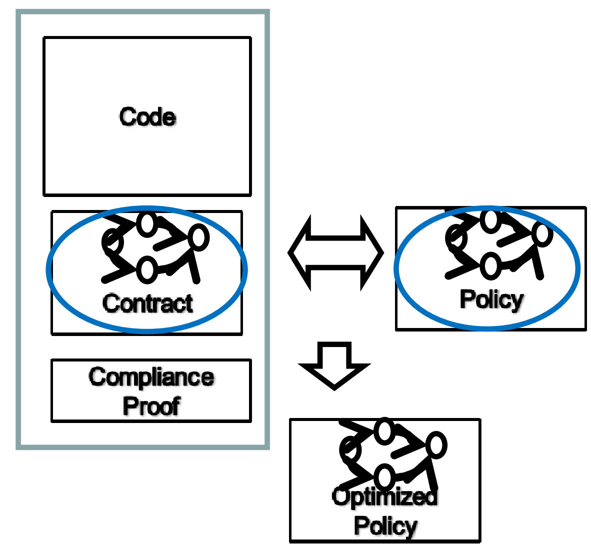

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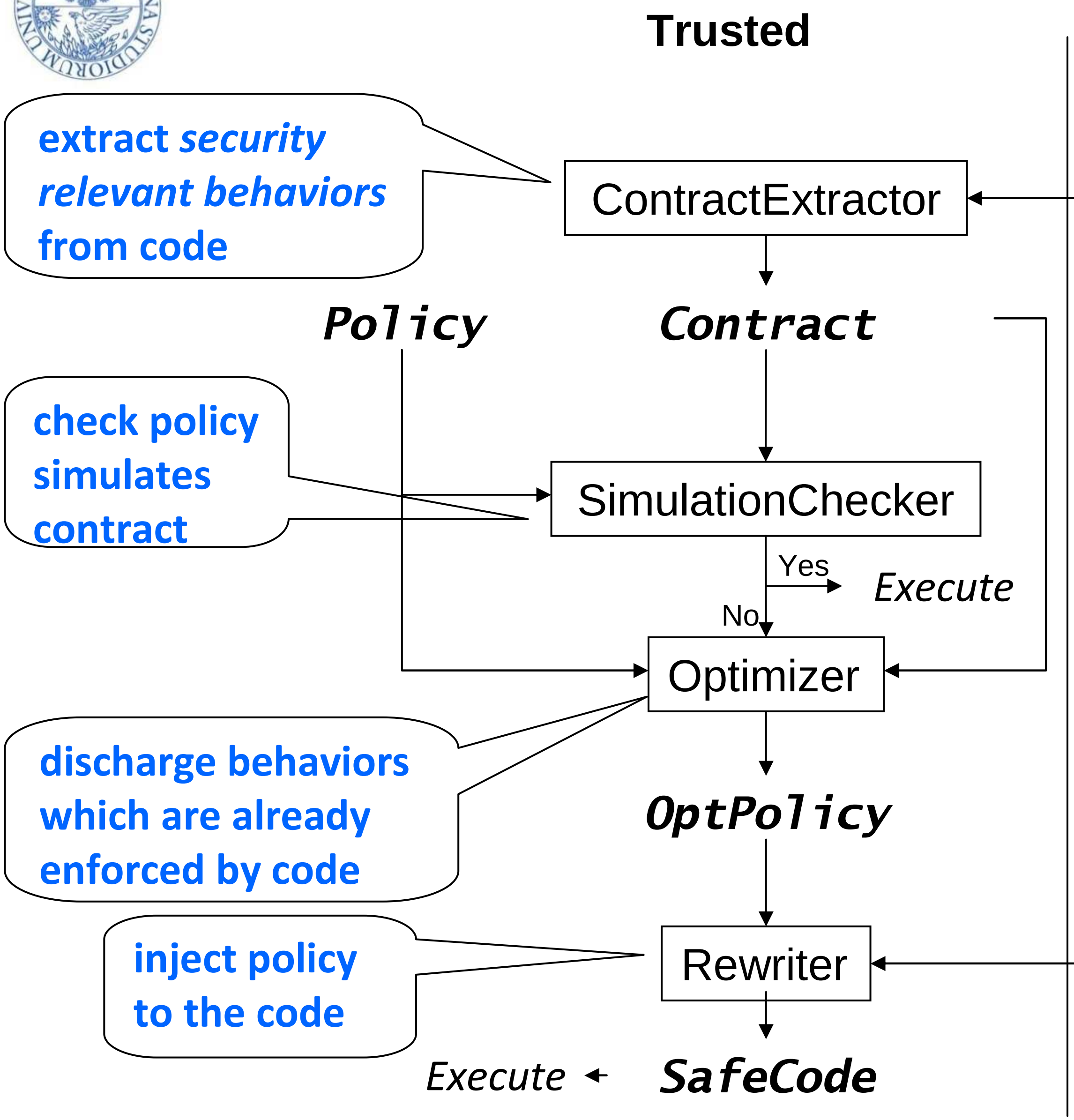

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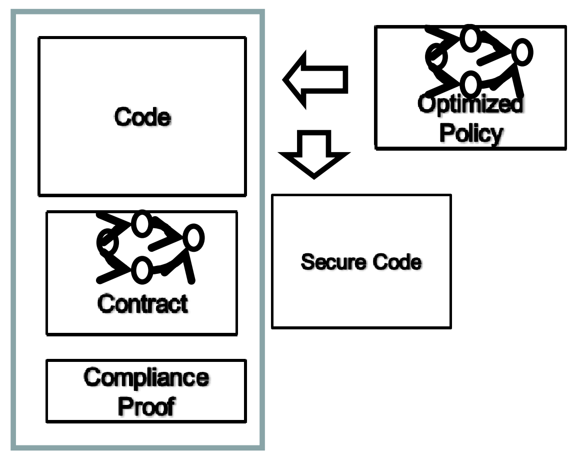

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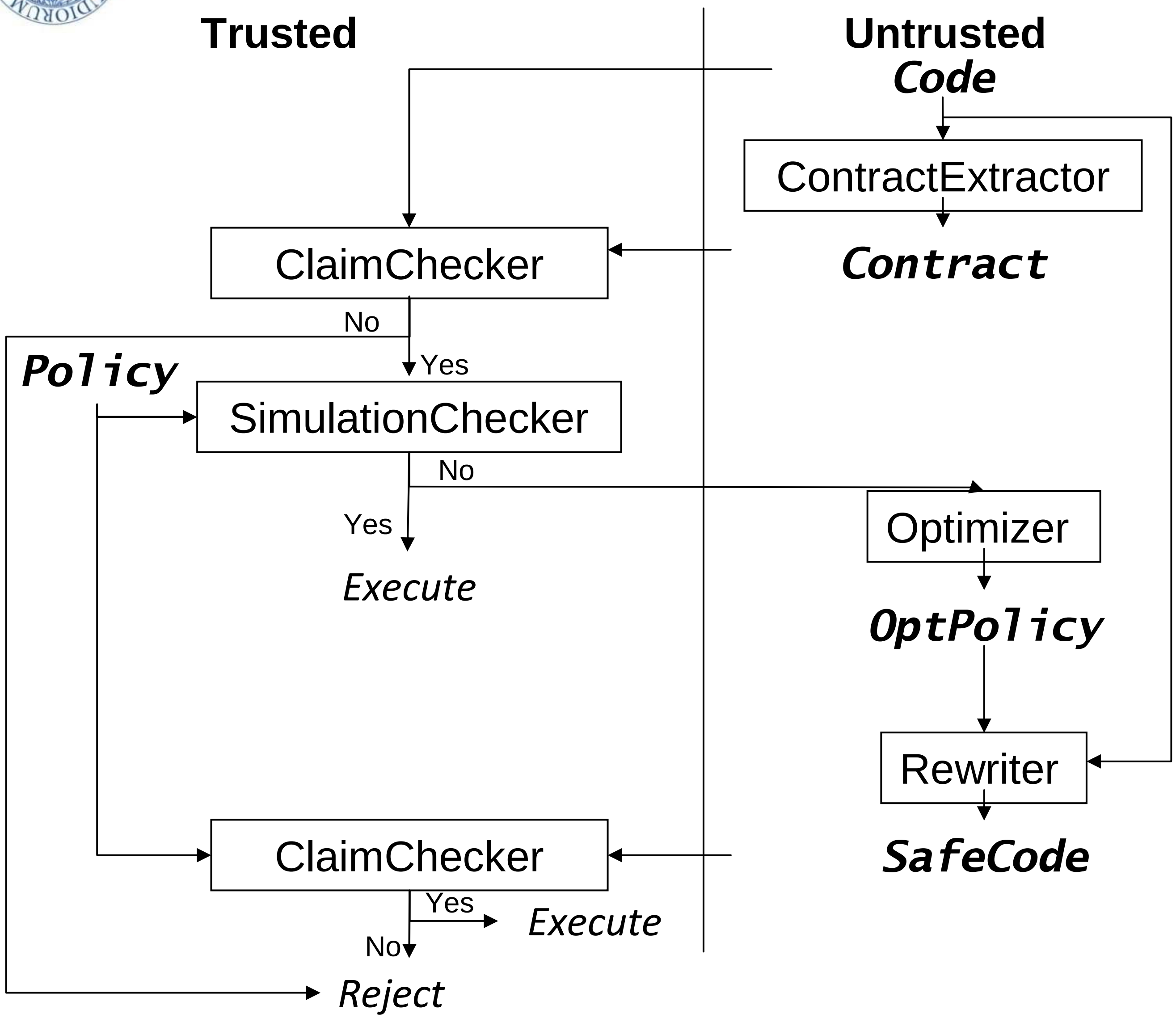
Optimizer and Rewriter on Untrusted part

