Generalized Abstract Non-Interference Abstract Secure Information-flow Analysis for Automata

Roberto Giacobazzi and **Isabella Mastroeni**

Dipartimento di Informatica

Università di Verona, Italy

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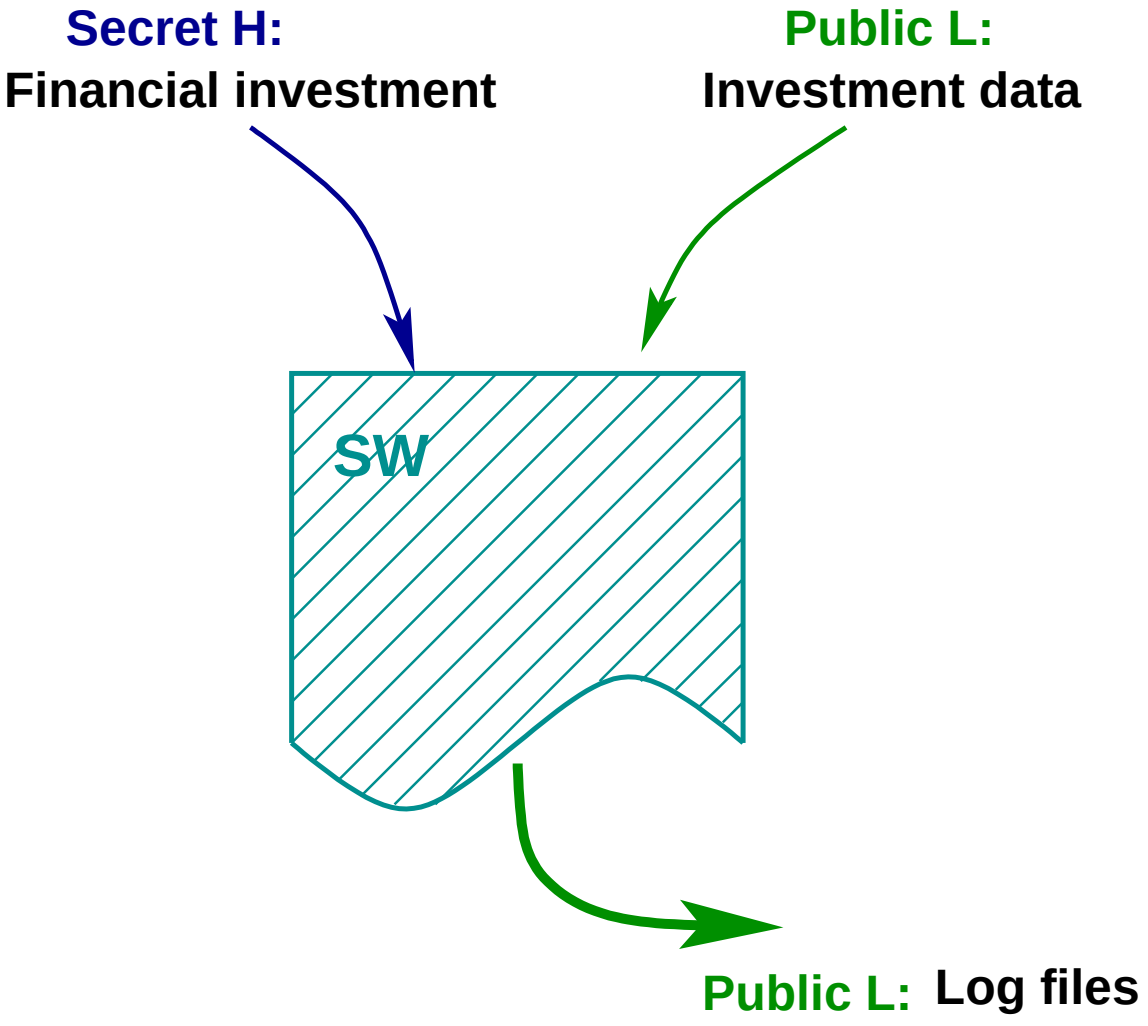
The Problem: Non-Interference



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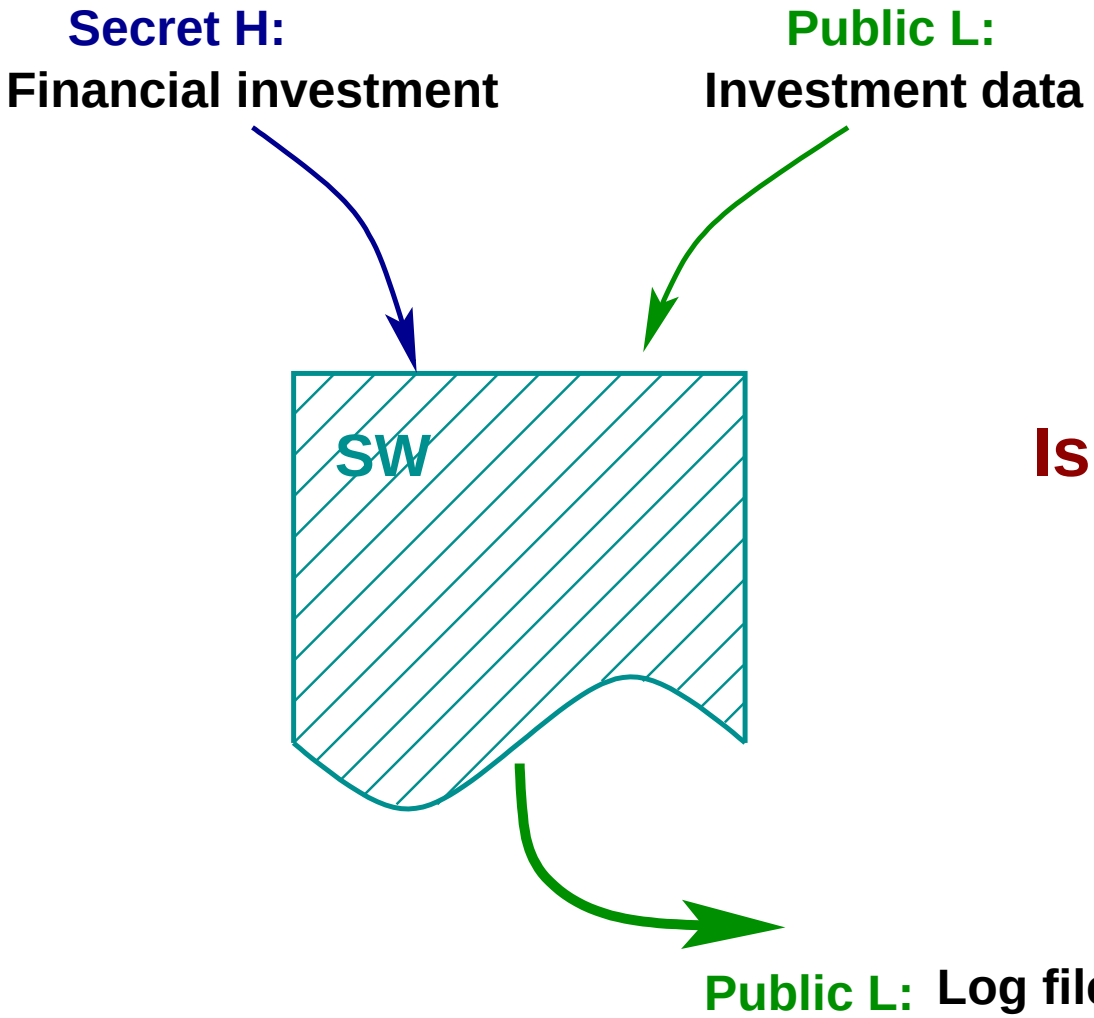
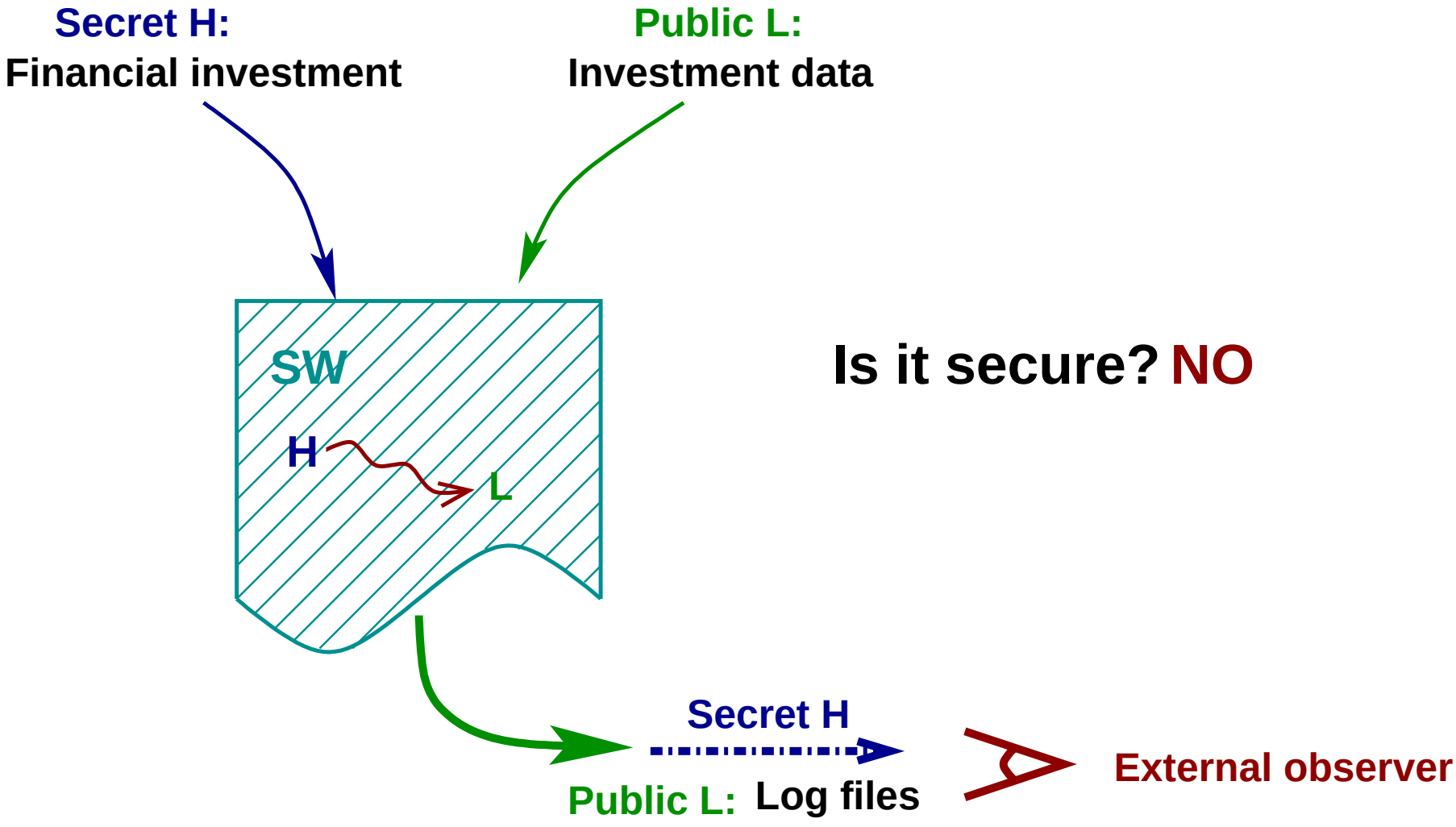


Is it secure?

The Problem: Non-Interference



Background

SECURITY PROPERTY: States which classes have not to interfere with other classes of objects.

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Non-interference policies require that any *change upon confidential data has not to be revealed through the observation of public data.*

- Many real systems are intended to leak some kind of information
- Even if a system satisfies non-interference, some kind of tests could reject it as insecure

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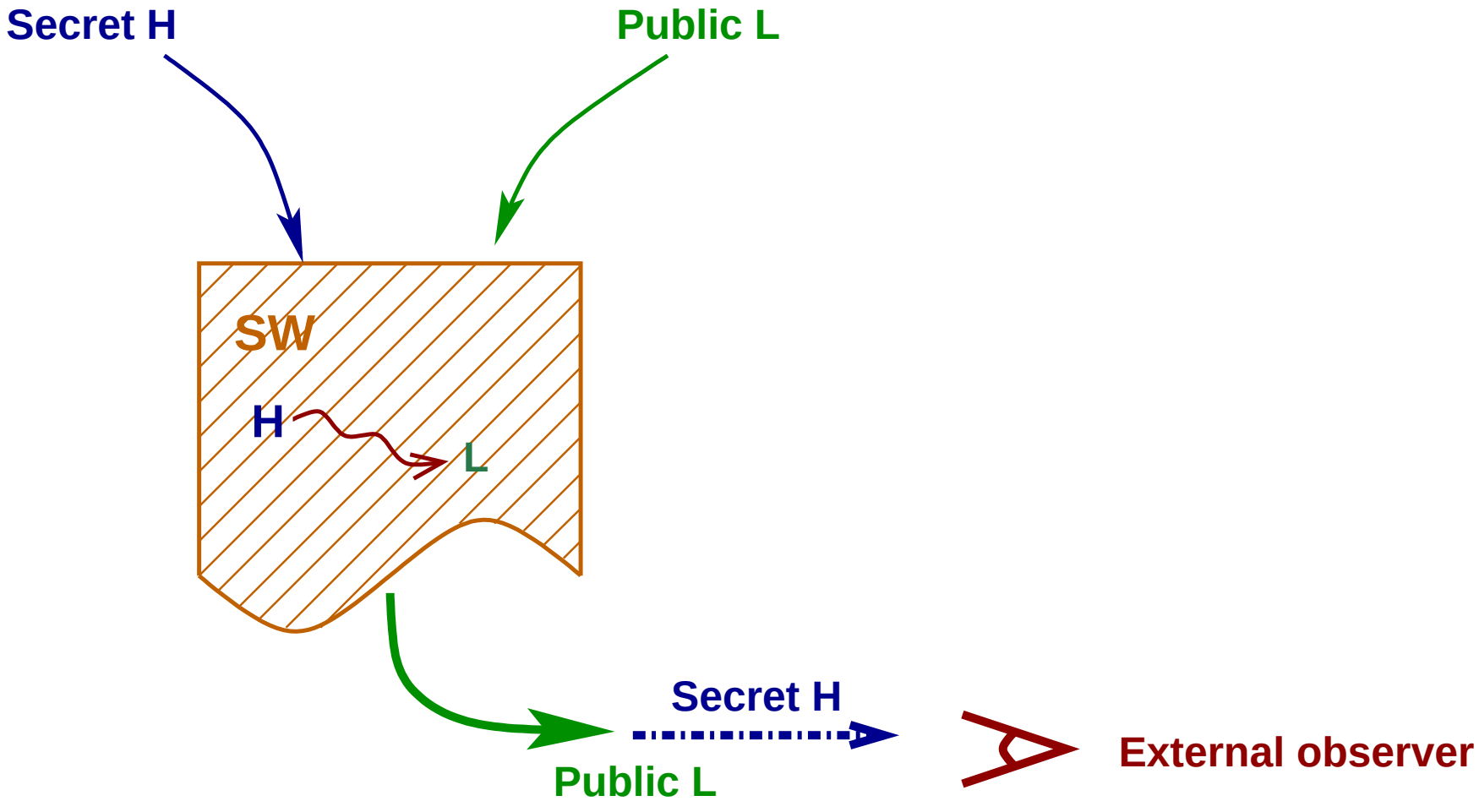
- Characterizing released information: [Cohen'77], [Zdancewic & Myers'01], [Clark et al.'04], [Lowe'02];
- Constraining attackers: [Di Pierro et al.'02], [Laud'01].