Model6: Contract Extractor on Untrusted part



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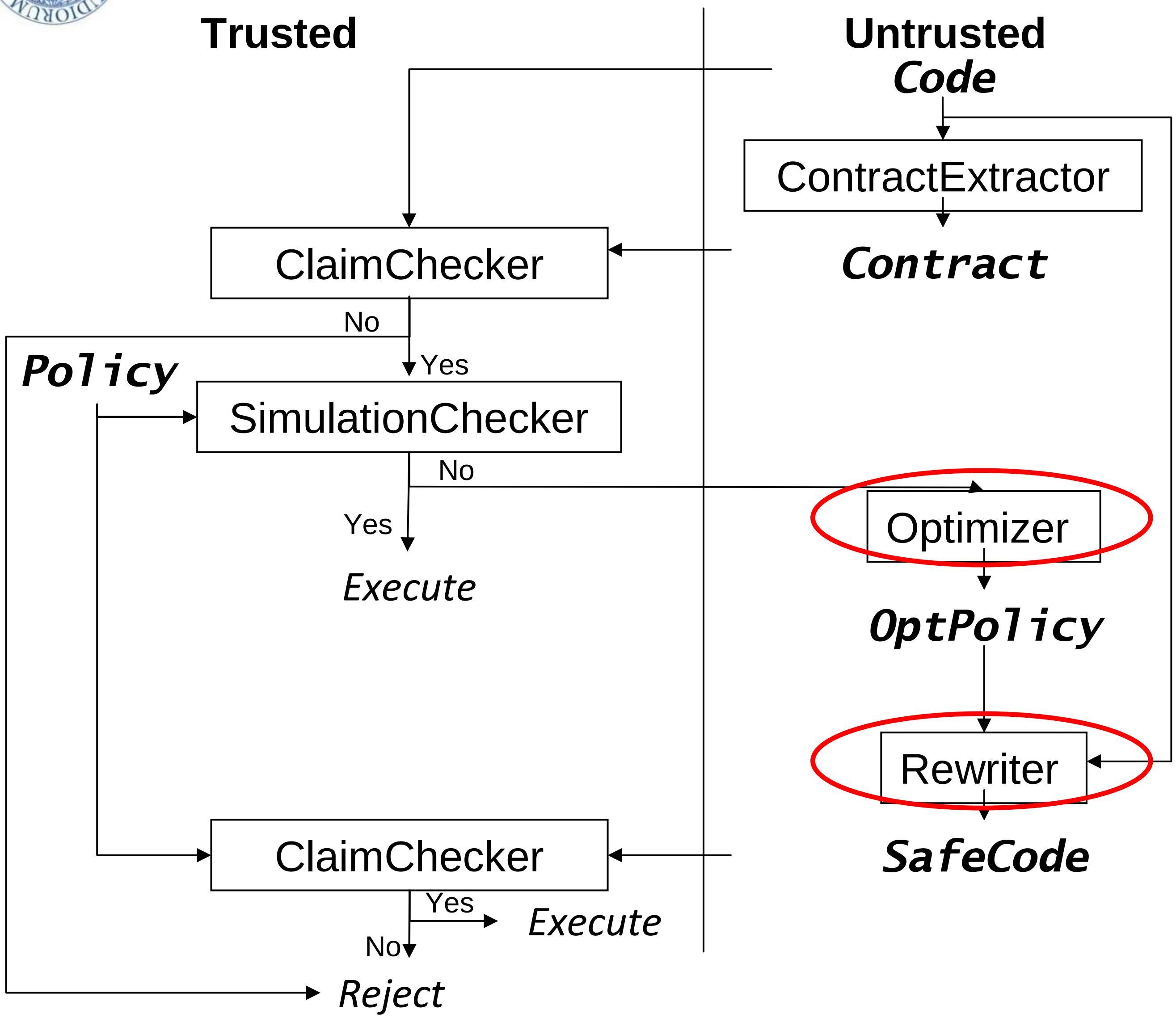
Optimizer and Rewriter on Untrusted part

Model6: Contract Extractor on Untrusted part



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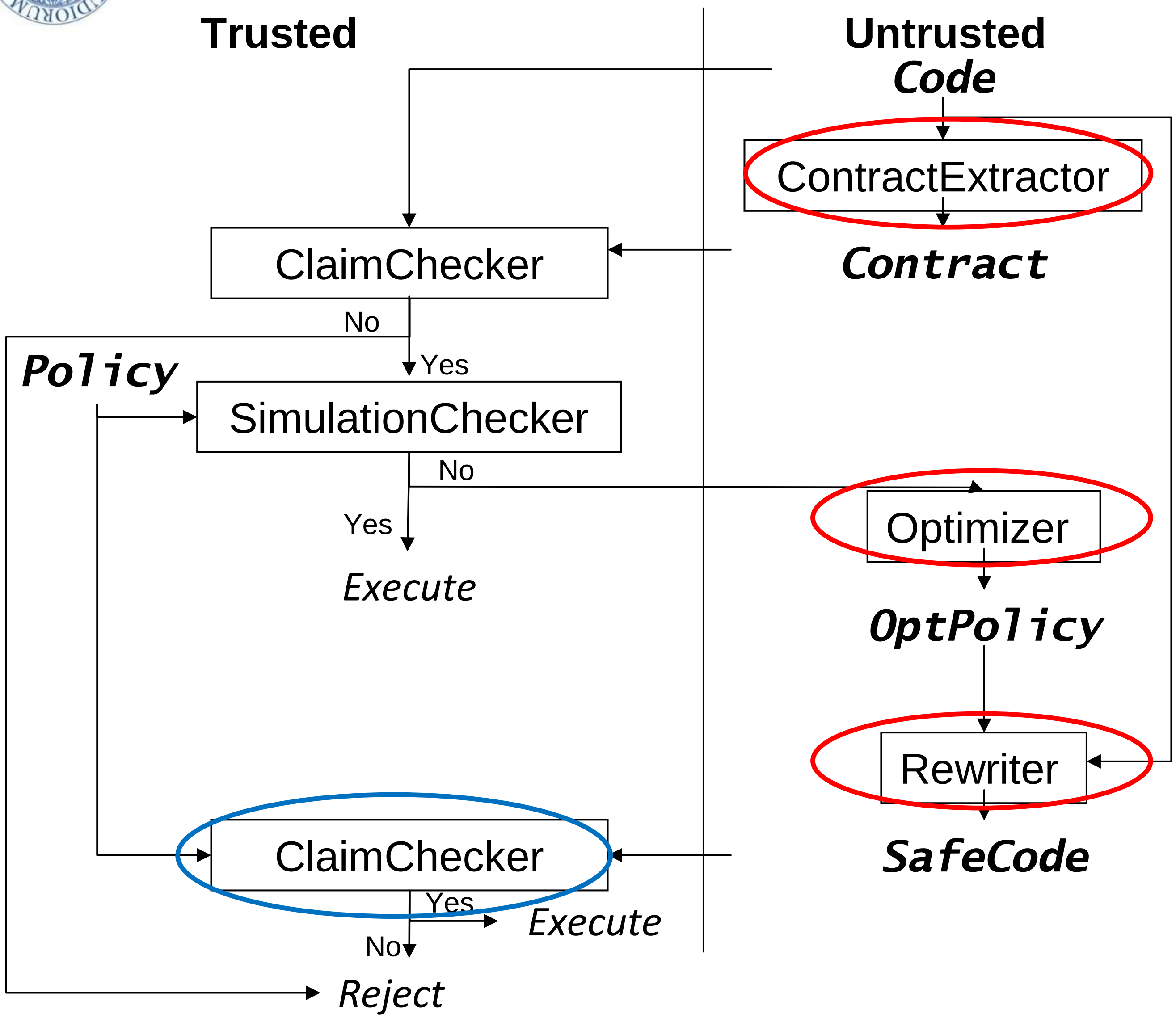

Model6:
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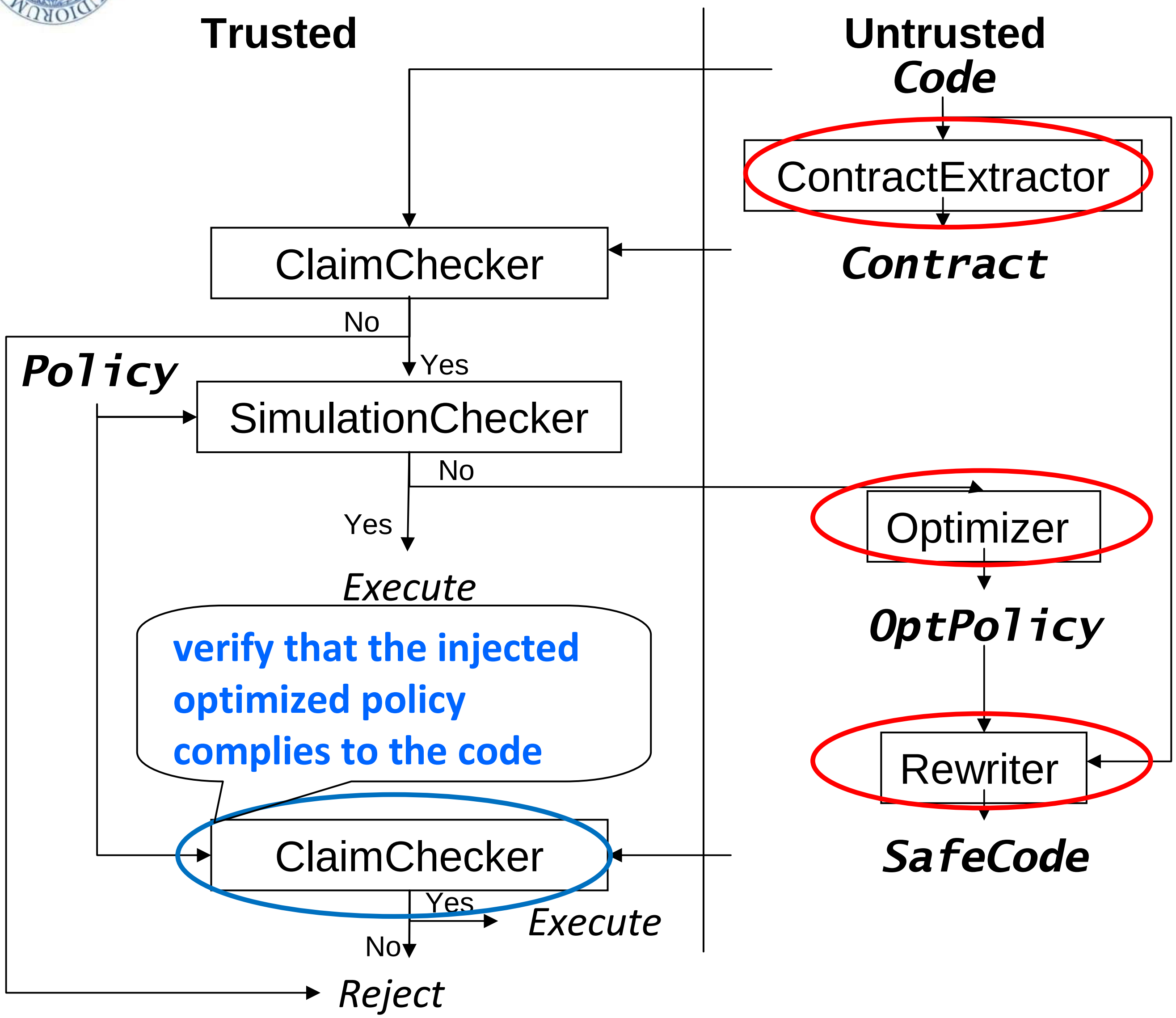
Optimizer and Rewriter on Untrusted part

Model6: Contract Extractor on Untrusted part



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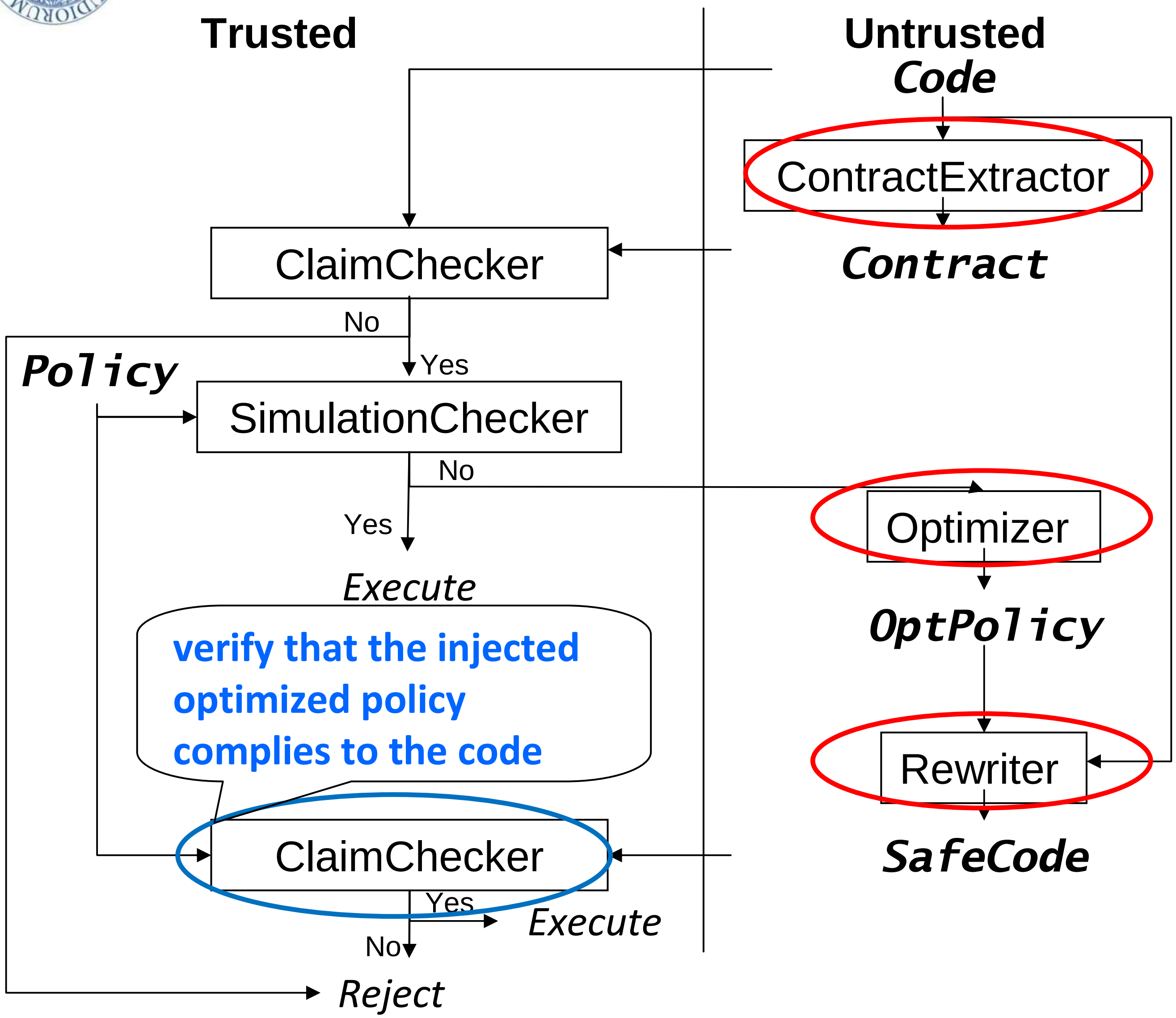

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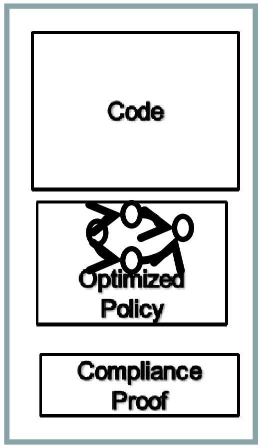

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Optimizer and Rewriter on Untrusted part