Abstracting Non-Interference

[Giacobazzi & Mastroeni, POPL'04]



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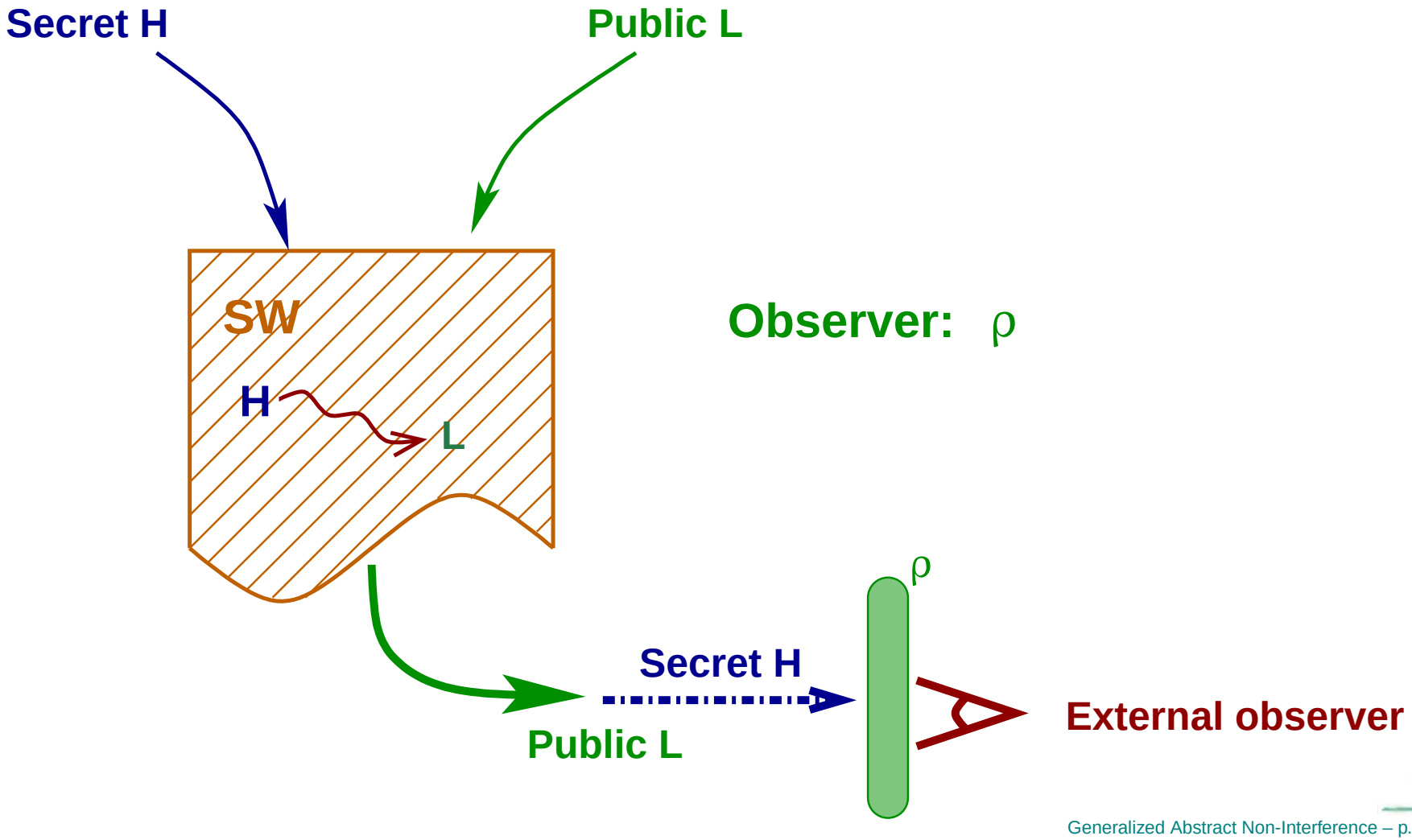

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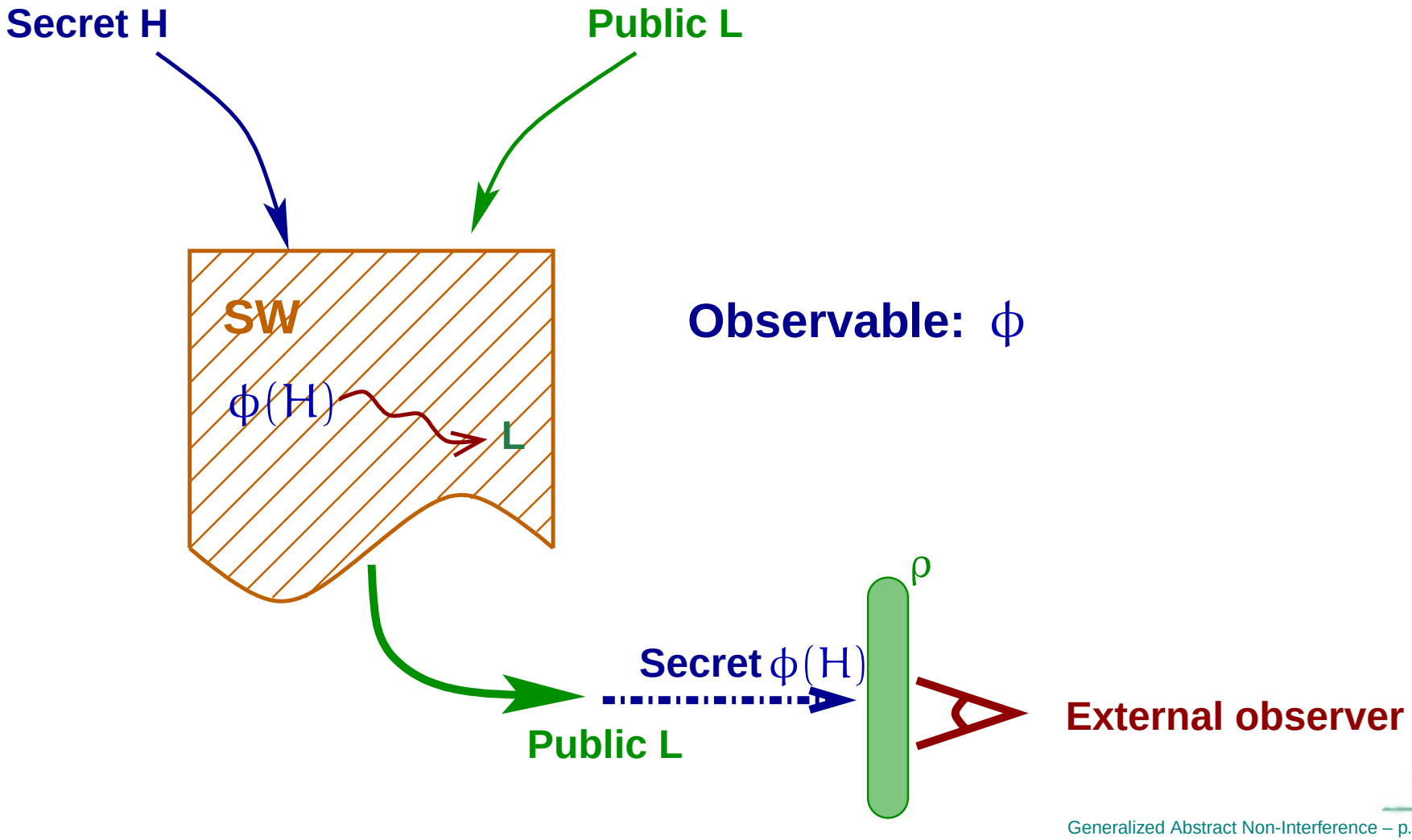


AI: Lattice of Abstractions

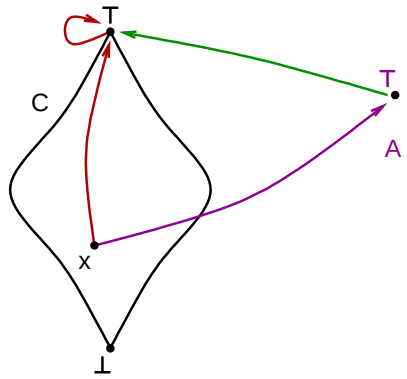
The concrete domain $< C, \leq, \wedge, \vee, \bot, \top >$ [Cousot & Cousot '79]

Lattice of abstract domains $\equiv Abs(C)$

$< Abs(C), \sqsubseteq, \sqcap, \sqcup, \top, C >$

$A_1 \sqsubseteq A_2 \quad \Leftrightarrow \quad A_2 \subseteq A_1$ (A_1 more precise than A_2)

Top:



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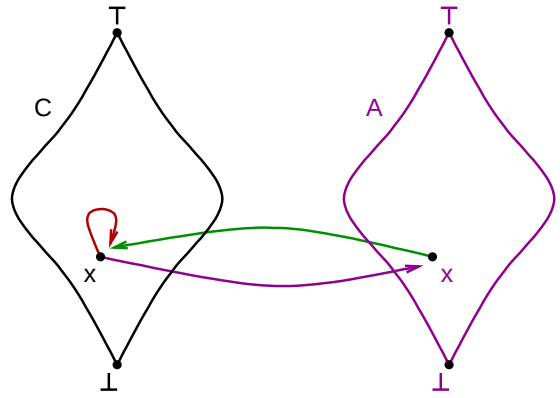

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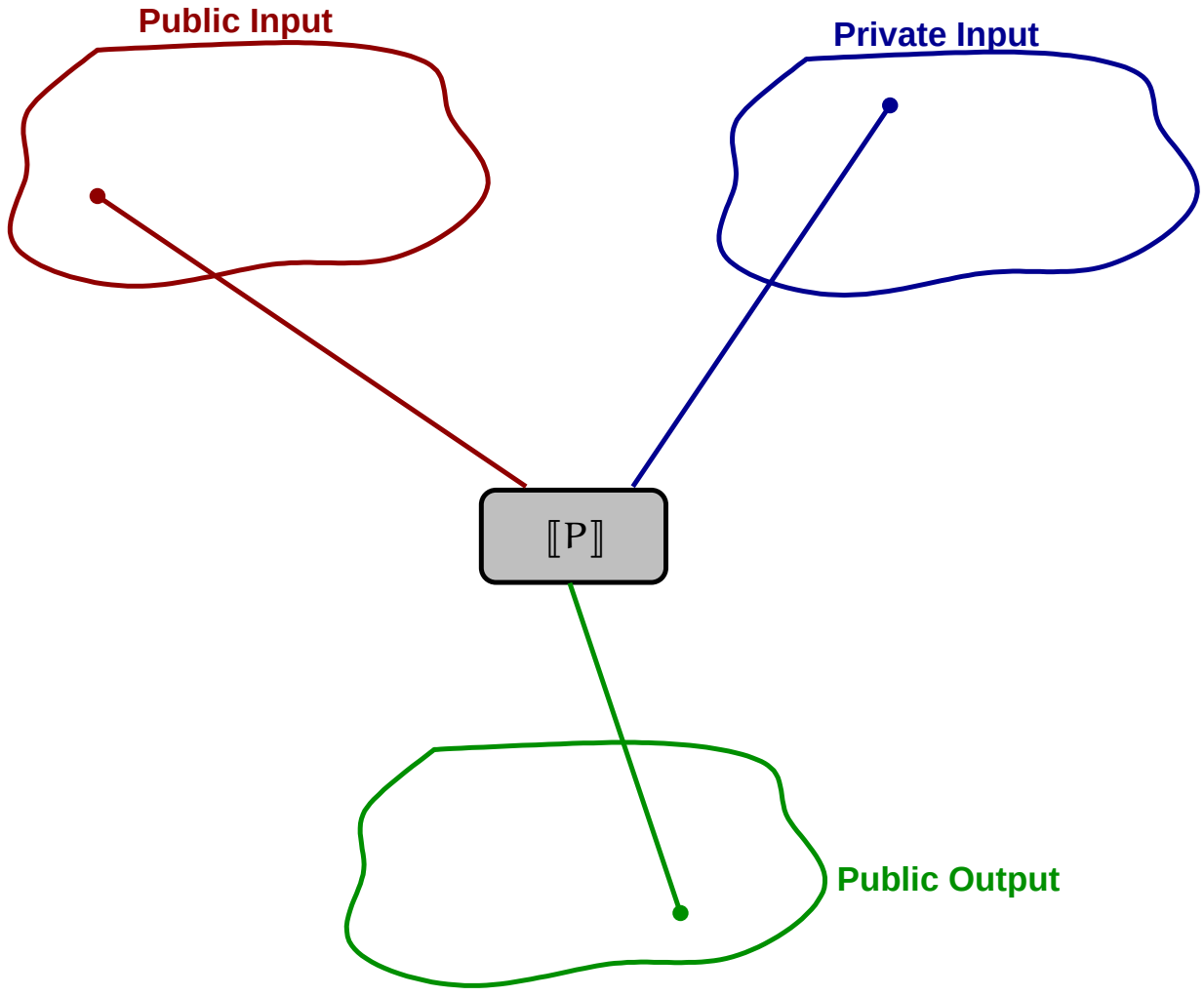

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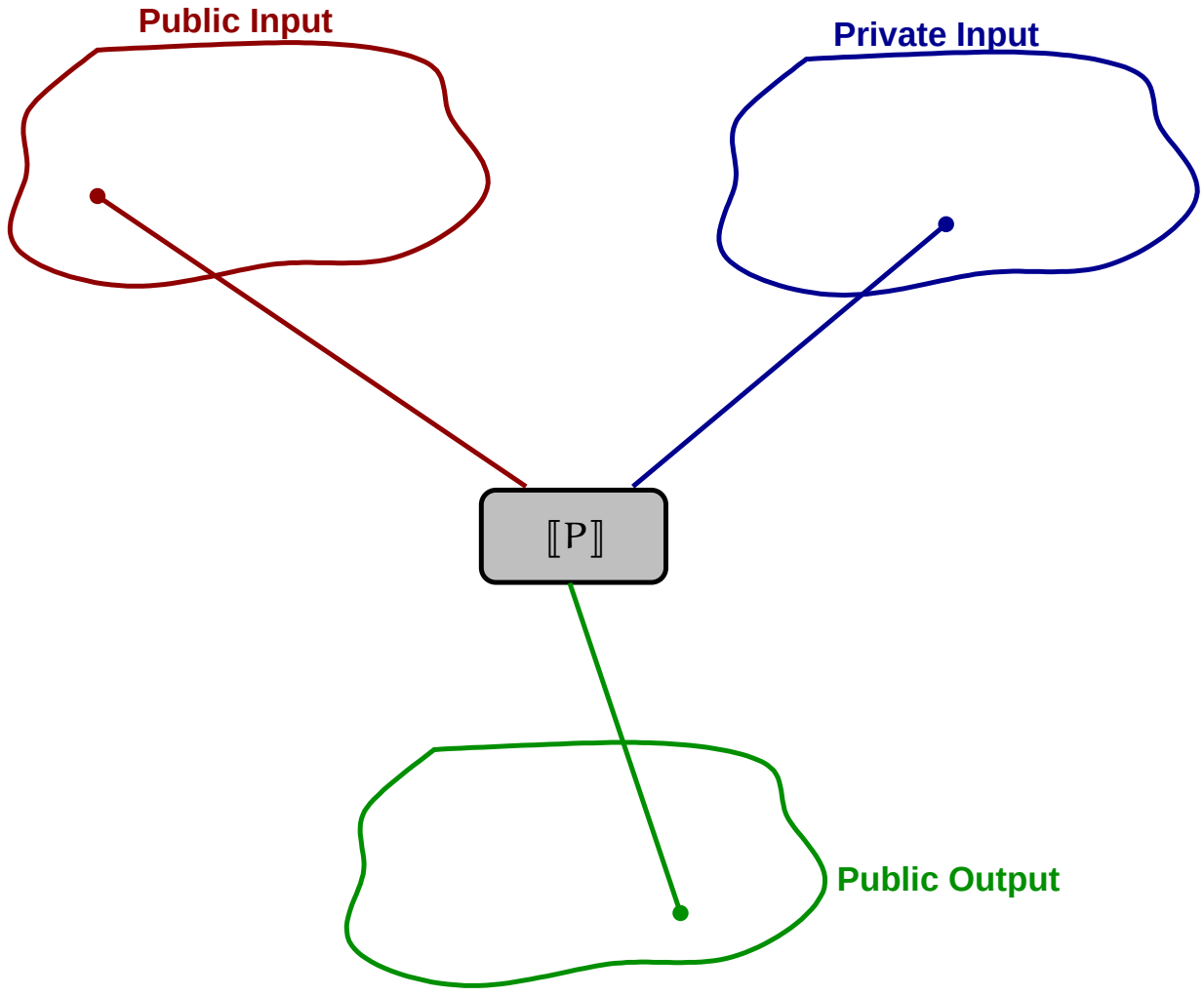

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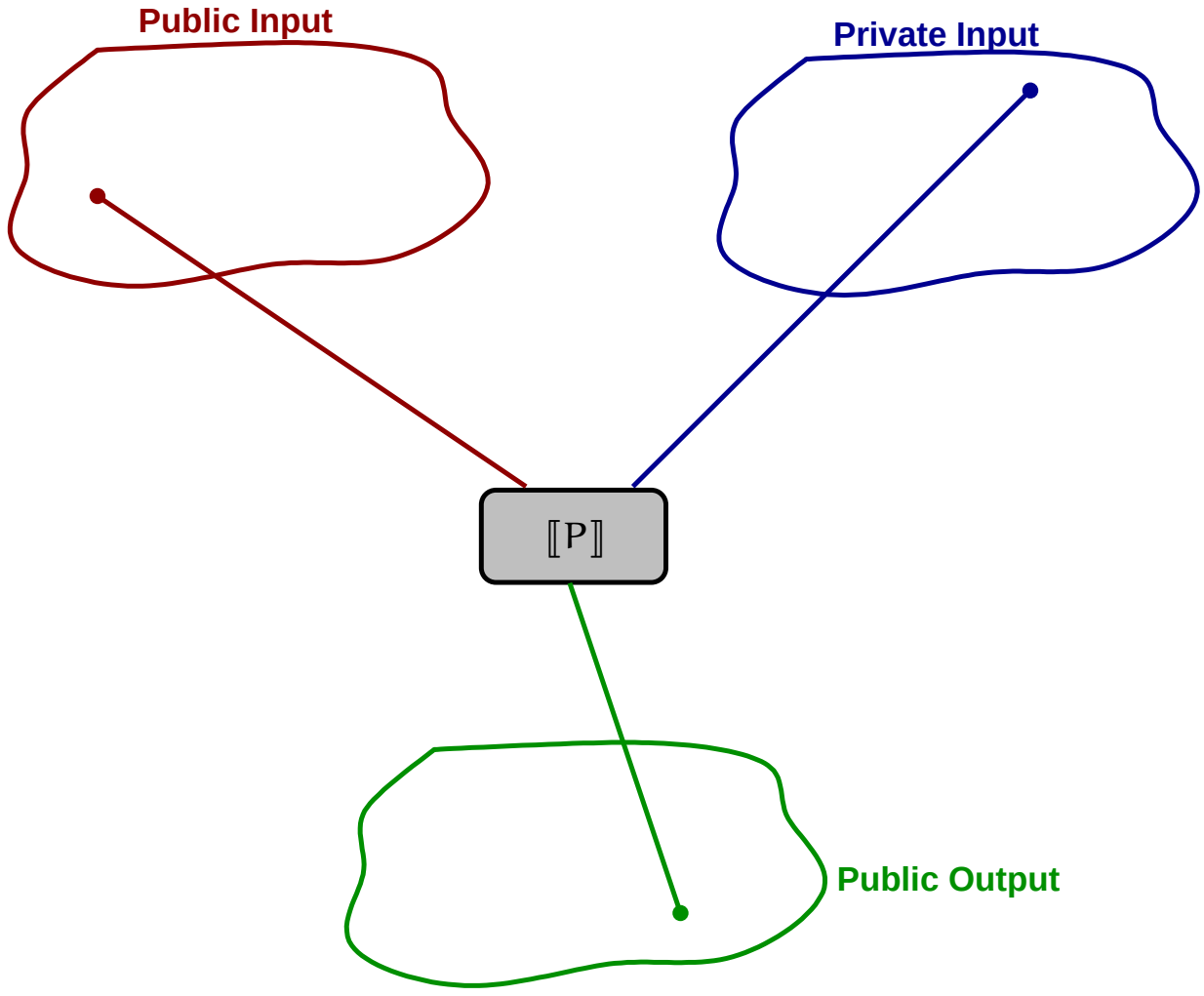