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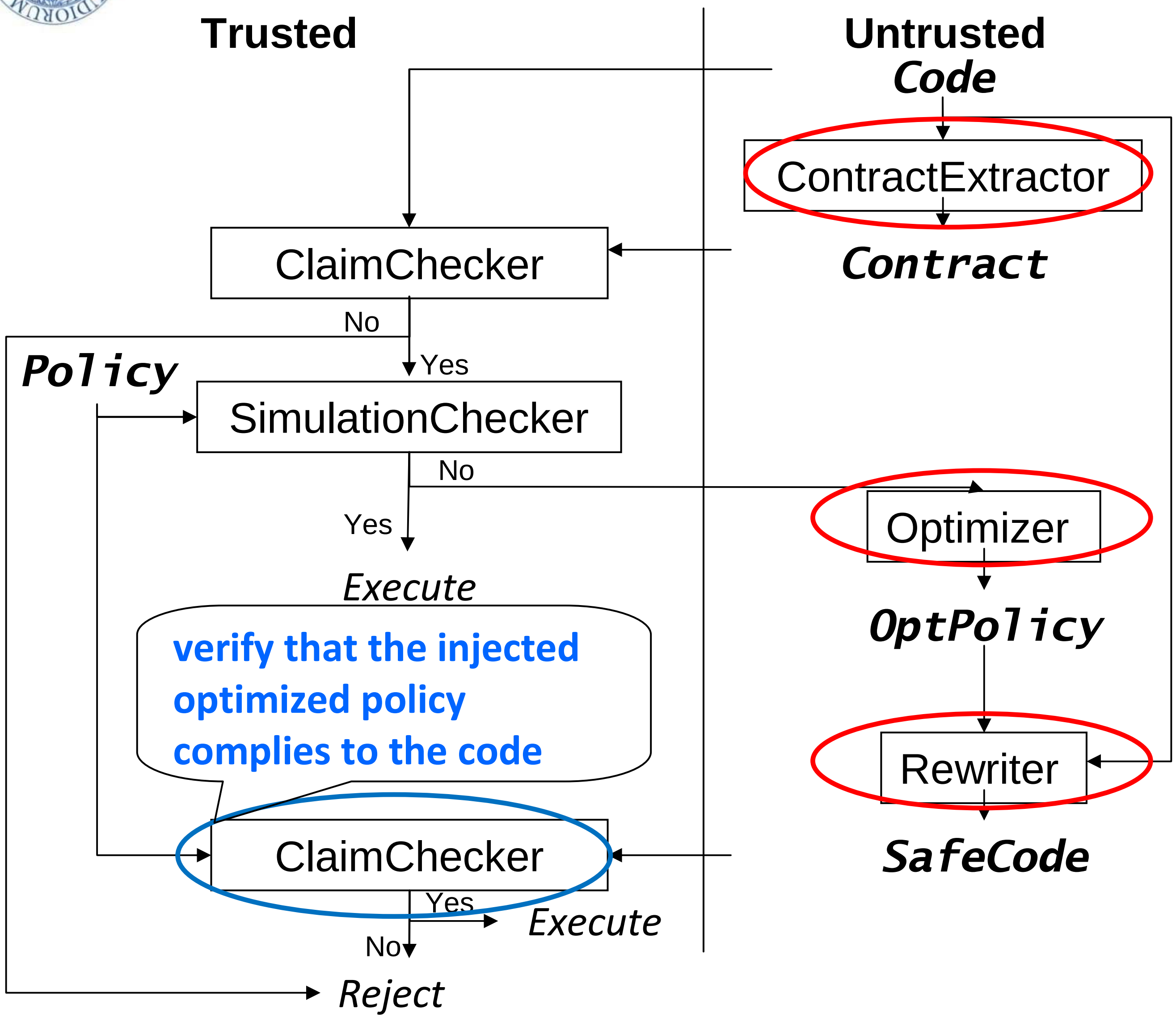
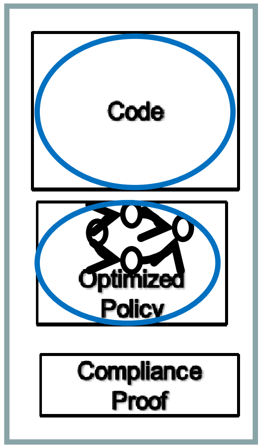
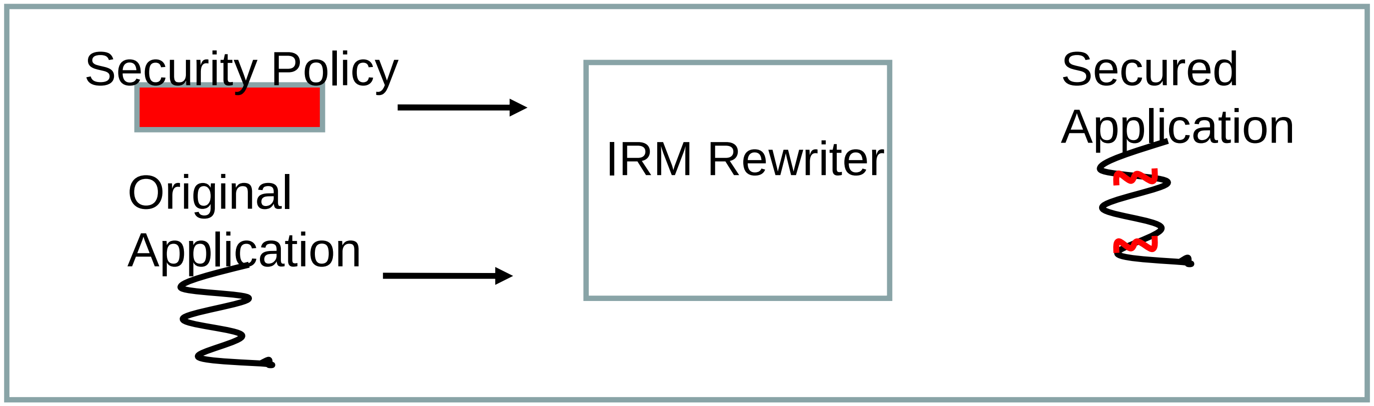




Optimizing Security Policy or Rewriter



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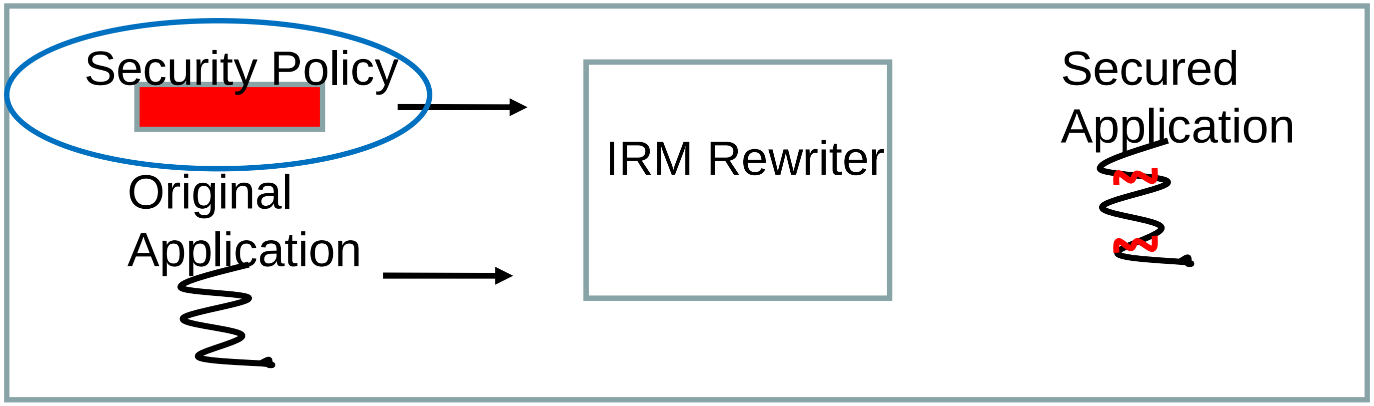

- **Security Automata SFI Implementation (SASI) [Erlingson-etal-NSPW’99]**
  - **Minimizing TCB by working at the level of object code**
- **Trade off between moving more processes out of trusted part and the complexity of the whole process [Hamlen-Thesis’06]**
- **Efficient IRM Enforcement [Yan-etal-ASIACCS’09]**
  - **a constrained representation of history-based access control policies**
  - **exploit the structure of this policy representation**
  - **extended into a distributed optimization protocol**

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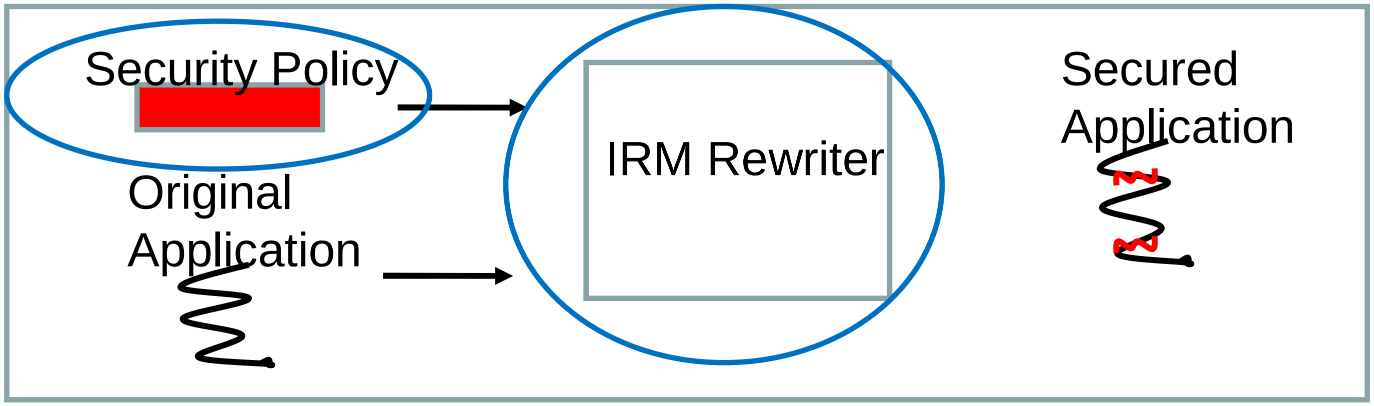
Optimizing Security Policy or Rewriter



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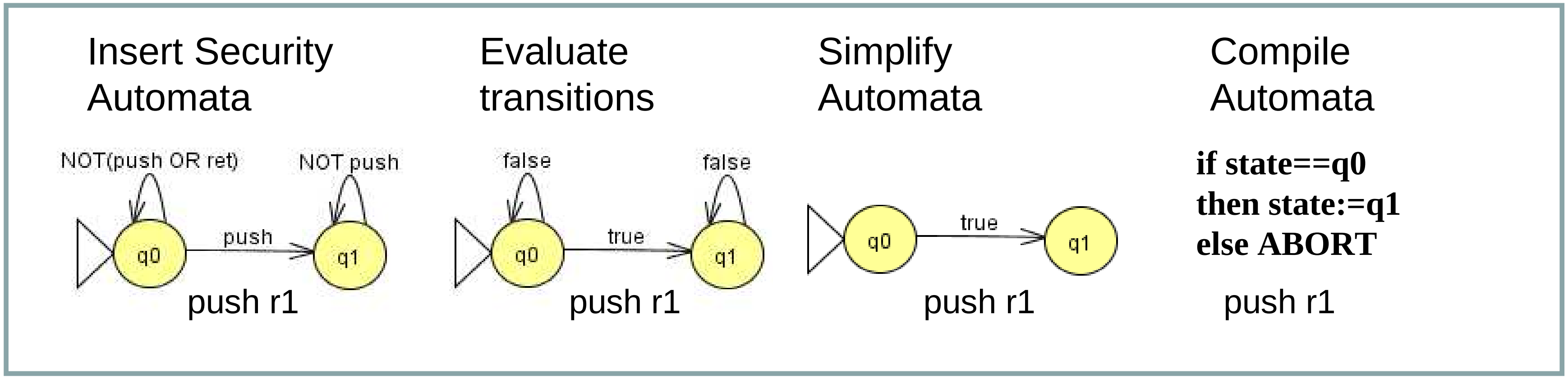
Optimizing Security Policy or Rewriter



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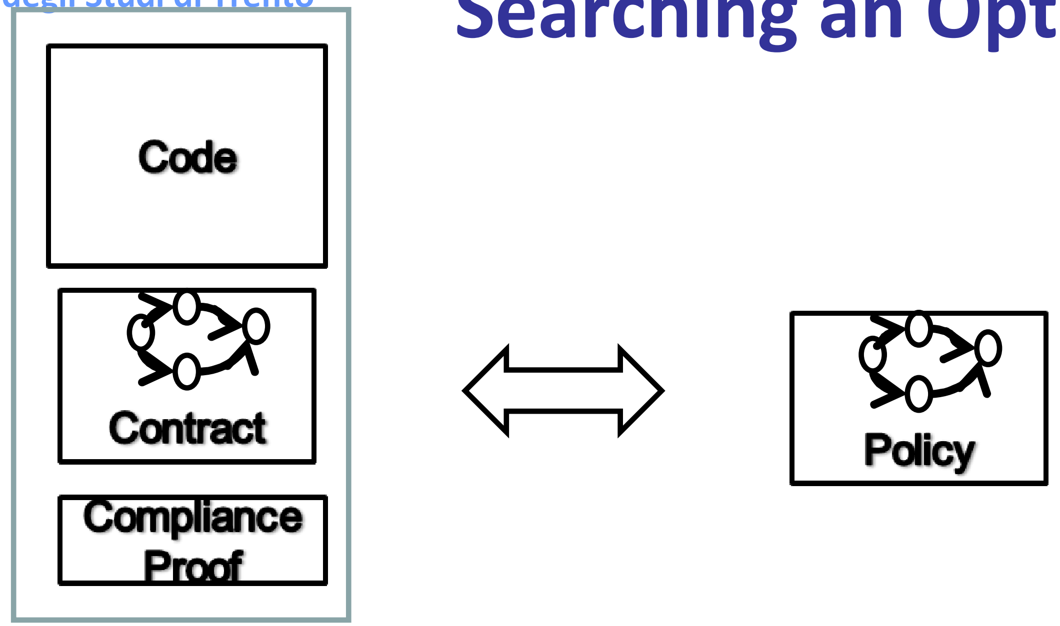
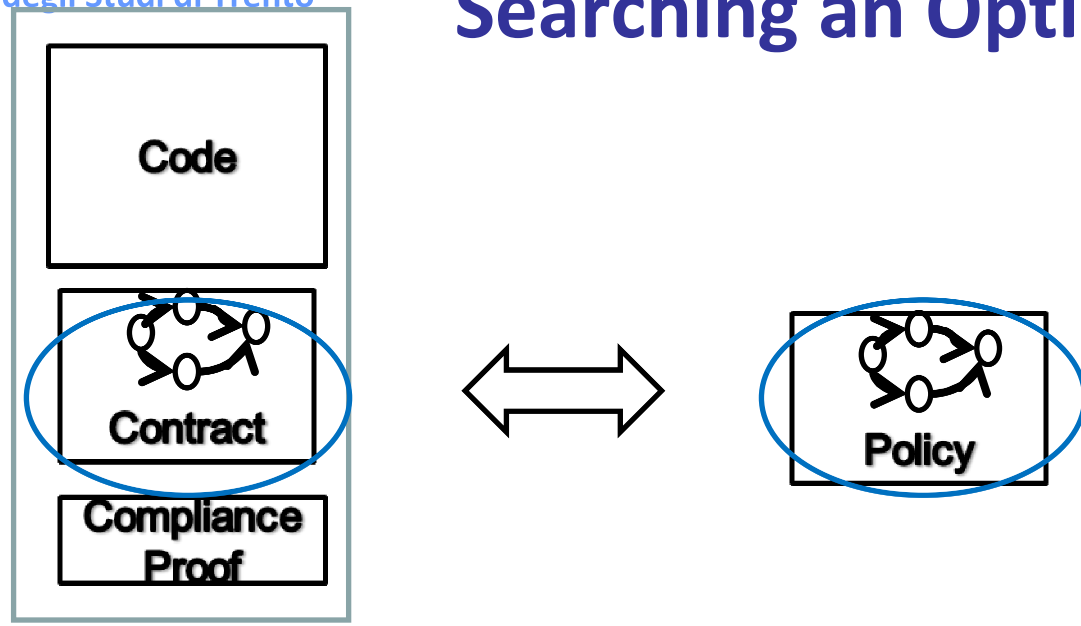
Searching an Optimized Policy



- **Given two automata C and P representing resp. the formal specification of a contract and of a policy, we have an efficient IRM O derived from P with respect to C when:**
  - every security-relevant event invoked by the intersection of O and C can also be invoked by P [sound]
  - O has smaller or equal number of transitions or states compared to P [optimal]

Searching an Optimized Policy



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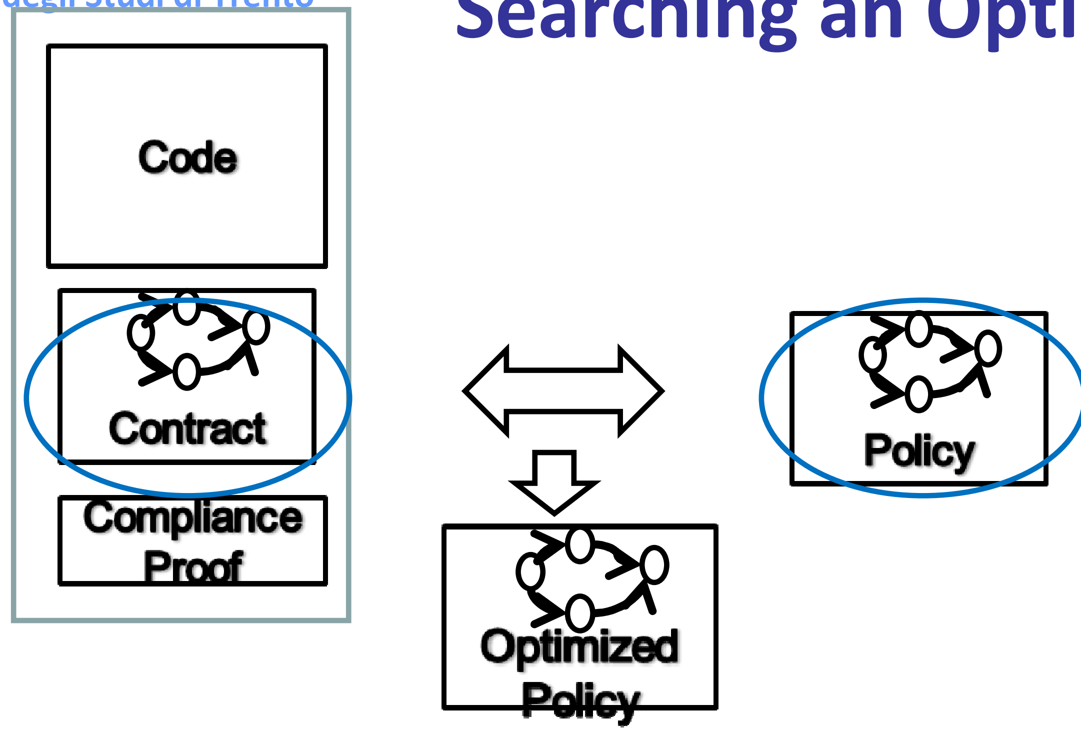
  - O has smaller or equal number of transitions or states compared to P [optimal]