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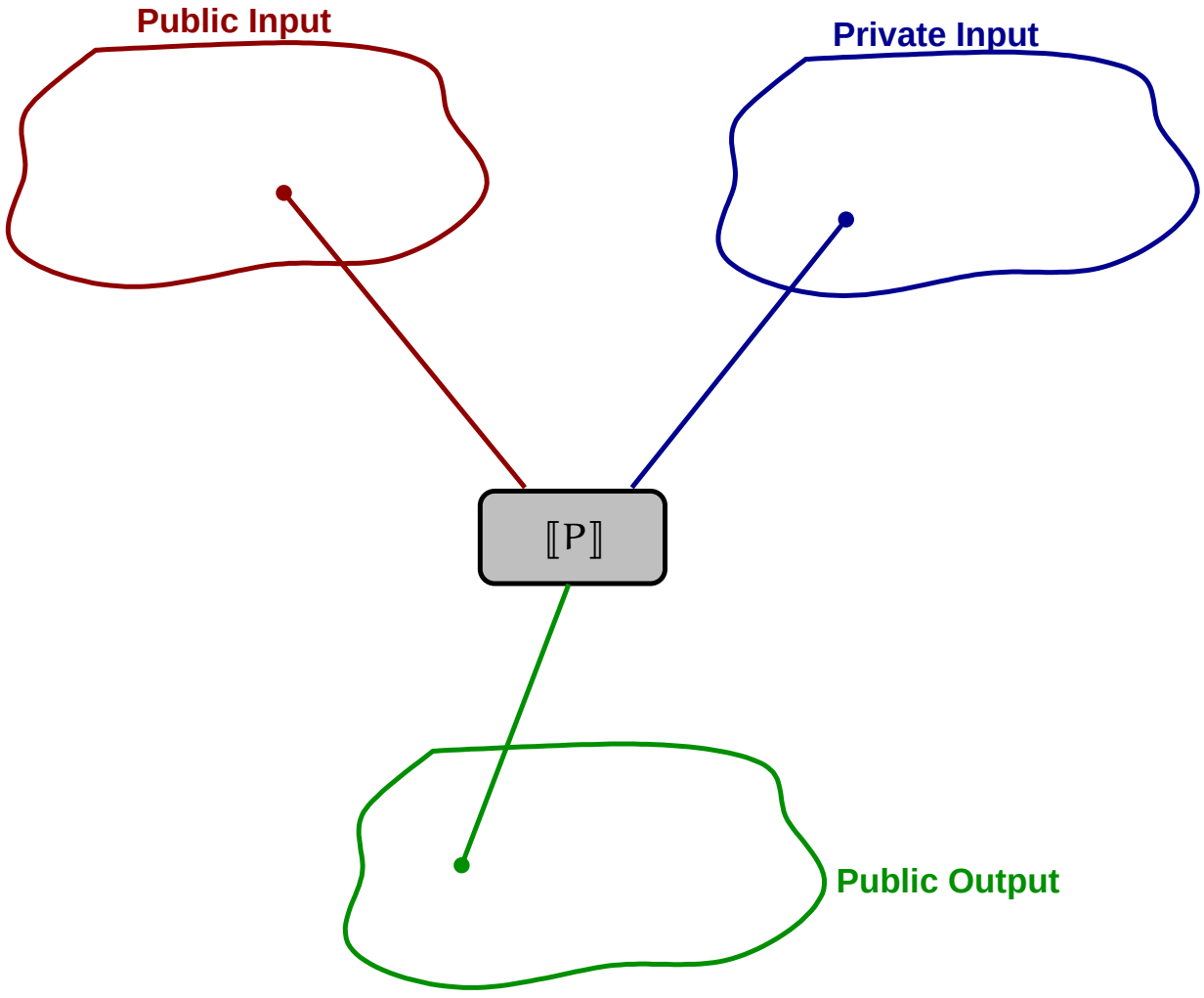

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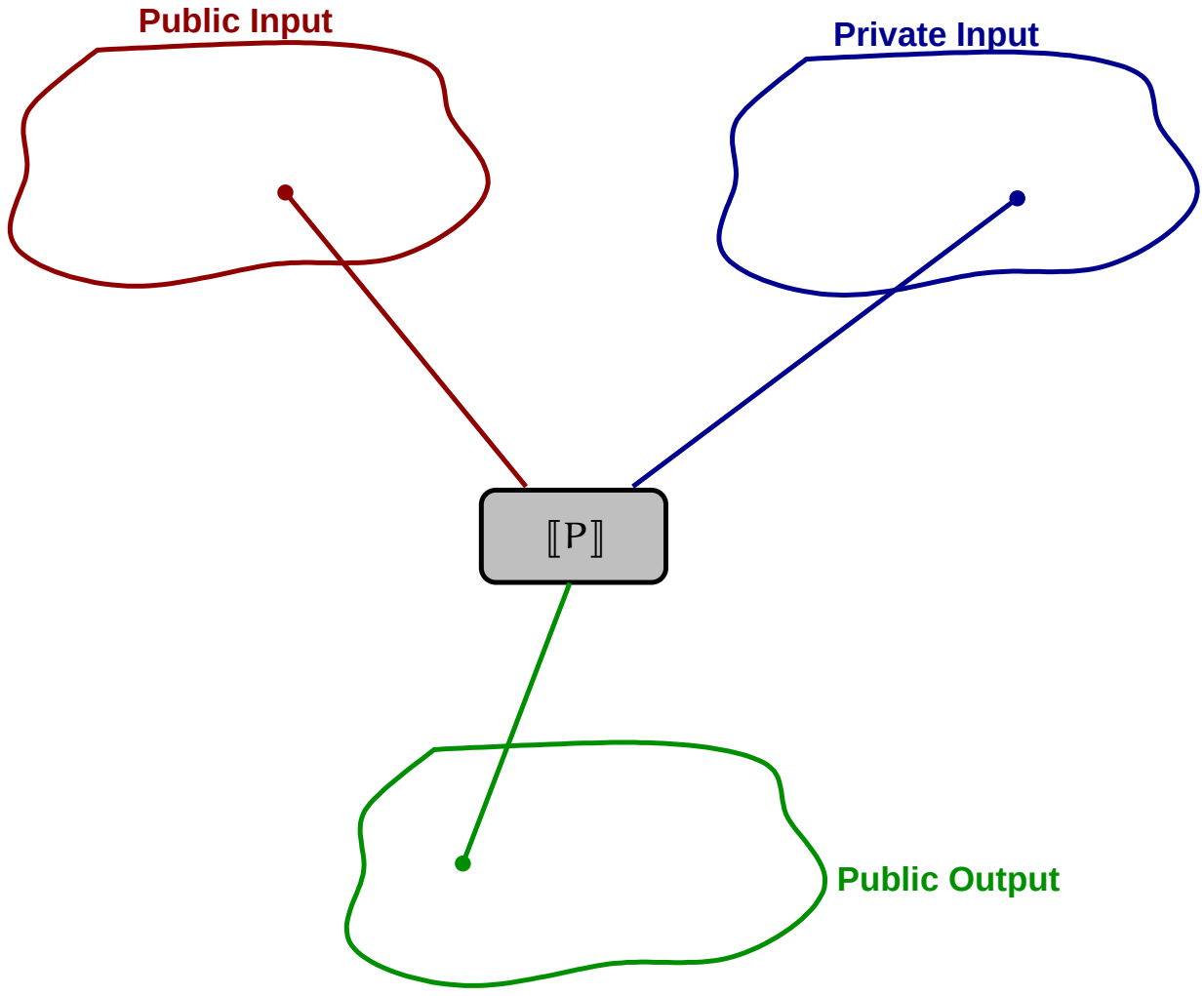

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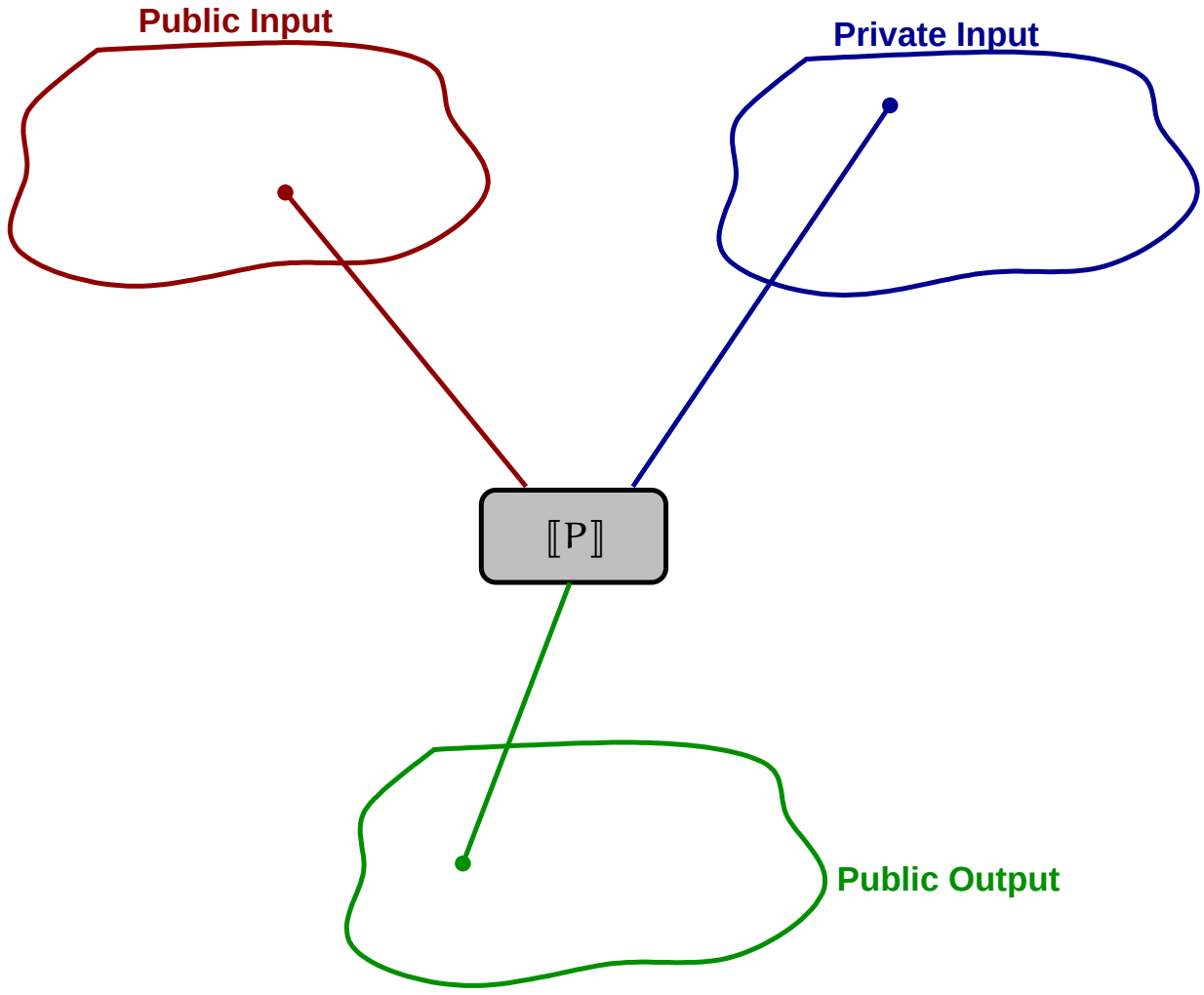

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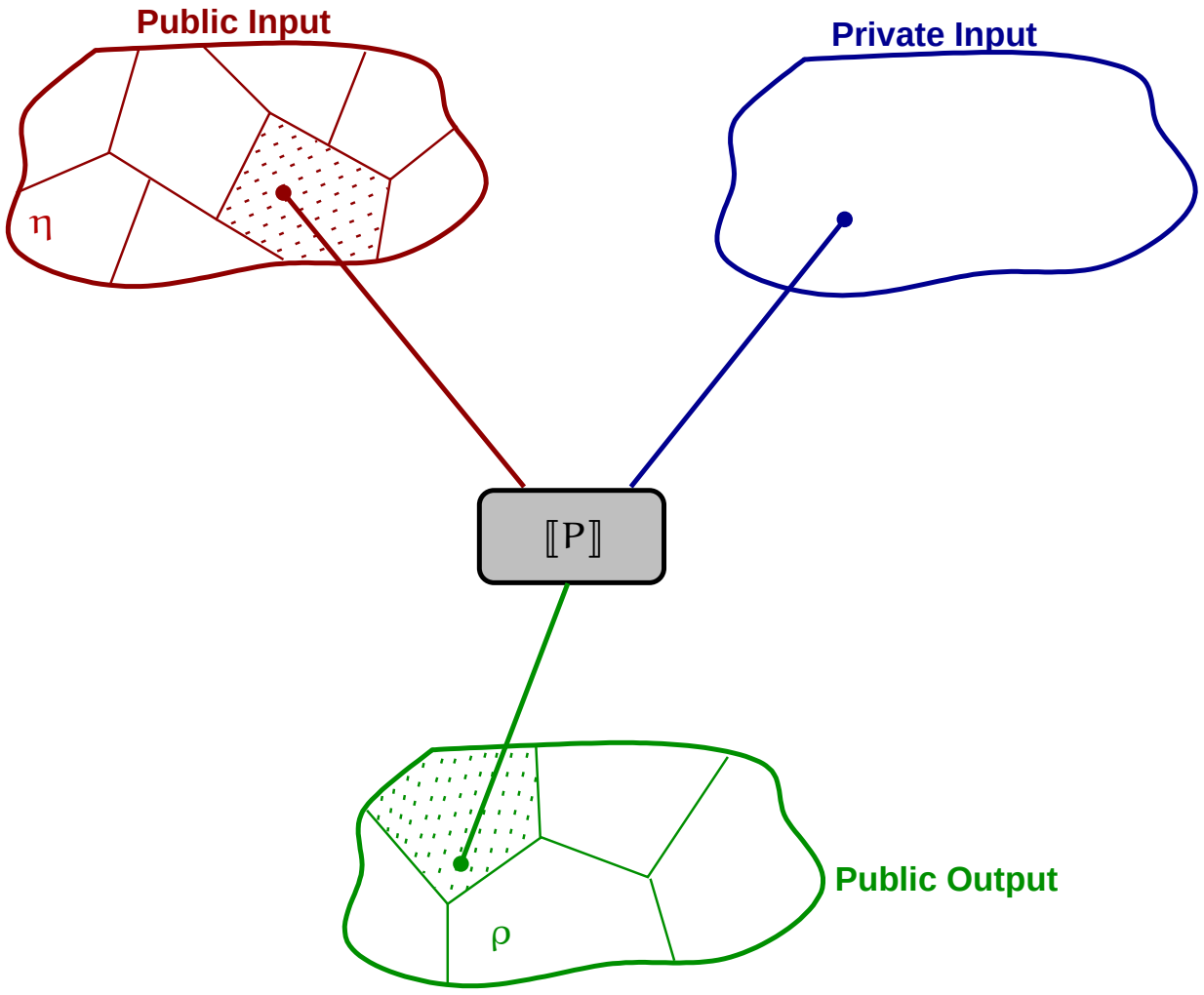