Searching an Optimized Policy



- **Given two automata C and P representing resp. the formal specification of a contract and of a policy, we have an efficient IRM O derived from P with respect to C when:**
  - every security-relevant event invoked by the intersection of O and C can also be invoked by P [sound]
  - O has smaller or equal number of transitions or states compared to P [optimal]

Inline Type Examples

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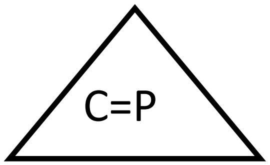	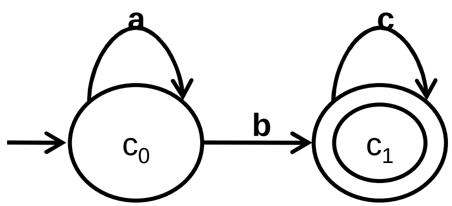	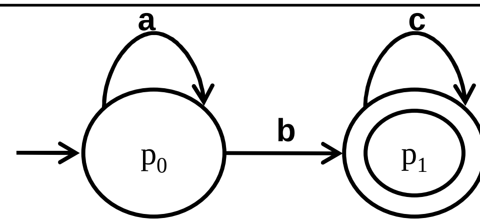

Inline Type Examples

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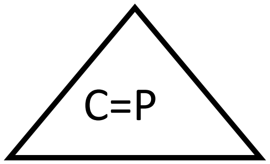	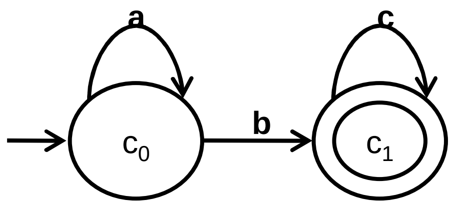	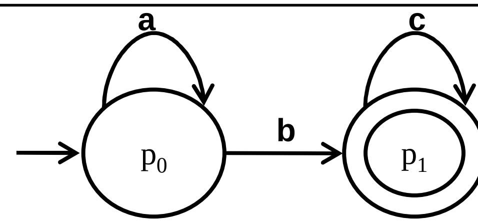
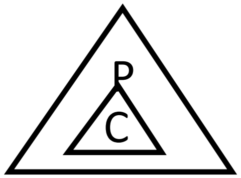	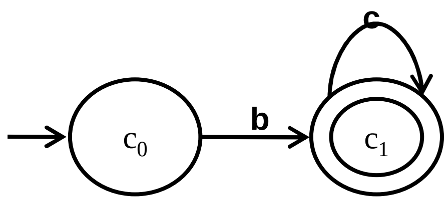	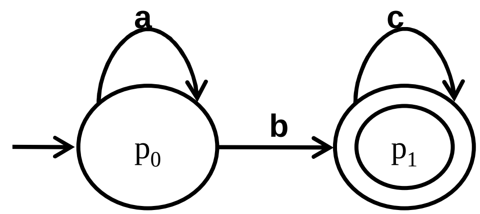

Inline Type Examples

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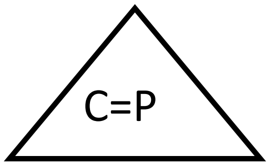	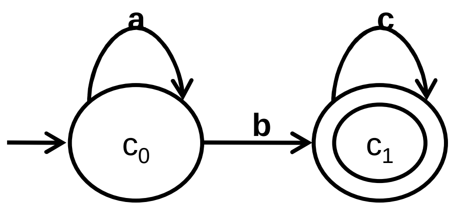	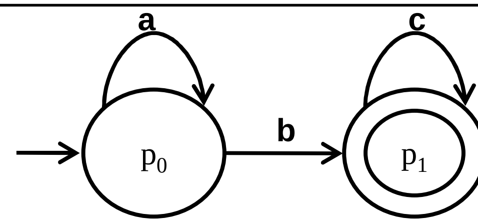
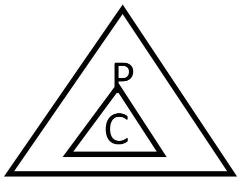	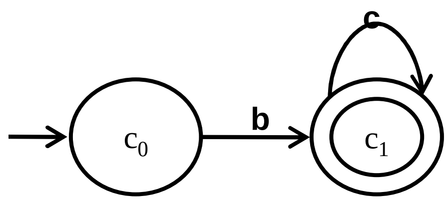	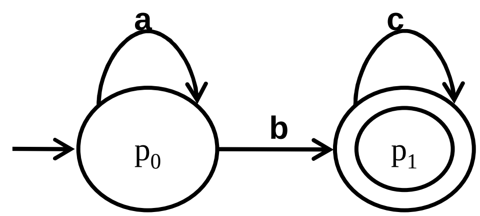

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Inline Type Examples

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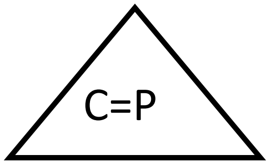	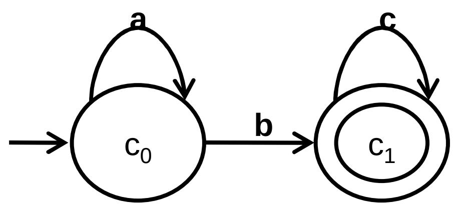	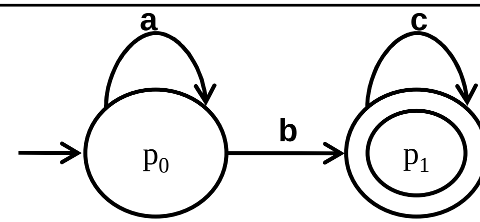
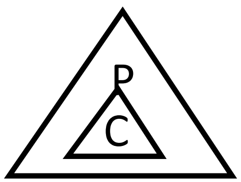	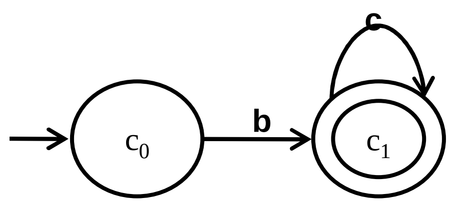	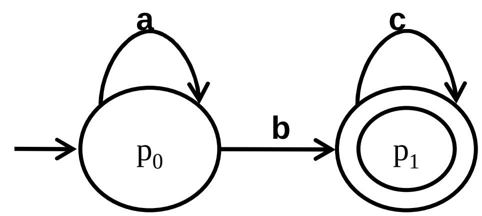
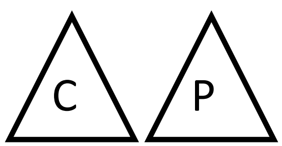	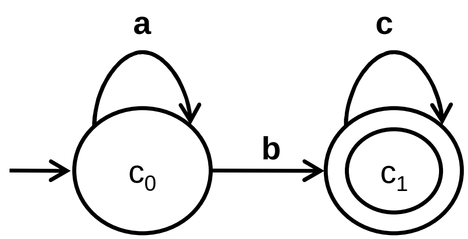	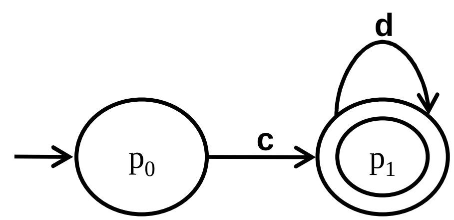