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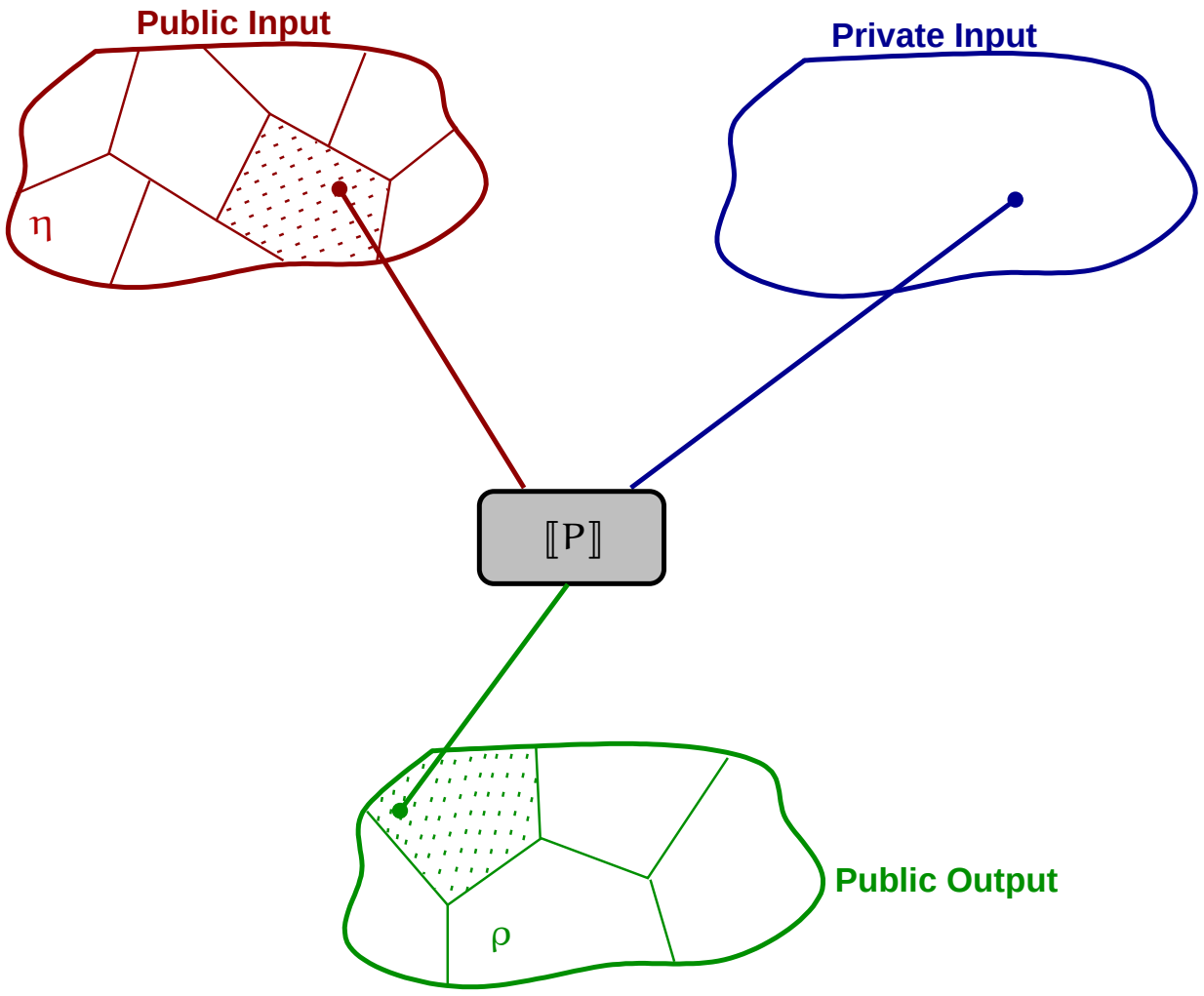

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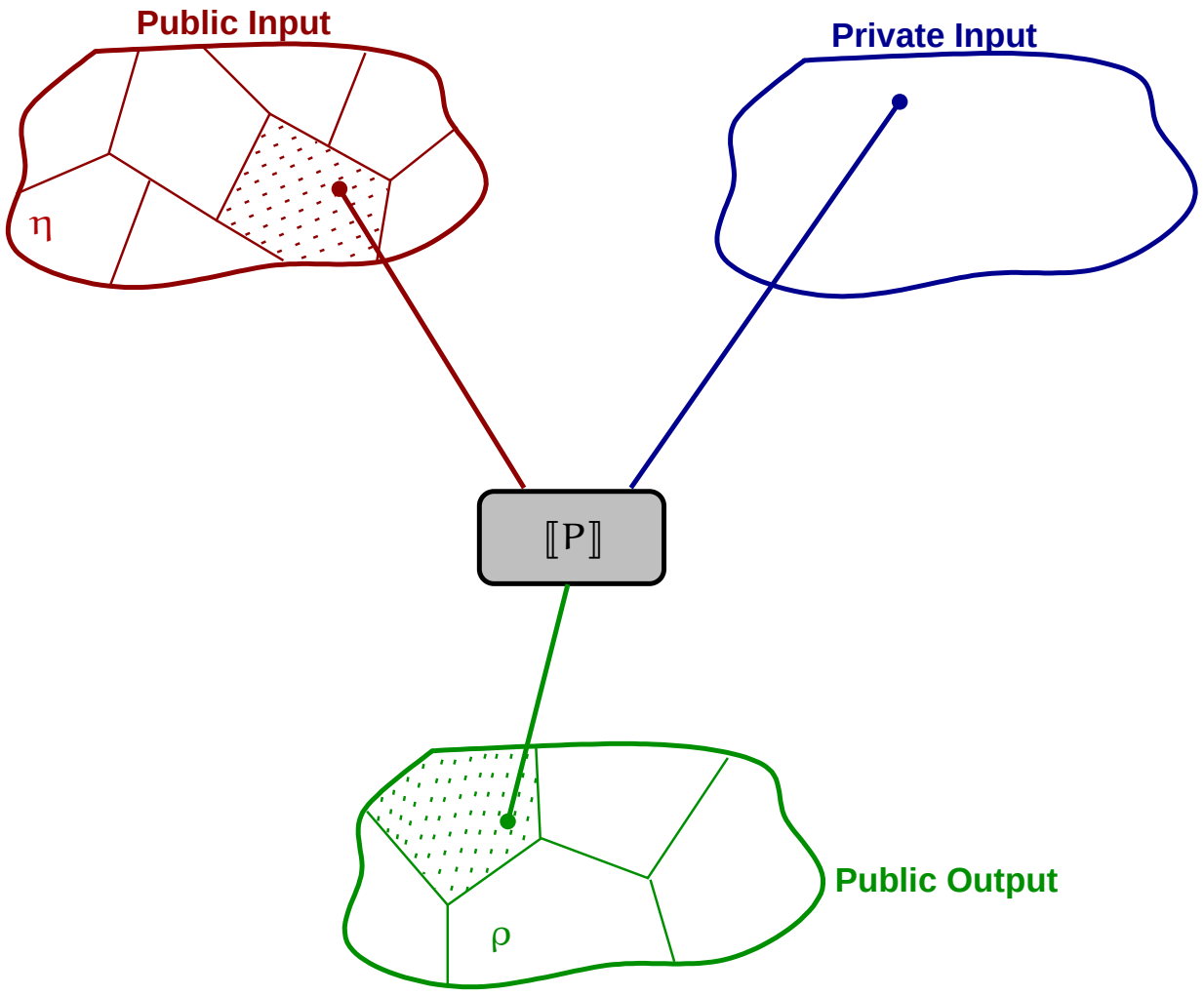

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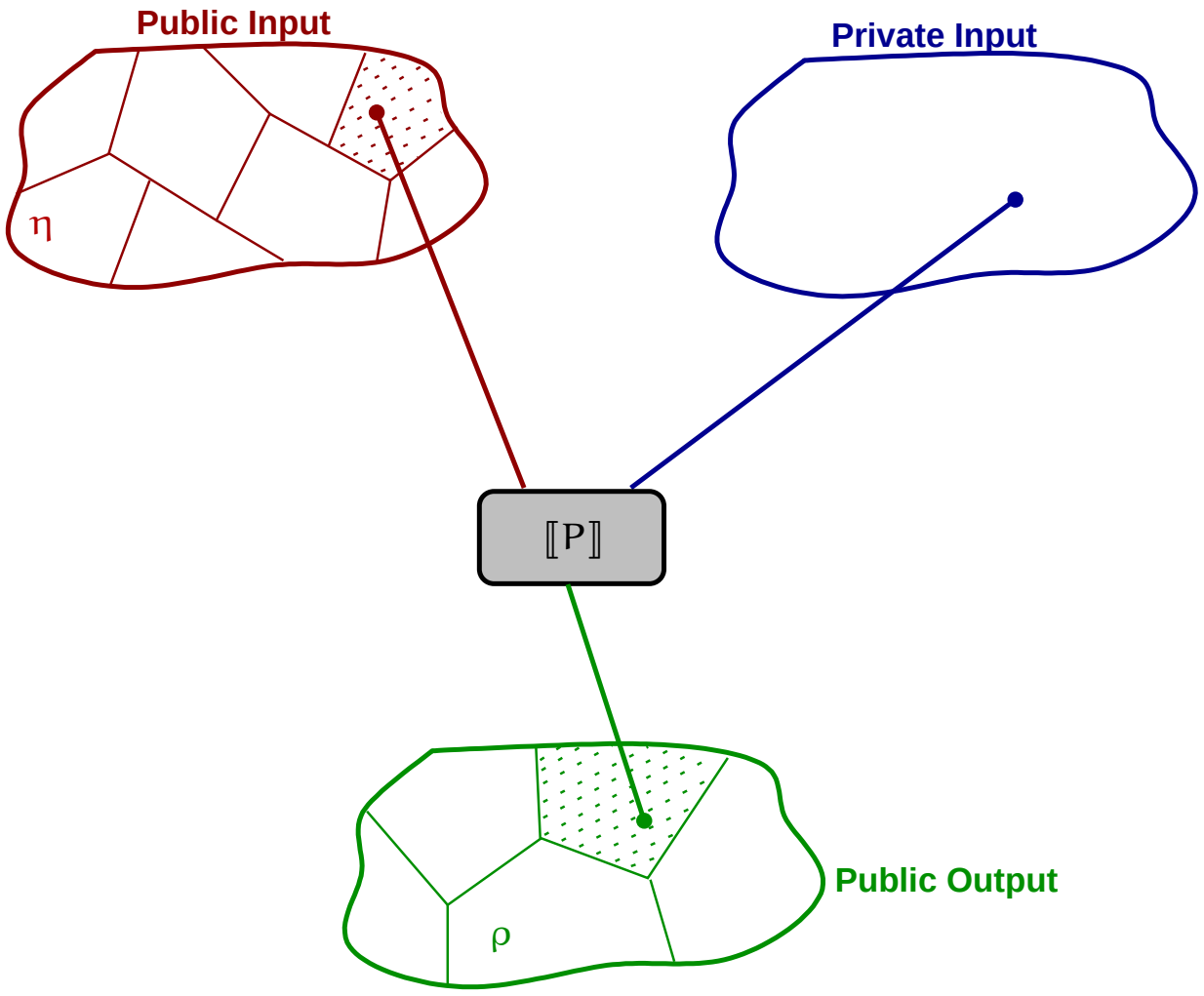

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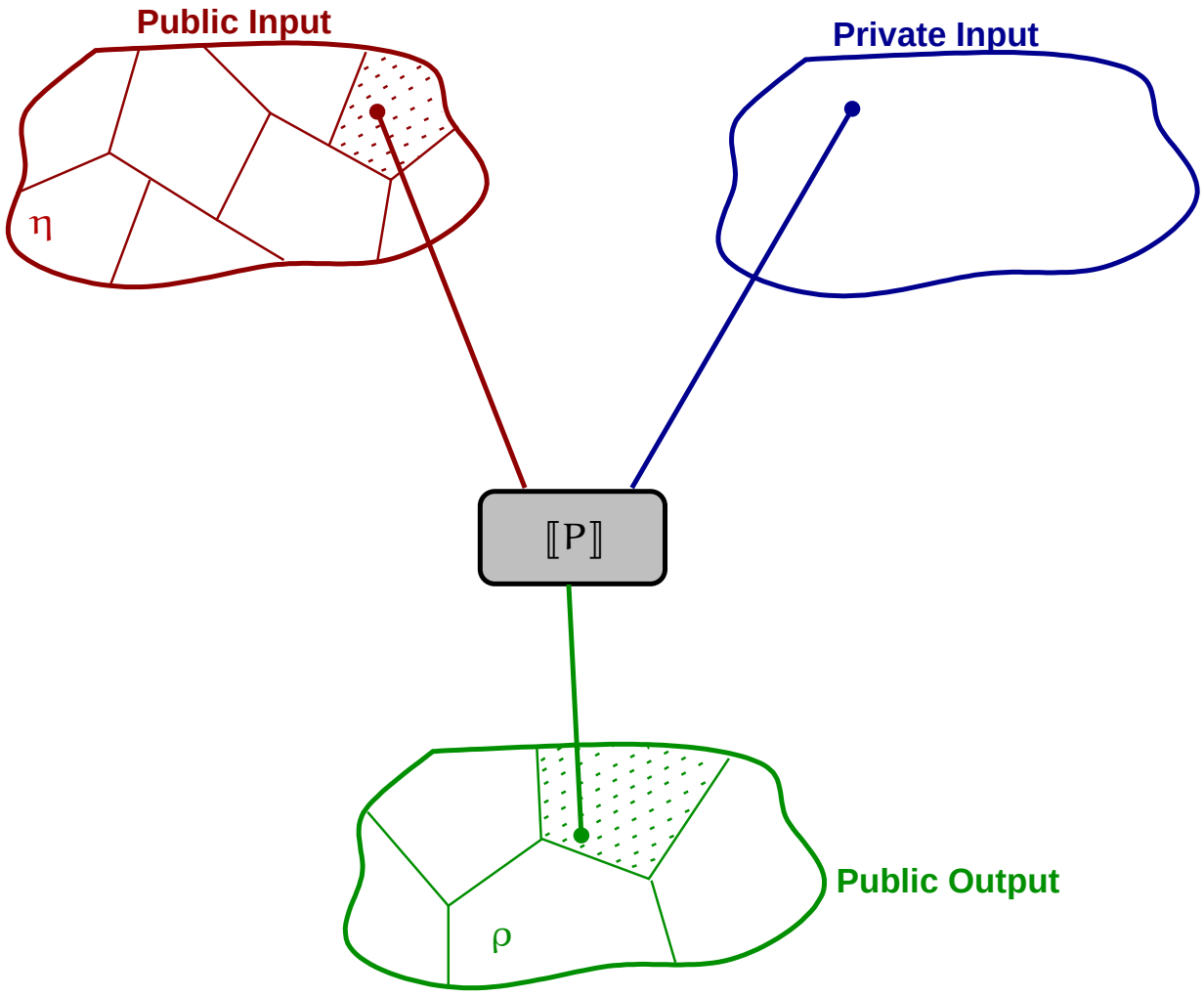

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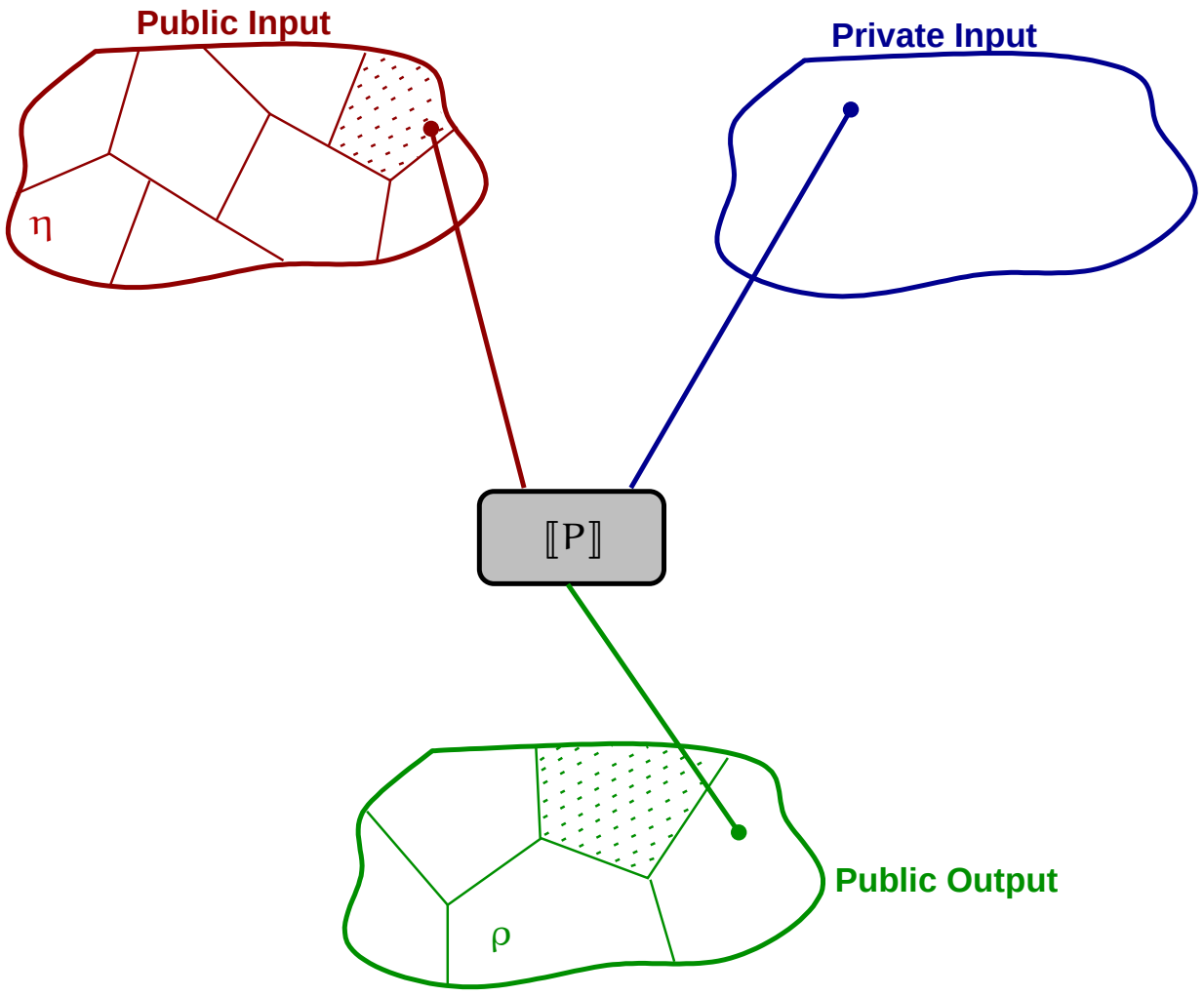