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Inline Type Examples

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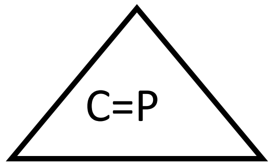	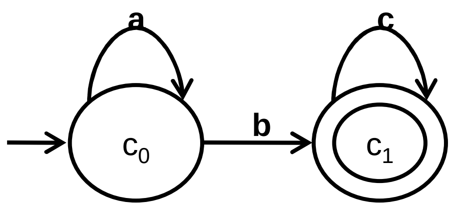	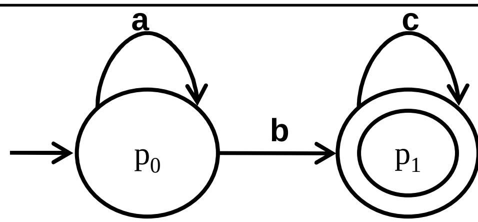
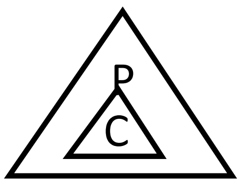	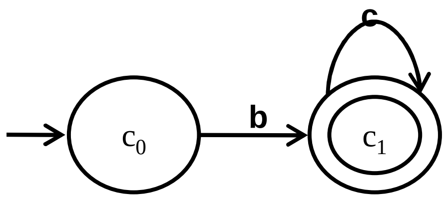	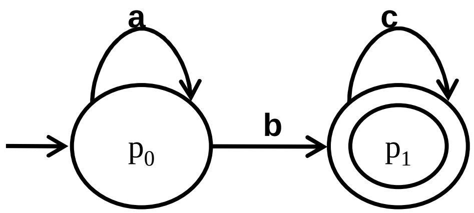
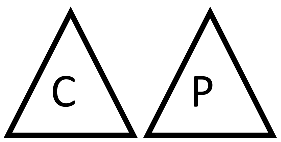	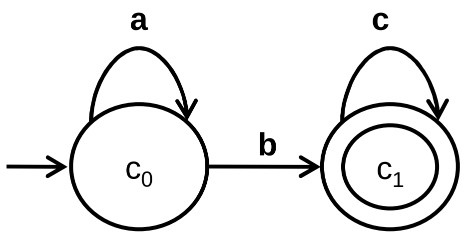	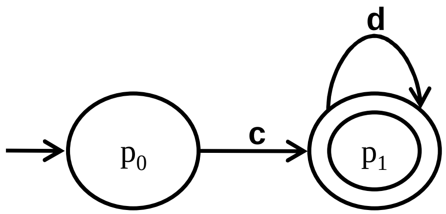
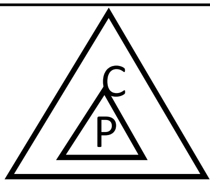	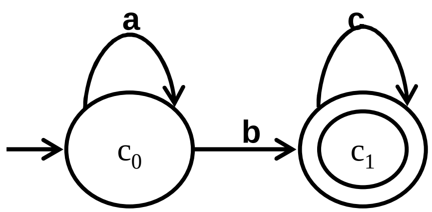	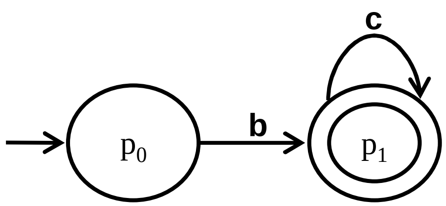

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Inline Type Examples

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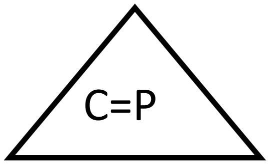	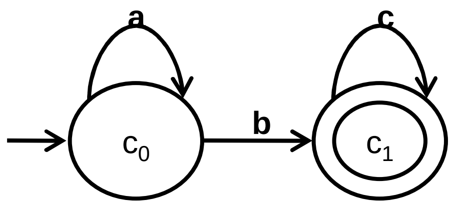	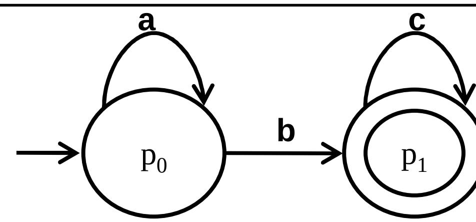
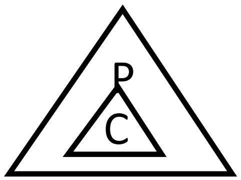	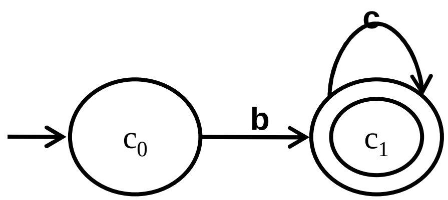	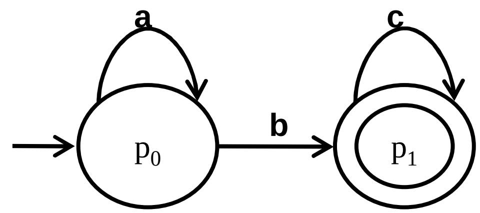
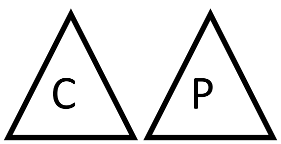	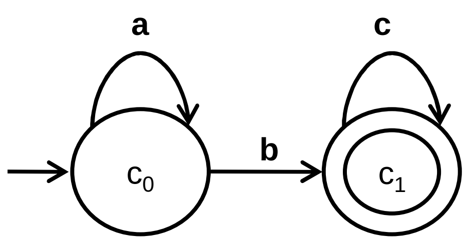	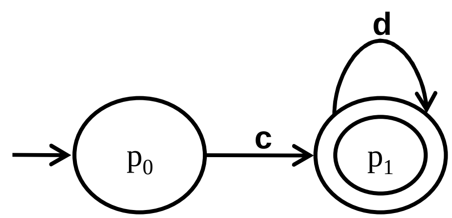
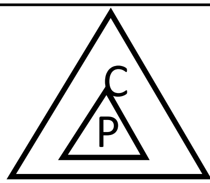	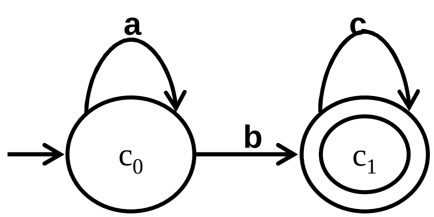	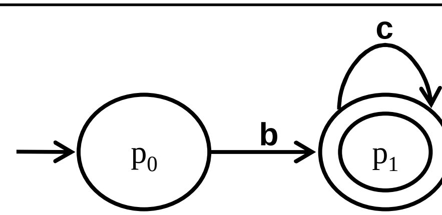

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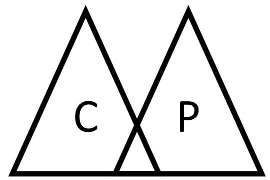
Inline all

Optimization Example

Inline-type



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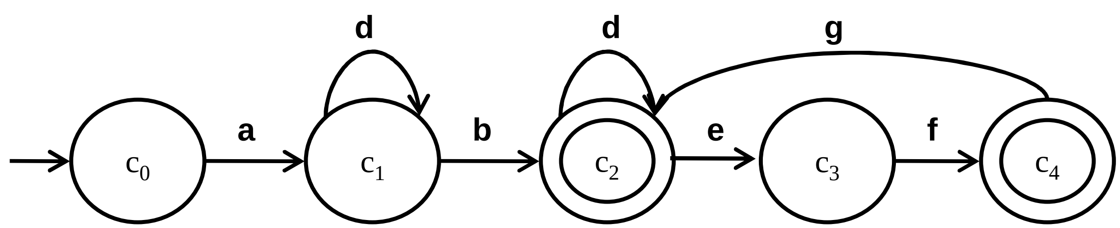