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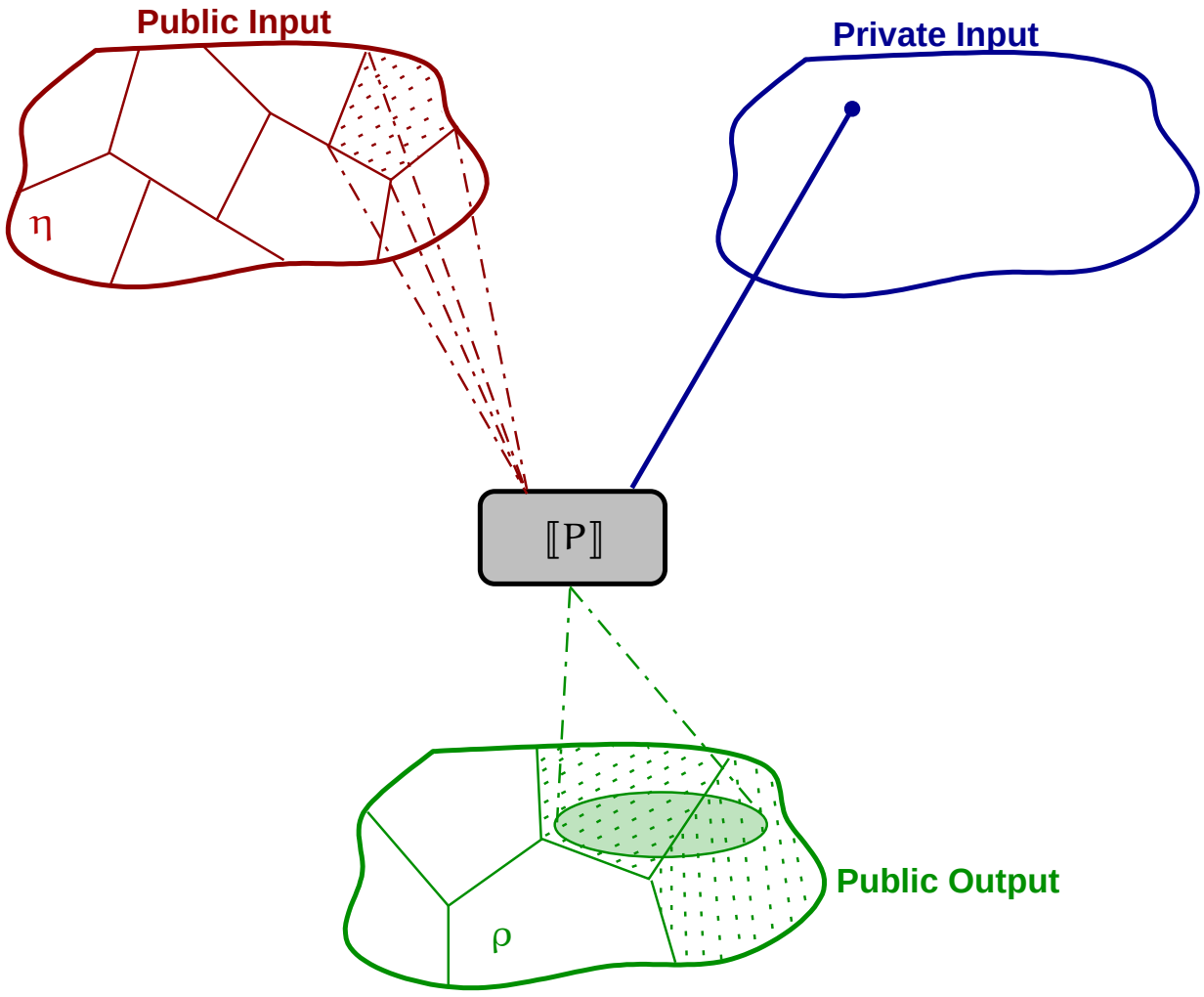

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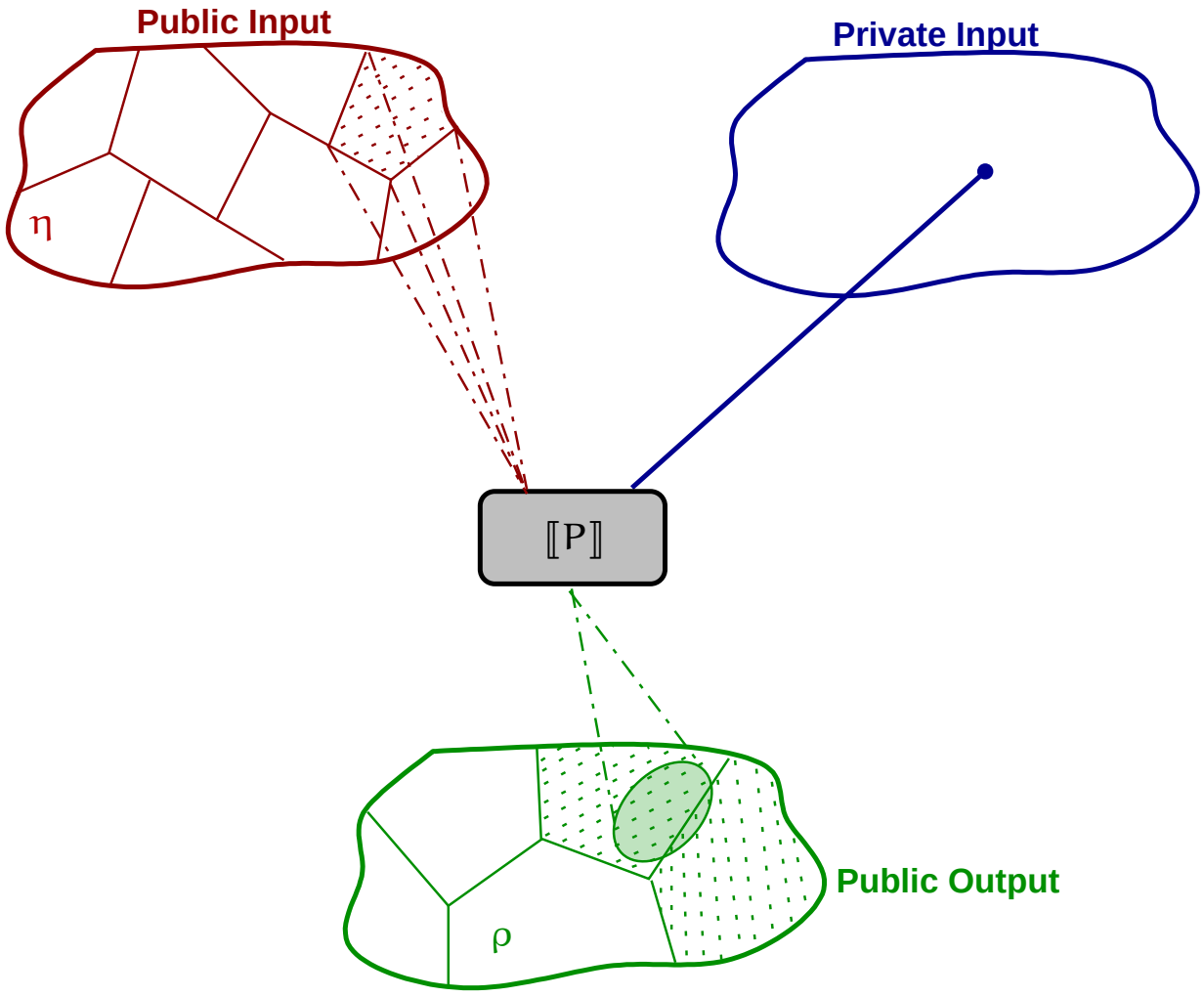

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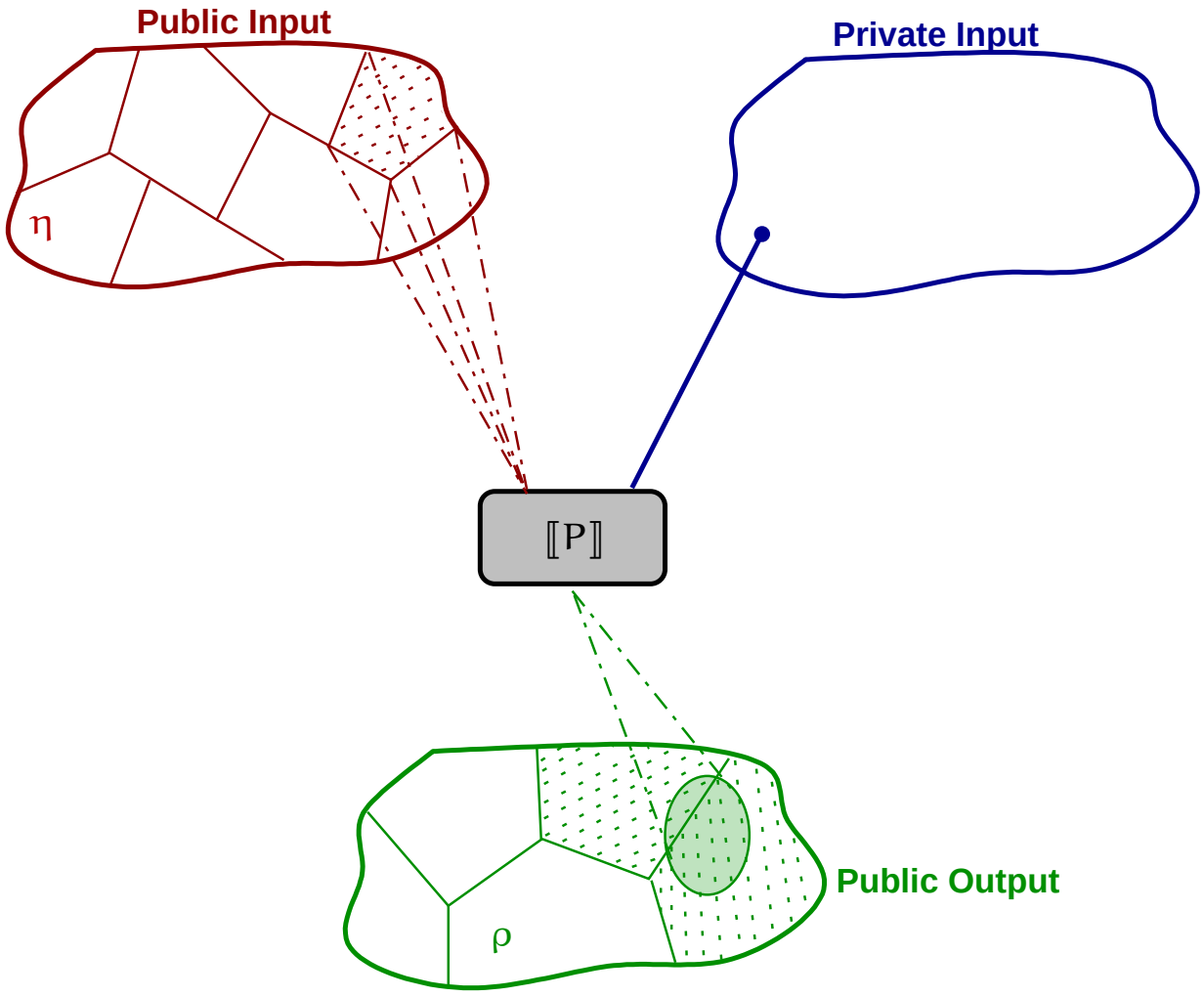

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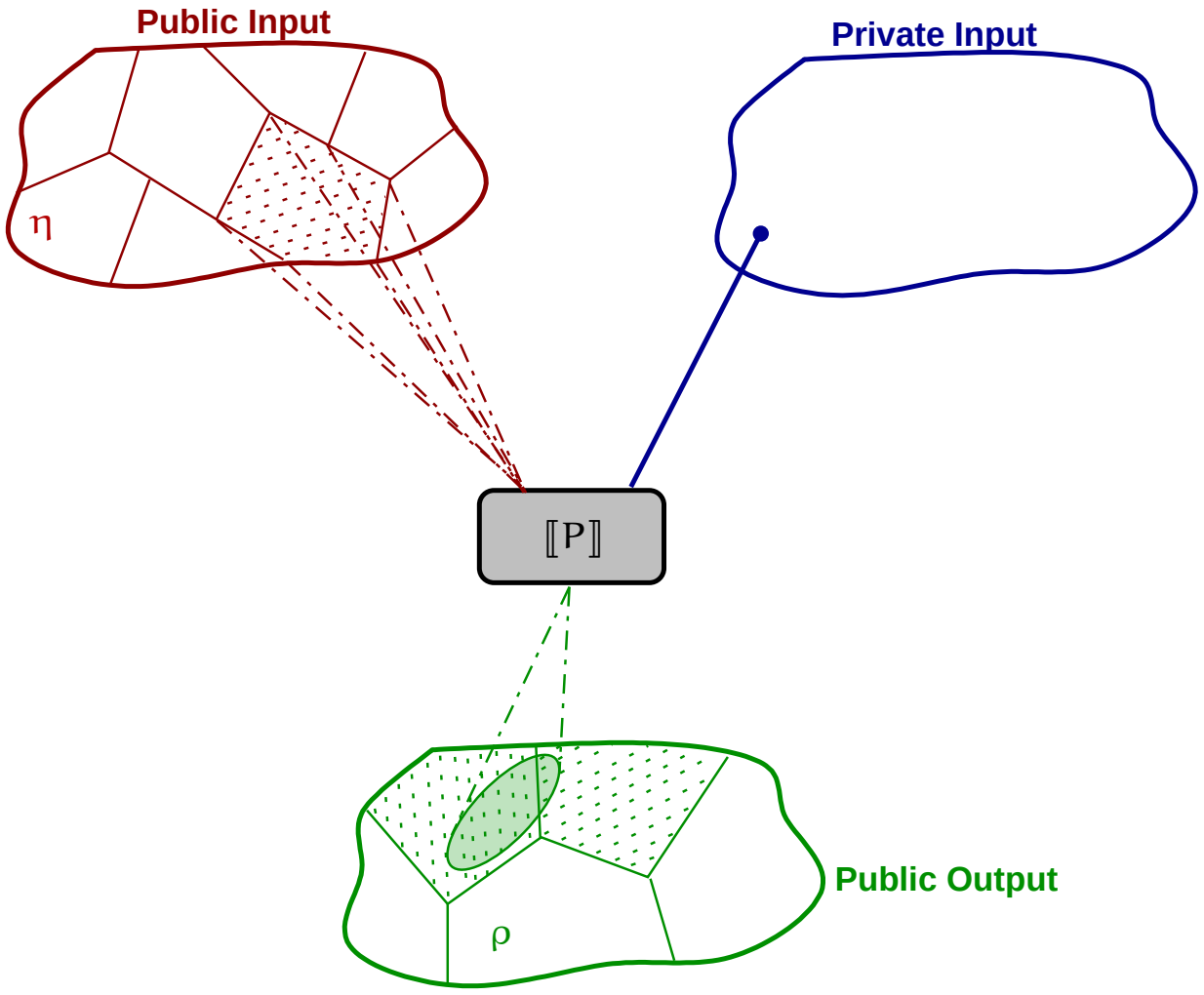

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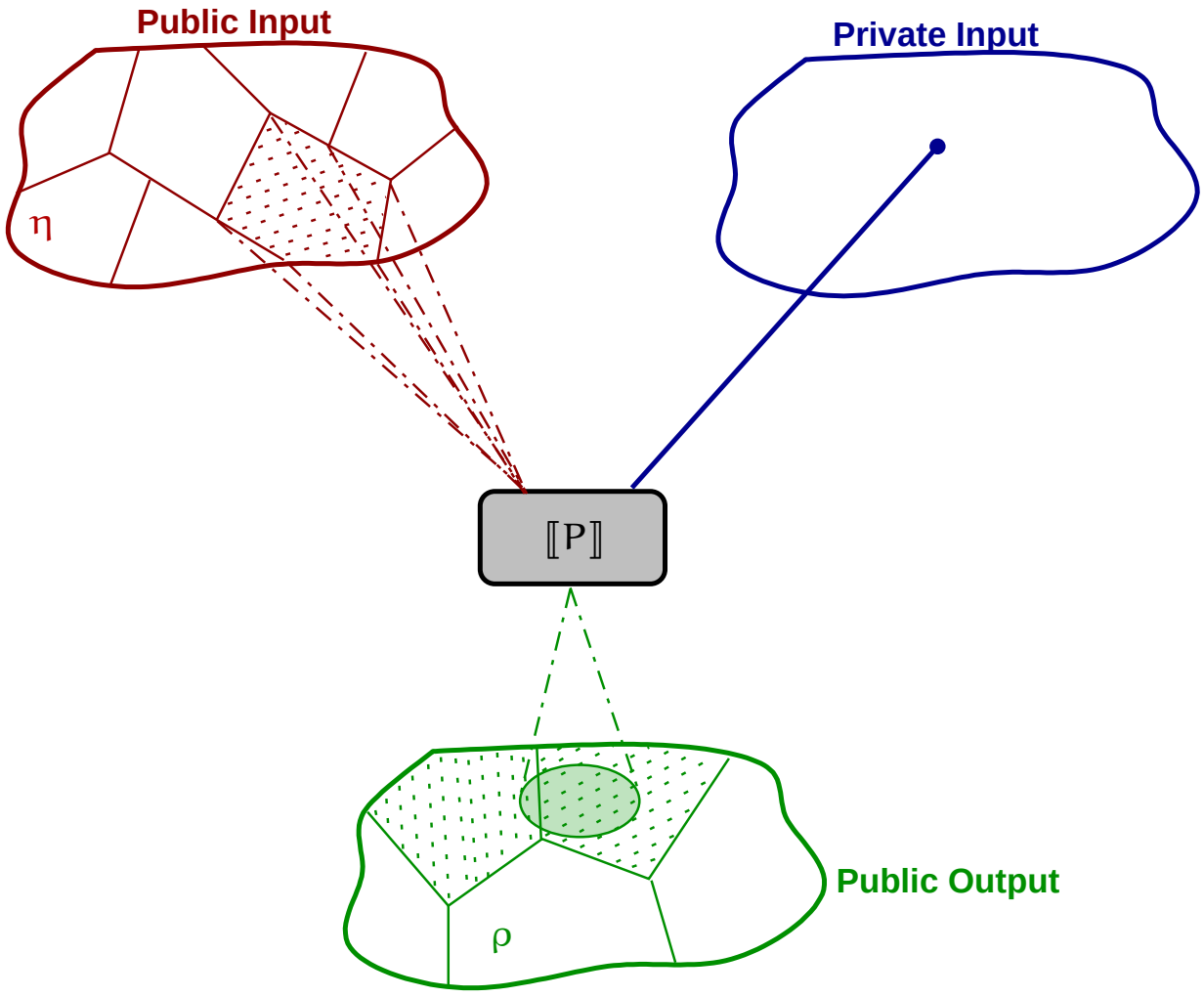

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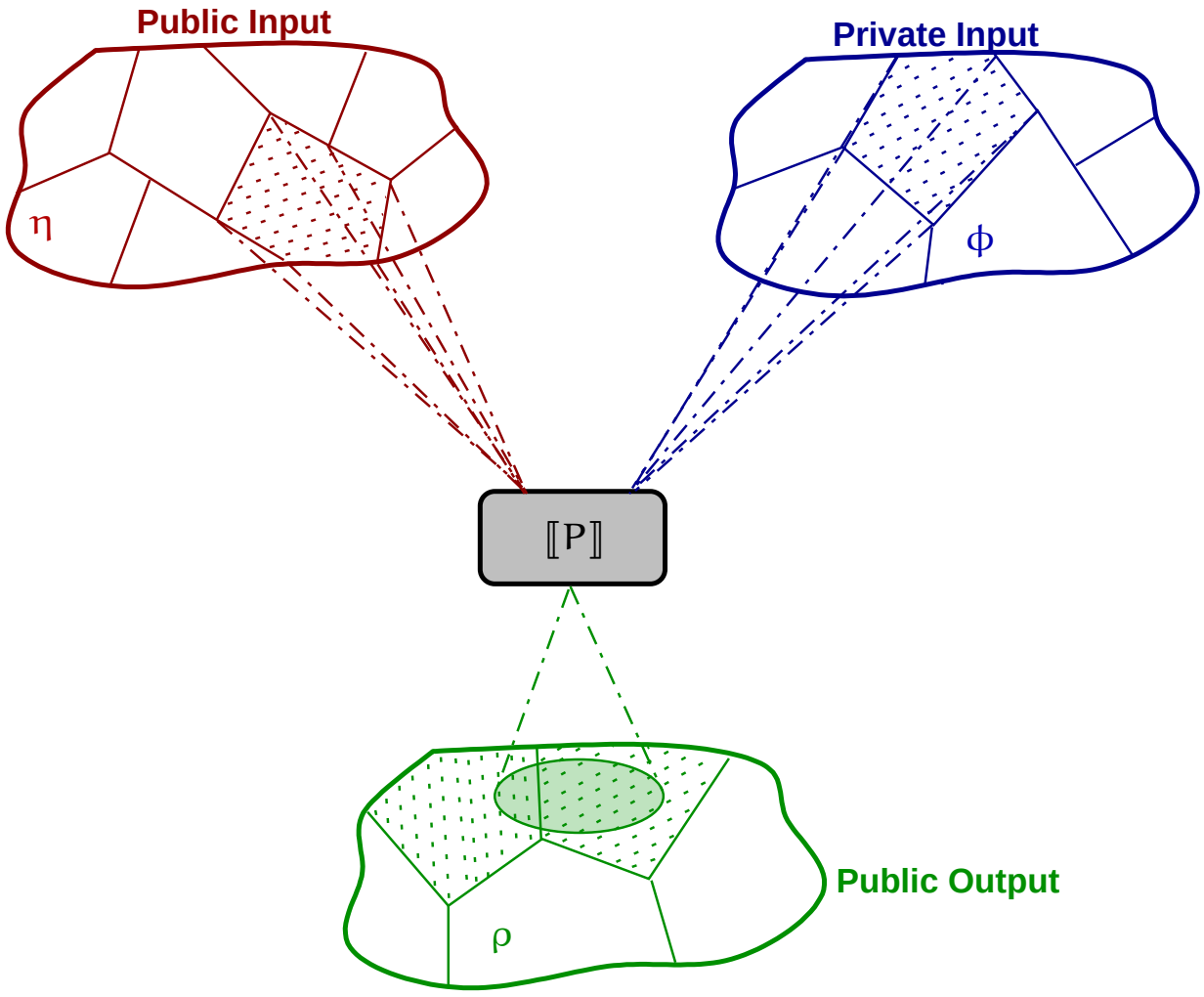

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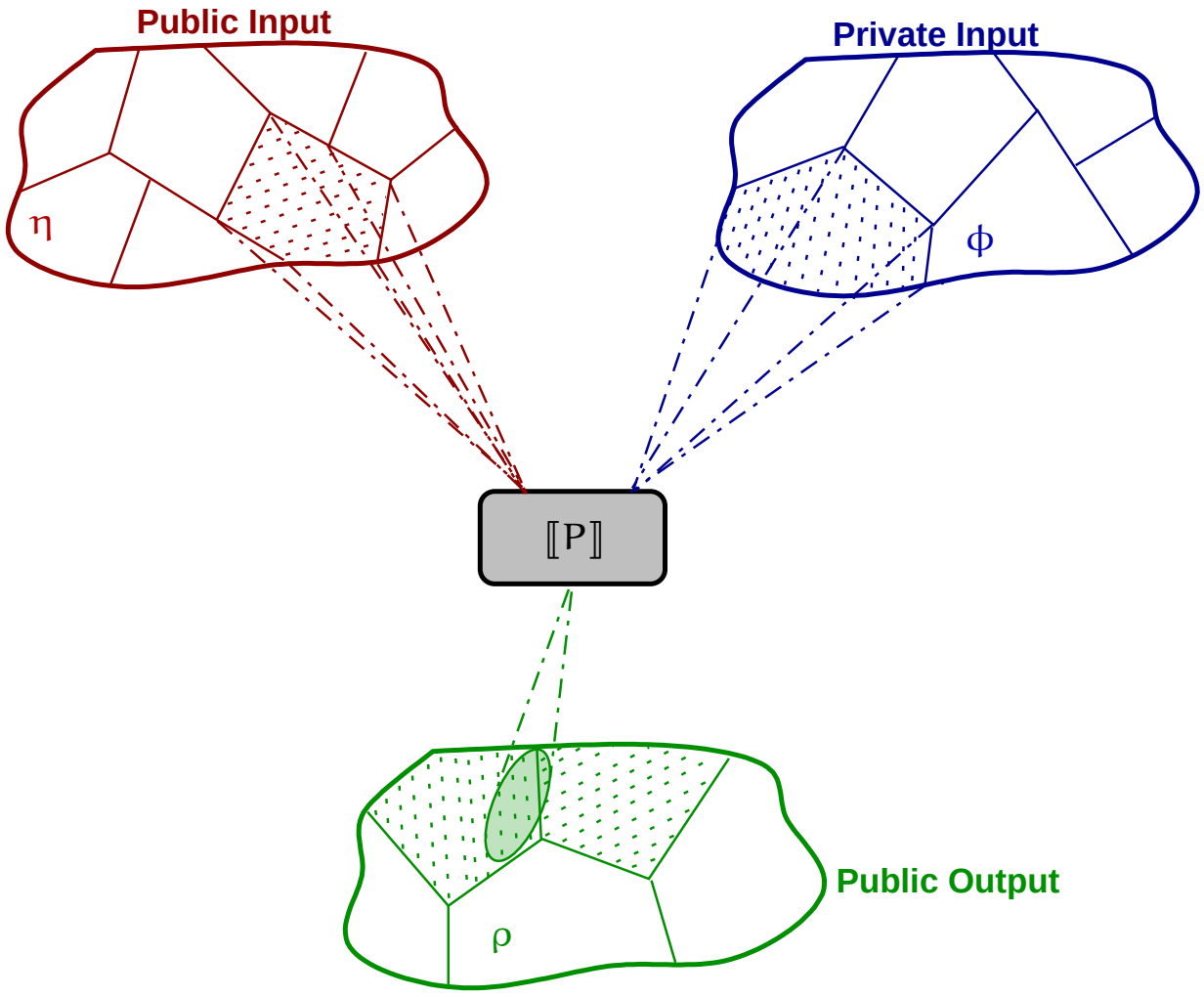

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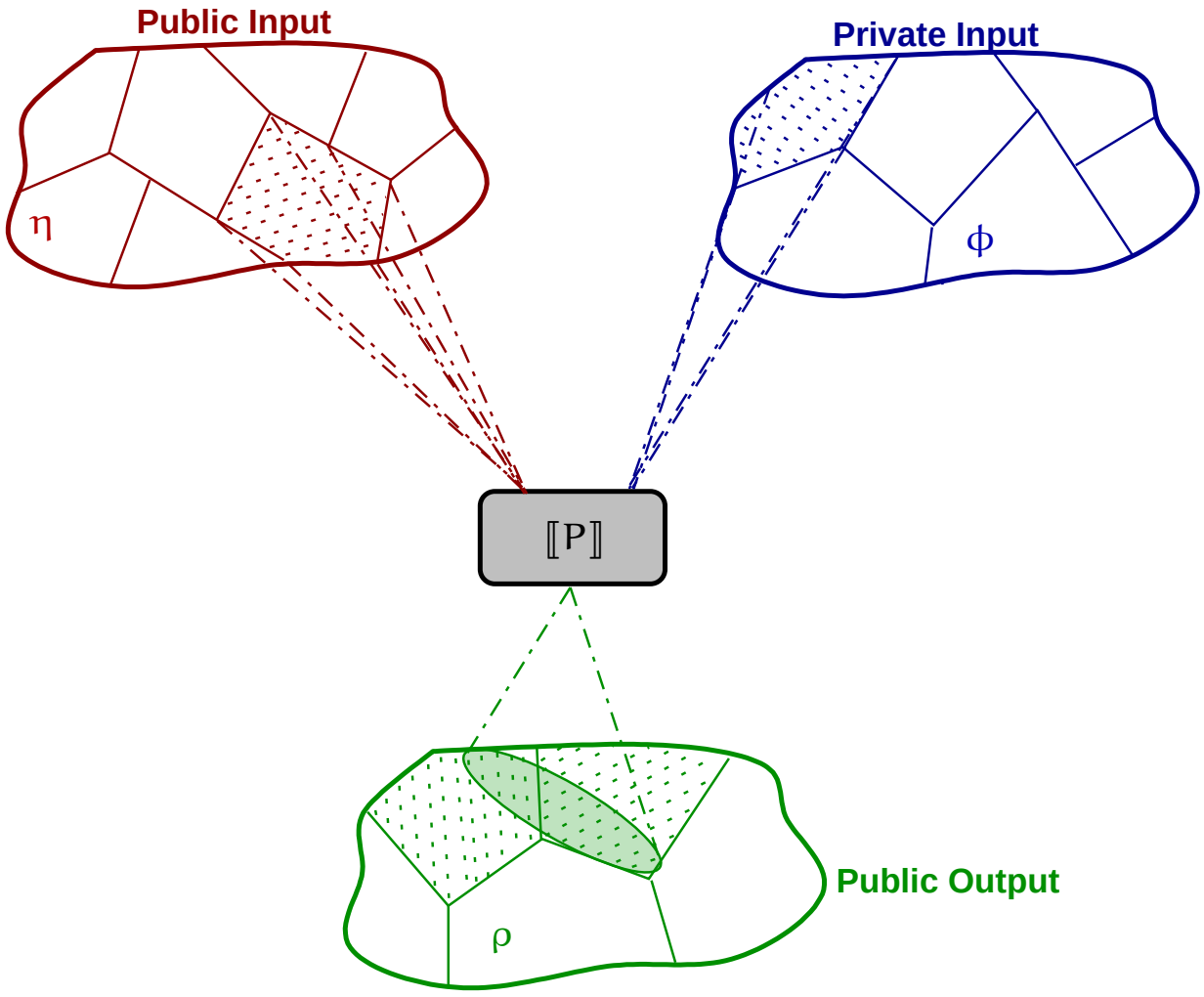

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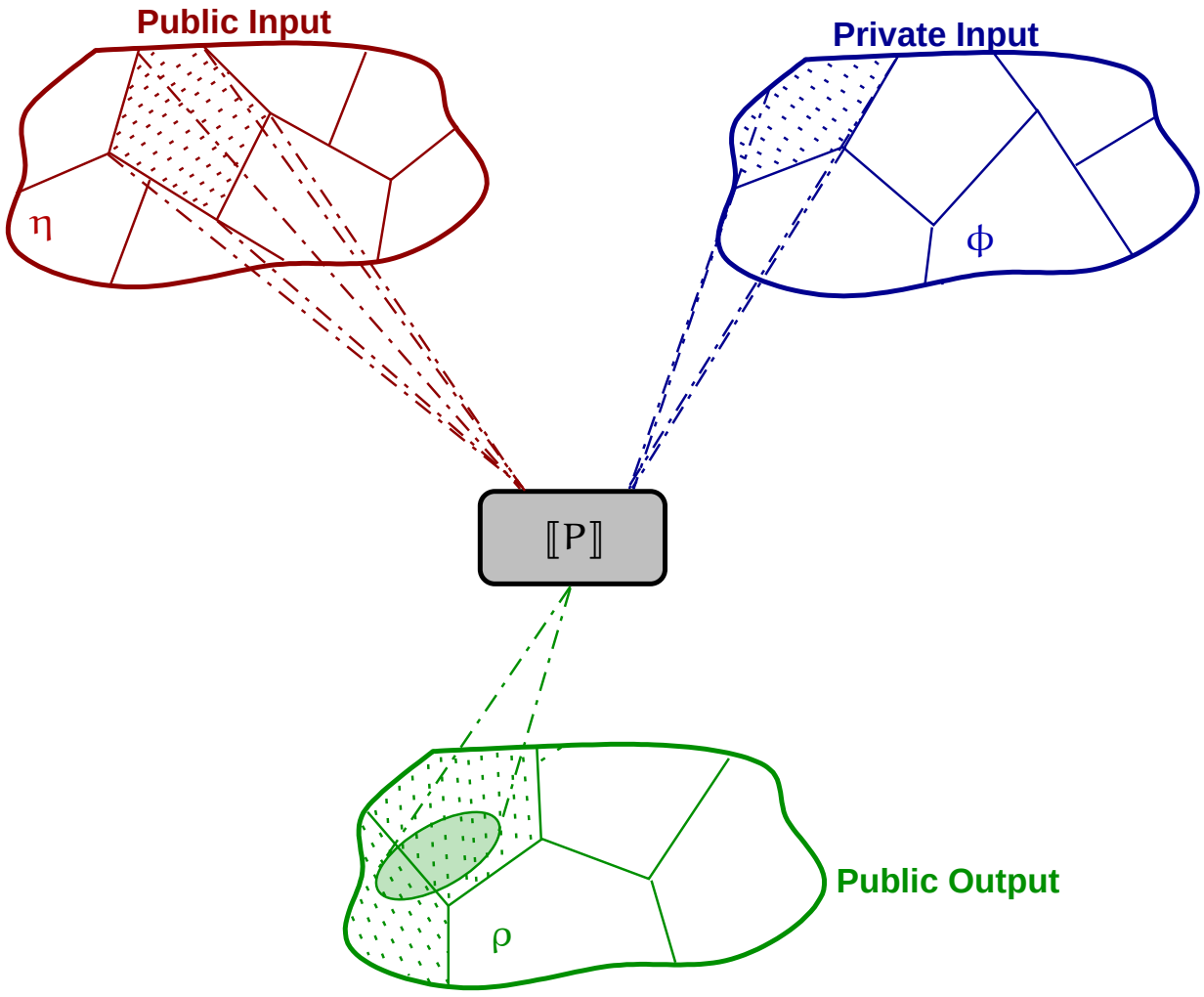