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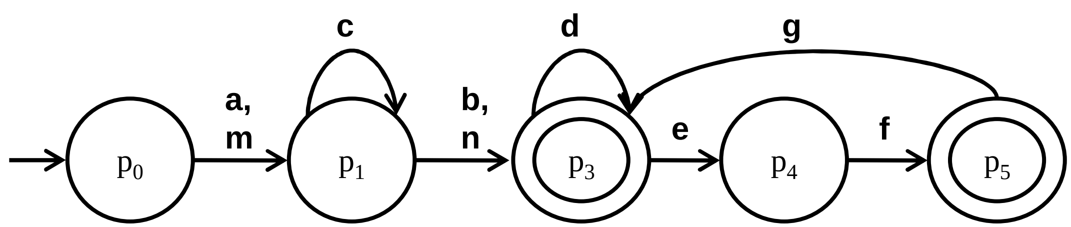
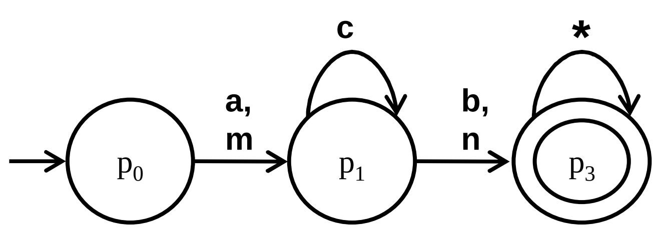
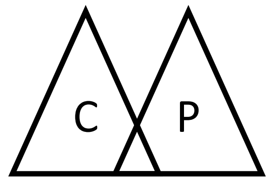
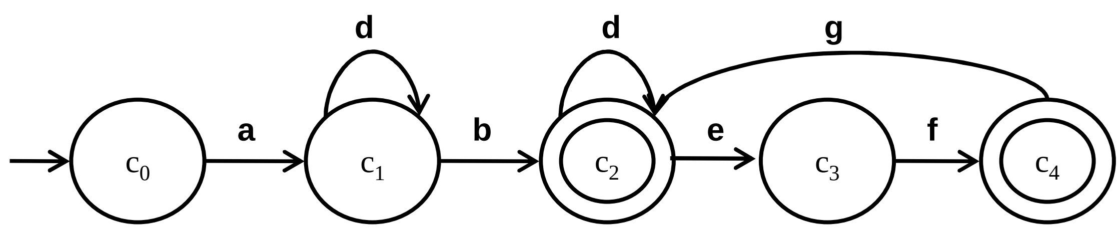
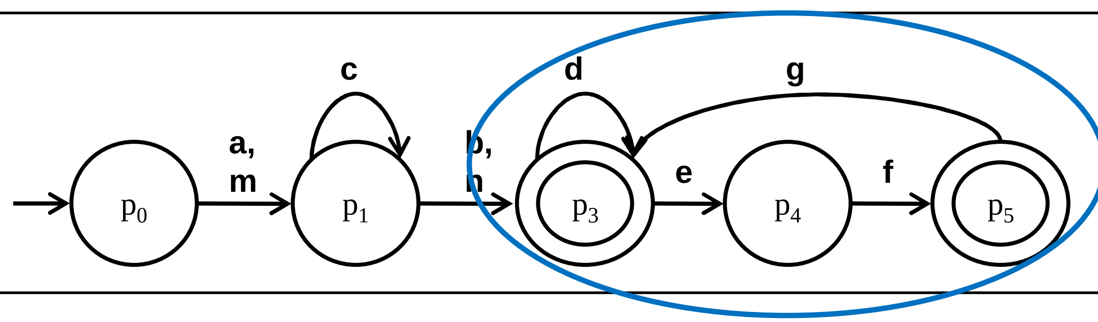
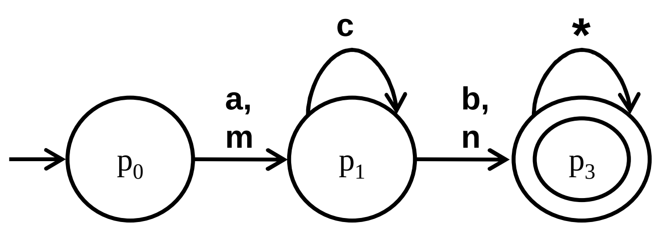


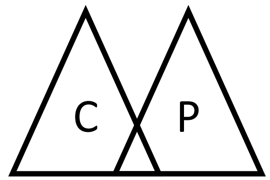
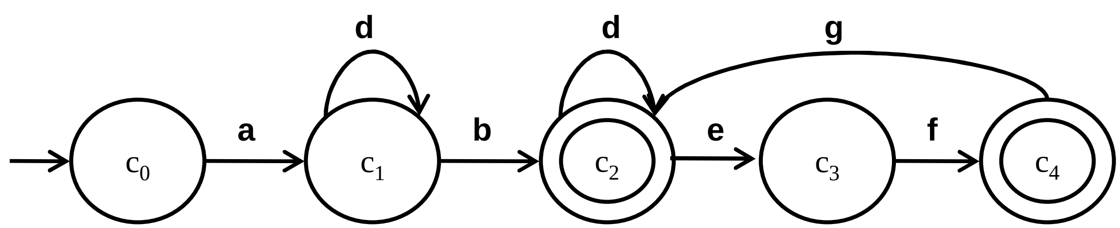
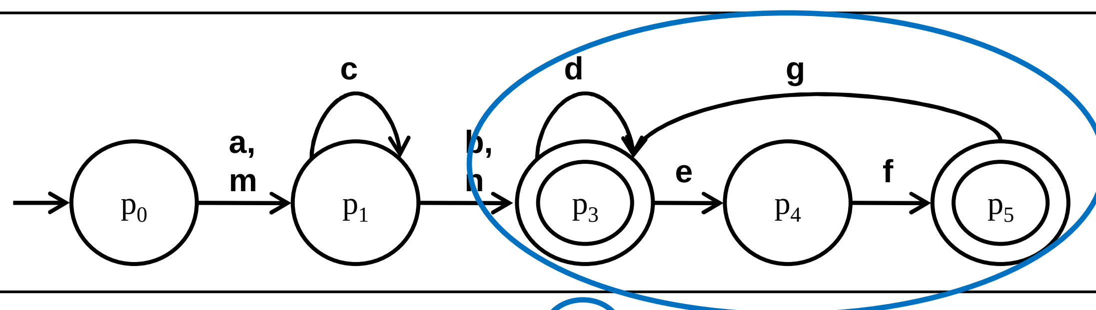
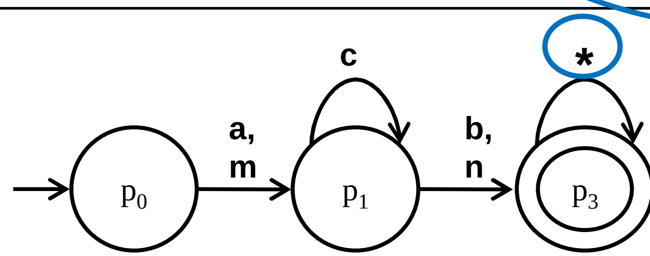
Optimized Policy



Optimization Example

Inline-type	
Contract	
Policy	
Optimized Policy	

Optimization Example

Inline-type	
Contract	
Policy	
Optimized Policy	

Publications

Journals:

- **[DJM+08] L. Desmet, W. Joosen, F. Massacci, P. Philippaerts, F. Piessens, I. Siahaan and D. Vanoverberghe. Security-by-contract on the .NET platform. In *Information Security Technical Report, Volume 13 Issue 1*, 2008.**
- **[BDM+09] N. Bielova, N. Dragoni, F. Massacci, K. Naliuka and I. Siahaan. Matching in Security-by-Contract for Mobile Code. In *Journal of Logic and Algebraic Programming***

Conferences:

- **[BTDS08] N. Bielova, M. DallaTore, N. Dragoni, and I. Siahaan. Matching Policies with Security Claims of Mobile Applications. In *Proc. of The 3rd International Conference on Availability, Reliability and Security (ARES'08)***

Publications

Workshops:

- [DMNS07] N. Dragoni, F. Massacci, K. Naliuka, and I. Siahaan. Security-by-Contract: Toward a Semantics for Digital Signatures on Mobile Code. In Proc. of The 4th European PKI Workshop (EuroPKI'07)
- [MS07] F. Massacci and I. Siahaan. Matching midlet's security claims with a platform security policy using automata modulo theory. In Proc. of The 12th Nordic Workshop on Secure IT Systems (NordSec'07)
- [MS08] F. Massacci and I. Siahaan. Simulating Midlet's Security Claims with Automata Modulo Theory. In Proc. of ACM SIGPLAN 3rd Workshop on Programming Languages and Analysis for Security (PLAS 2008)
- [BMS08a] N. Bielova and I. Siahaan. Testing Decision Procedures for Security-by-Contract. In Proc. of Joint Workshop on Foundations of Computer Security, Automated Reasoning for Security Protocol Analysis and Issues in the Theory of Security (FCS-ARSPA-WITS'08)
- [MS09] F. Massacci and I. Siahaan. Optimizing IRM with Automata Modulo Theory. In 5th International Workshop on Security and Trust Management (STM 2009).

Conclusions

- **Security policies of both safety and liveness properties**
- **Mechanism for defining a general security policies (not platform-specific)**
- **Mechanism for representing an infinite structure as a finite structure**
- **Goal:**
  - to provide contract-policy matching
  - issues: small memory footprint, efficient computations
  - the tractability limit is the complexity of the satisfiability procedure for the background theories used to describe expressions
- **Results:**
  - Contract-policy matching problem for AMT using language inclusion and simulation
  - Policy optimization problem for AMT using fair simulation

Thank you

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- J.R. Büchi, “On a decision method in restricted second-order arithmetic. ”, Int. Cong. on Logic, Methodology and Philosophy of Science, 1962.
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- U. Erlingsson, F. B. Schneider, “IRM Enforcement of Java Stack Inspection”, IEEE Symposium on Security and Privacy 2000
- K. Hamlen, “Security policy enforcement by automated program-rewriting,” Ph.D. thesis, Cornell University, 2006.
- F. Schneider, “Enforceable Security Policies”, ACM Transactions on Information and System Security, Vol. 3, No. 1, February 2000
- R. Sebastiani,“Lazy Satisability Modulo Theories”, Journal on Satisability, Boolean Modeling and Computation 3 (2007) 141-224
- F. Yan, P.W.L. Fong , “Efficient IRM Enforcement of History-Based Access Control Policies.”, ASIACCS 2009