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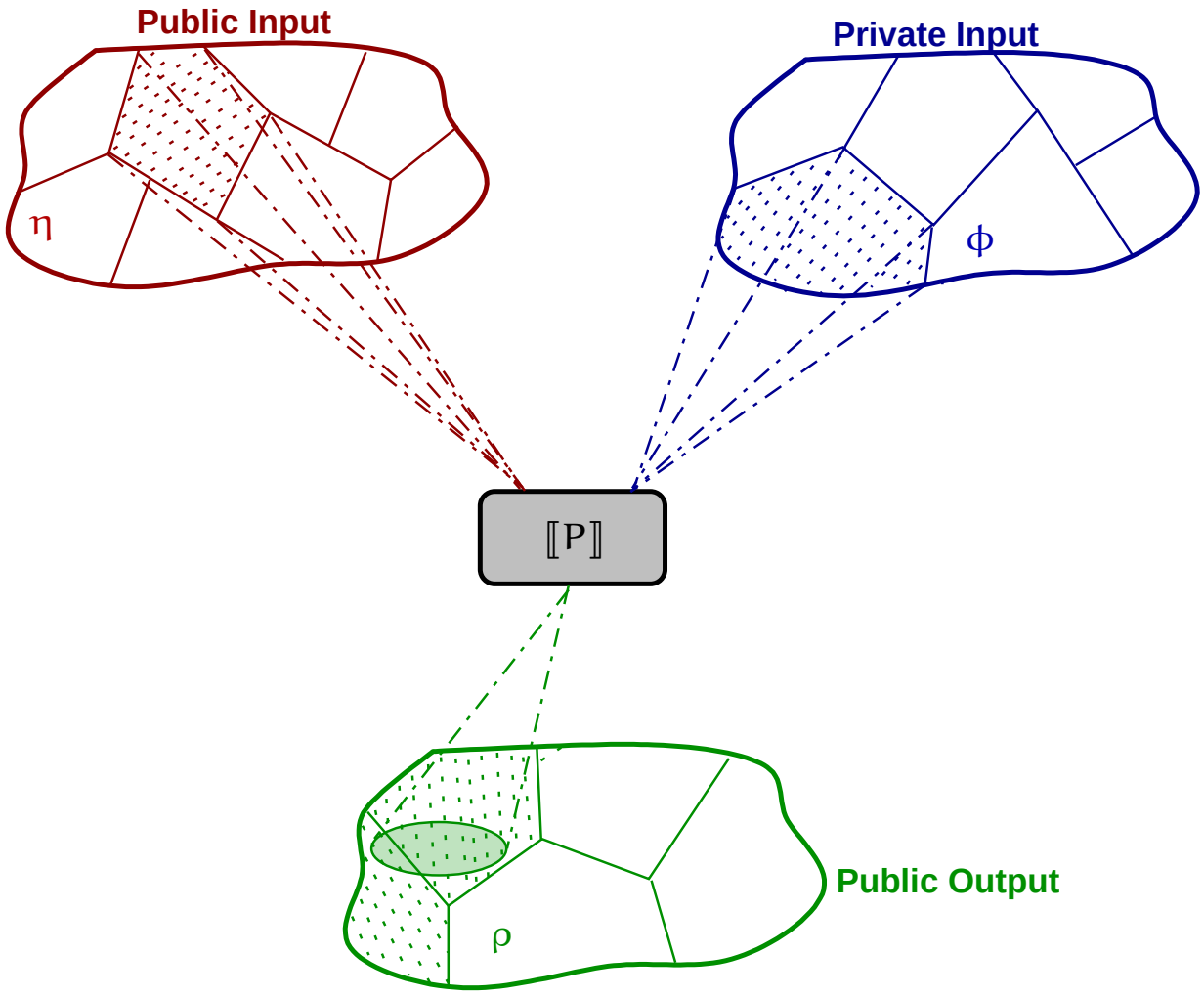

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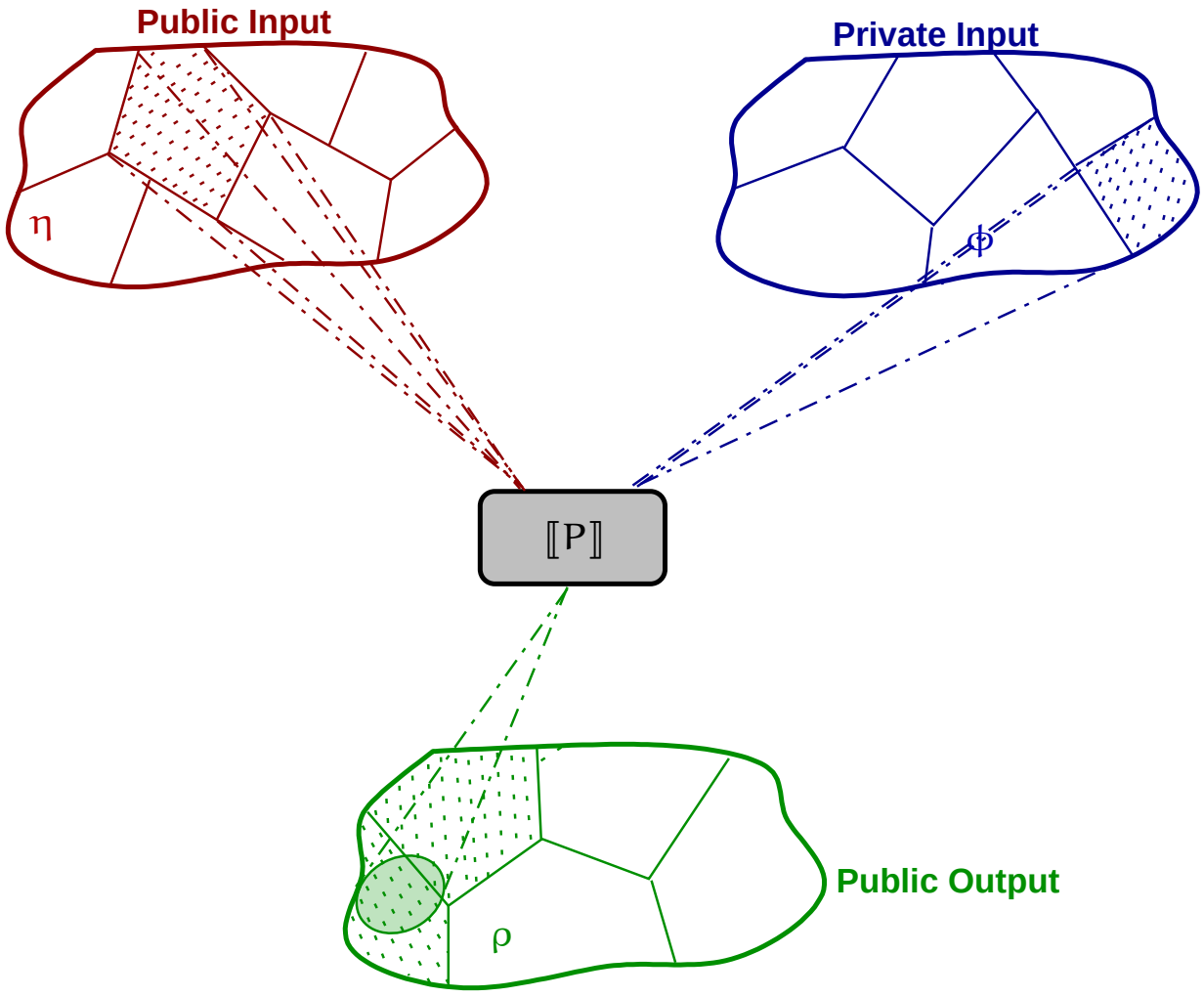

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Deriving output attackers

Abstract interpretation provides advanced methods for designing abstractions (refinement, simplification, compression ...) [Giacobazzi & Ranzato ’97]

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$\Rightarrow$ This would provide a certificate for security with a fixed input observation.

Generalized abstract non-interference

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$$\alpha_{ATT} \circ \alpha_{OBS}([\![\mathrm{P}]\!]) = \alpha_{ATT} \circ \alpha_{INT} \circ \alpha_{OBS}([\![\mathrm{P}]\!]).$$

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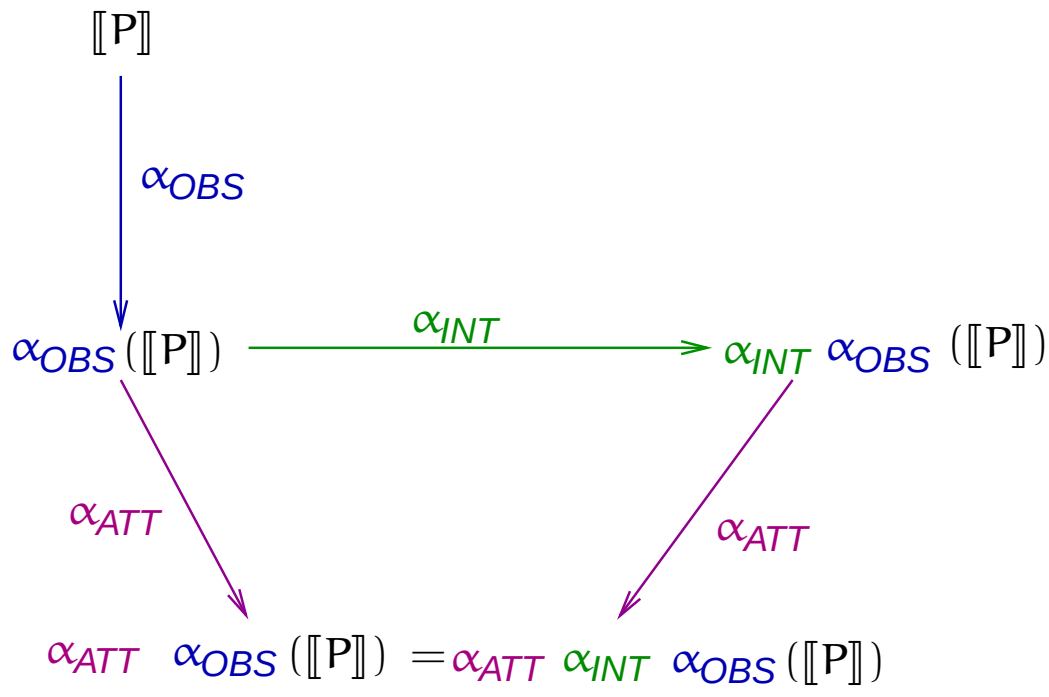
NON-INTERFERENCE

Corresponds to asking that the behavior of the chosen relevant aspects of the computation be invariant with respect to what an attacker may observe.

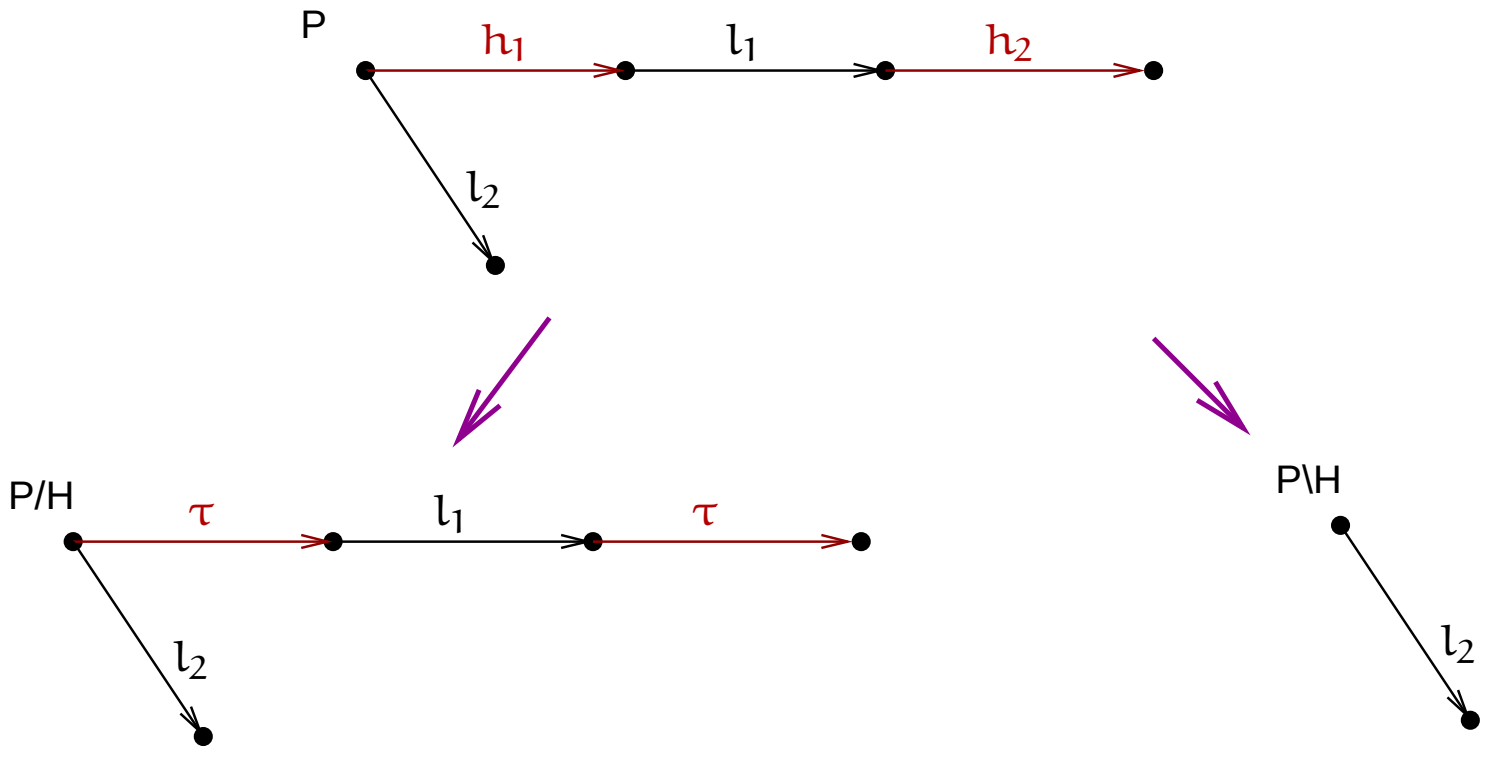
- α_{OBS}: Specifies the semantics of the computations relevant for interference (*observation abstraction*);
- α_{INT}: Specifies the maximum amount of information that an attacker may observe concerning a computation (*interference abstraction*);
- α_{ATT}: Characterizes what the model of the attacker can observe about the system behavior (*attacker abstraction*).

$\Rightarrow$ We characterize the minimal abstraction of α_{ATT} that guarantees GANI.

The global picture



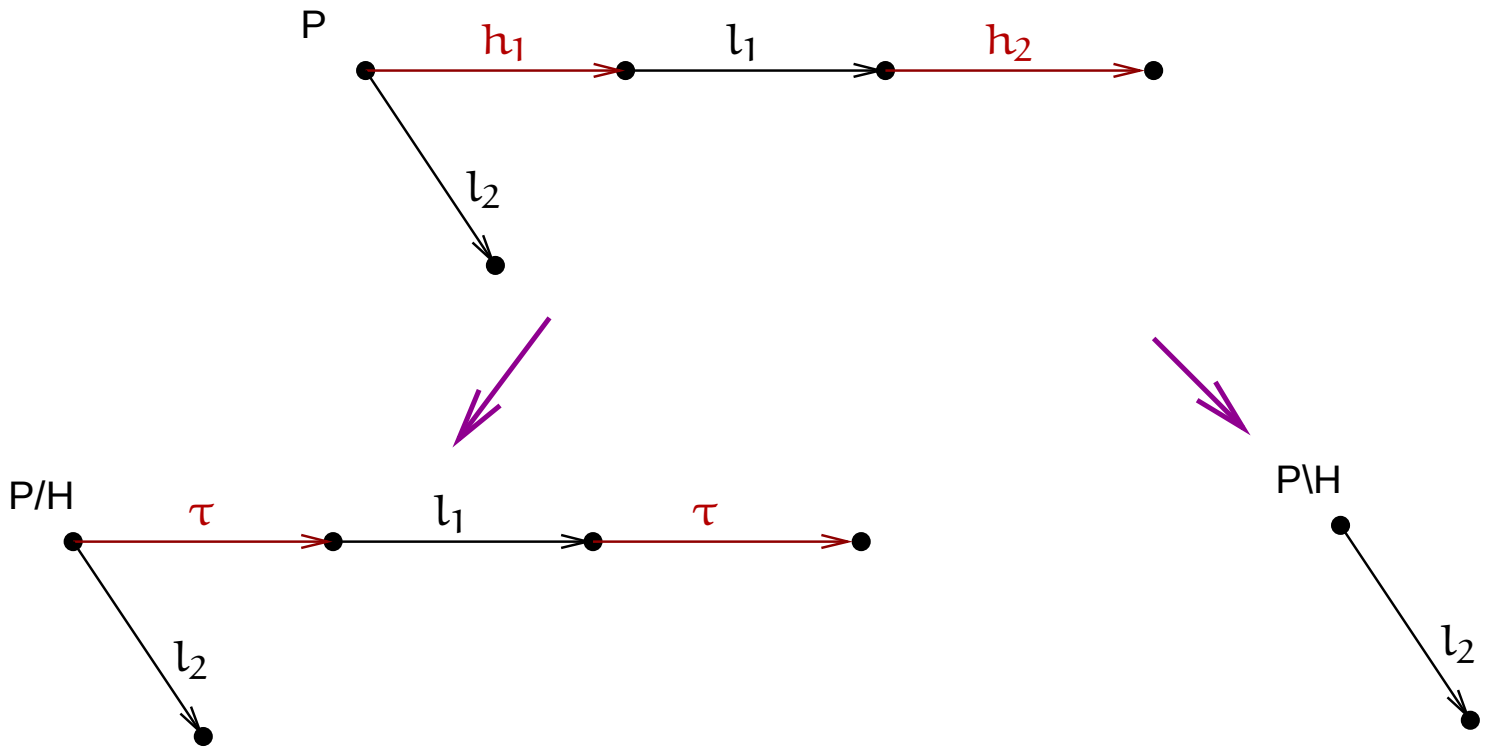
A general framework



SNNI= $P/H \approx P\backslash H$

[Focardi & Gorrieri '95]

A general framework

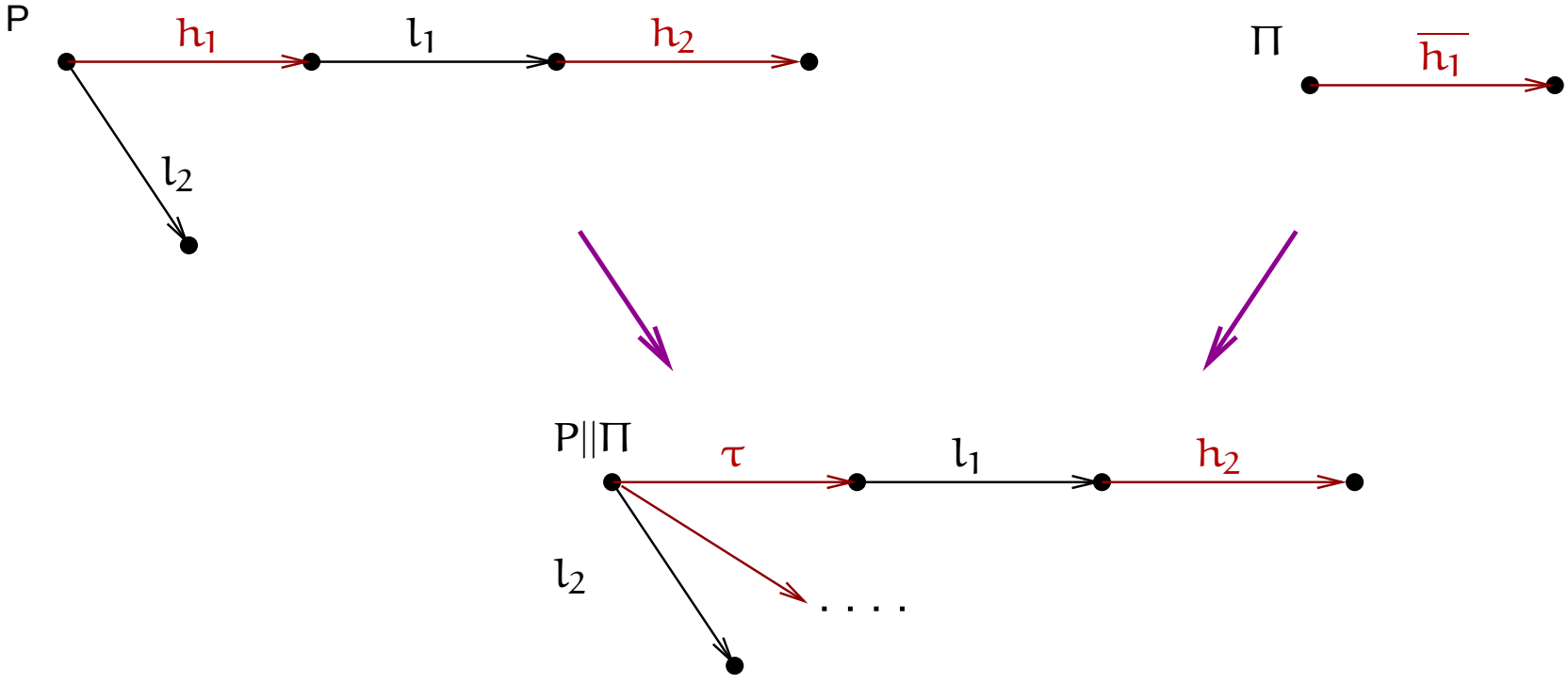


SNNI= $P/H \approx P\backslash H$

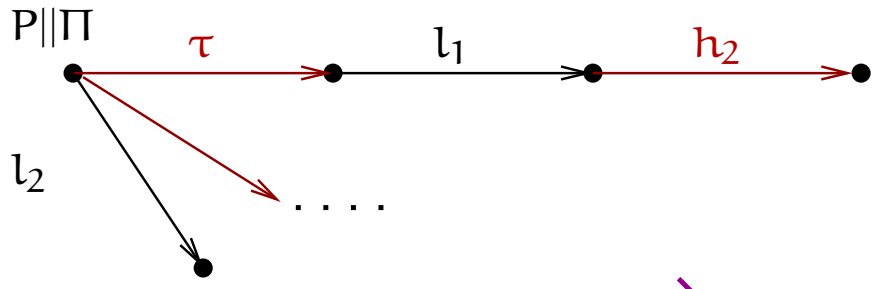
$$\Downarrow$$

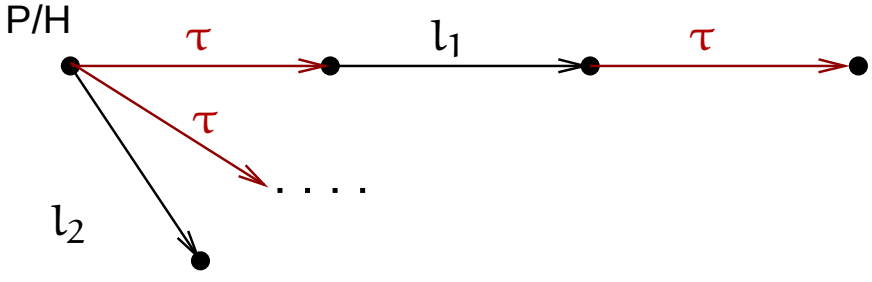
$$\text{SNNI} = \alpha_T \circ \alpha_{low} \circ id([\![P]\!]) = \alpha_T \circ \alpha_{low} \circ \alpha_L \circ id([\![P]\!]).$$

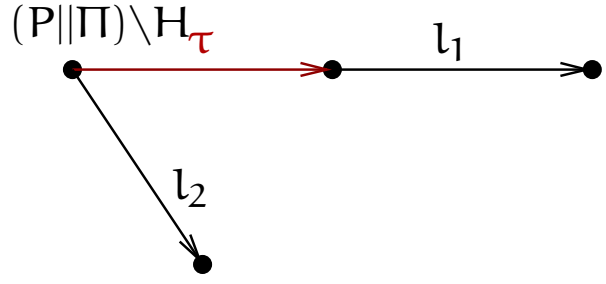
A general framework



A general framework



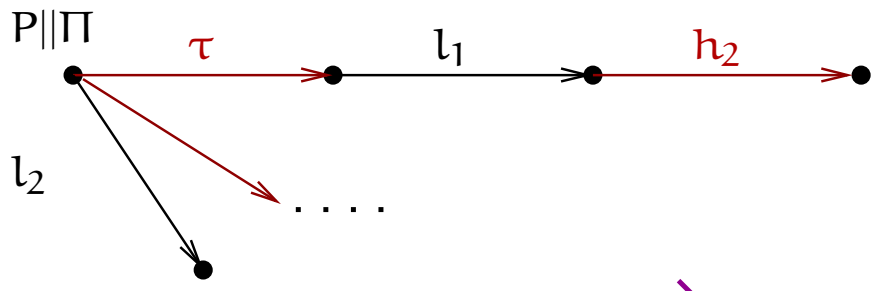


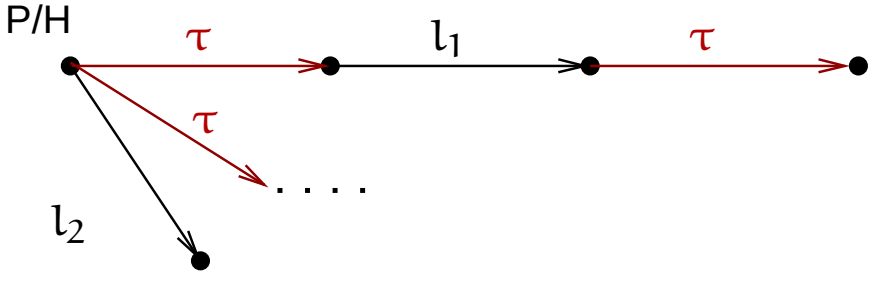


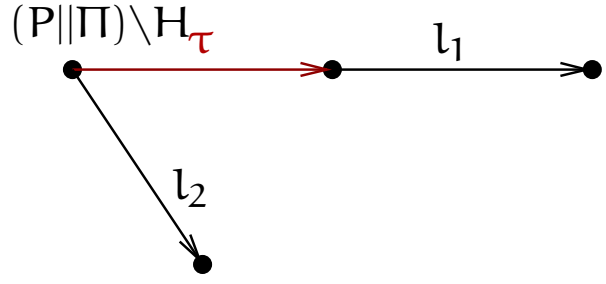
BNDC= $\forall \Pi.\ P/H \approx_B (P||\Pi)\backslash H$

[Focardi & Gorrieri '95]

A general framework





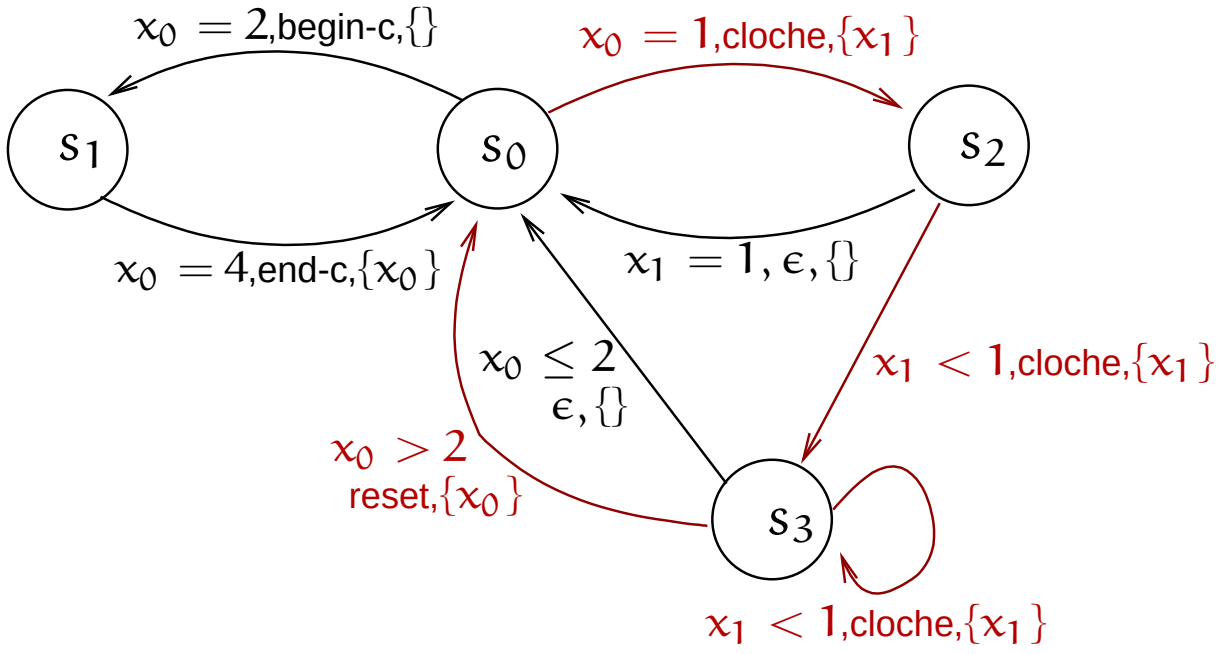


$$\text{BNDC} = \forall \Pi.\ P/H \approx_B (P||\Pi)\backslash H$$

$$\Downarrow$$

$$\text{BNDC} = \forall \Pi.\ \alpha_B \circ \alpha_L \circ id([\![P||\Pi]\!]) = \alpha_B \circ \alpha_L \circ \alpha_{sec} \circ id([\![P||\Pi]\!]).$$

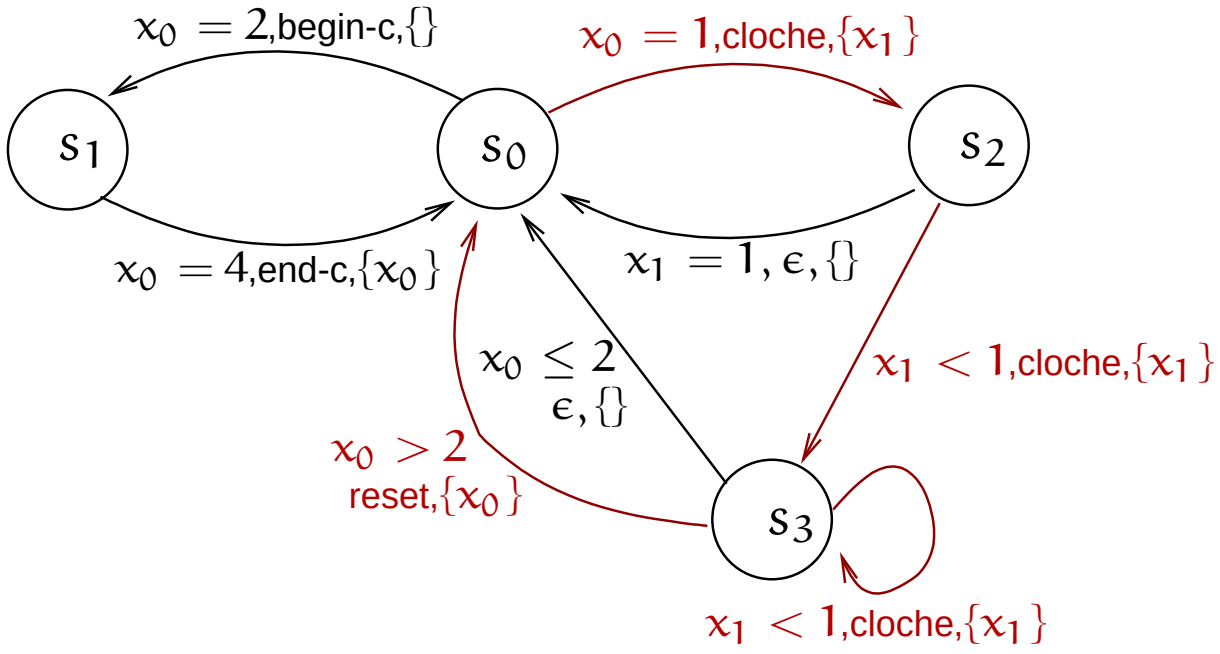
A general framework



n-Non-Int = $\mathcal{L}^n_H/H = \mathcal{L}|_L$

[Barbuti et al. '02]

A general framework



$$n\text{-Non-Int} = \mathcal{L}^n_H / H = \mathcal{L}|_L$$

$$\Downarrow$$

$$\boxed{n\text{-Non-Int} = \alpha_{low} \circ \alpha_n(\llbracket P \rrbracket) = \alpha_{low} \circ \alpha_L \circ \alpha_n(\llbracket P \rrbracket).}$$

Conclusion

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- We introduced a generalized notion of Abstract Non-Interference for dealing with computational systems modeled by computational trees;
- We show that many of the known notions of Non-Interference can be modeled as instantiation of GANI;
- We believe that generalized abstract non-interference may provide advanced techniques for analysing in a *modular* way how sub-components *interact* (e.g. in biological systems).
- We are working for designing a tool support for checking generalized abstract non-interference properties.