Certificate Translation for Specification Preserving Advices

Gilles Barthe and César Kunz
INRIA Sophia Antipolis - Méditerranée

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MOTIVATION

SPECIFICATION PRESERVING ADVICES

PROVING SPECIFICATION PRESERVING ADVICES

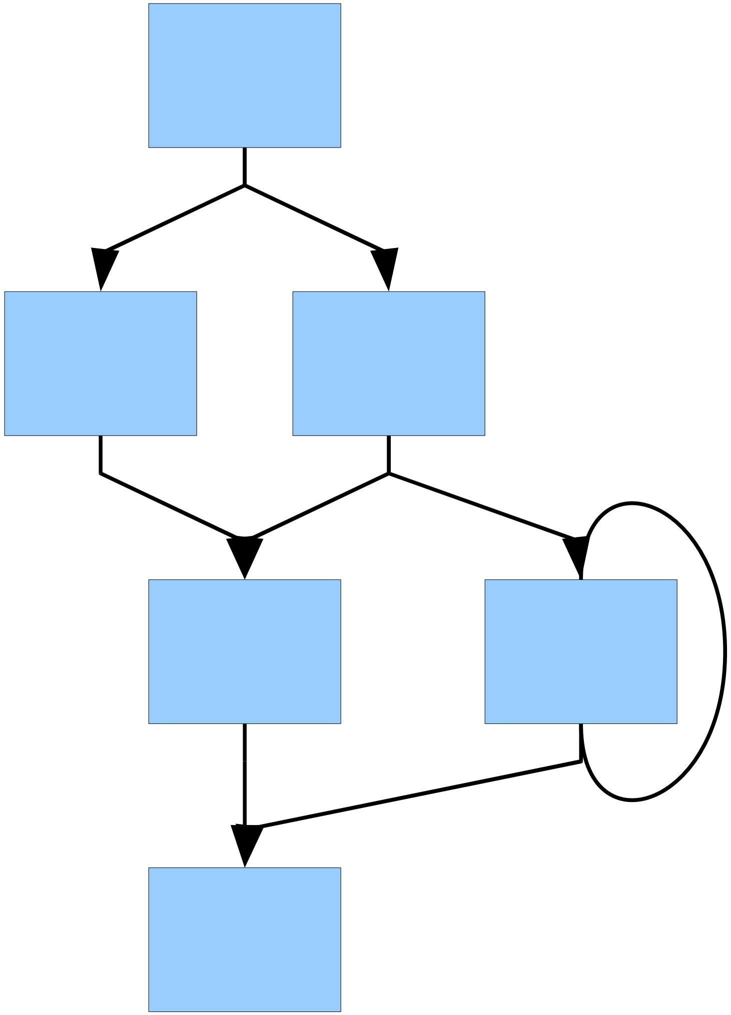
REDUCING PROOF OBLIGATIONS

IMPROVING THE VERIFICATION POWER

CERTIFICATE TRANSLATION

Local reasoning on:

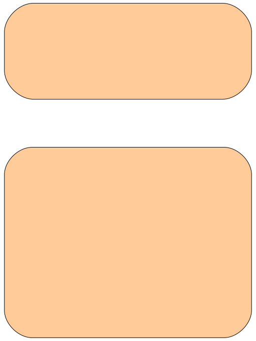
- Baseline Code (to understand main functionality)



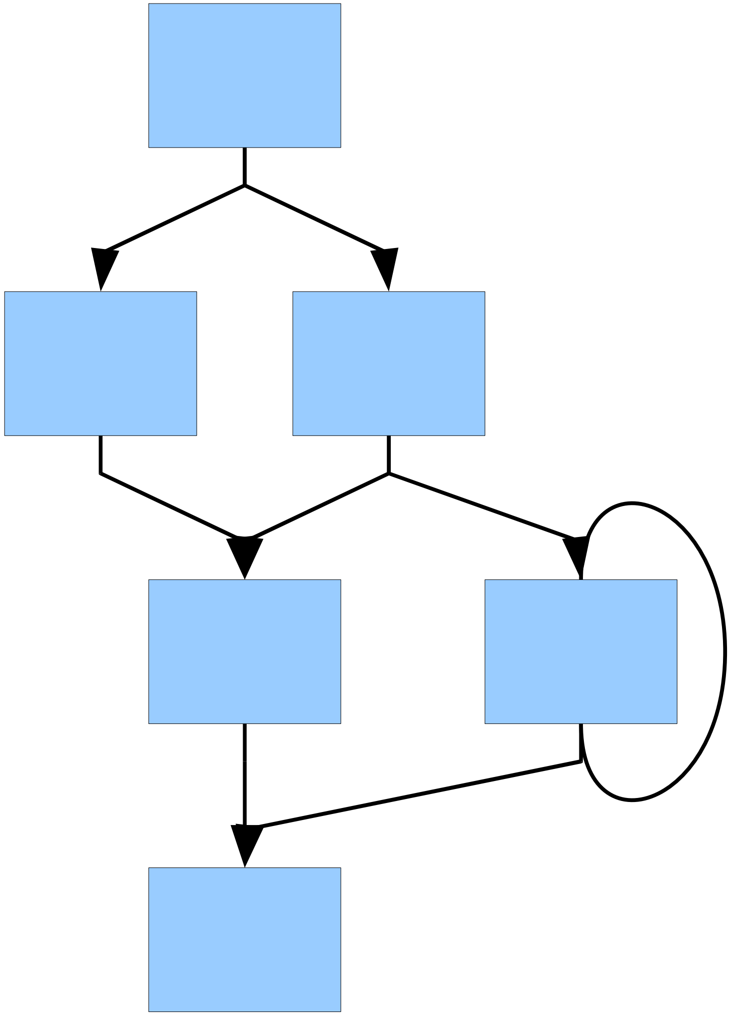
Local reasoning on:

- Baseline Code (to understand main functionality)

- Advice Code
(to understand the implemented aspect



Incremental concerns:
- Contract enforcement
- Logging / Profiling
- Evolving Security Requirements



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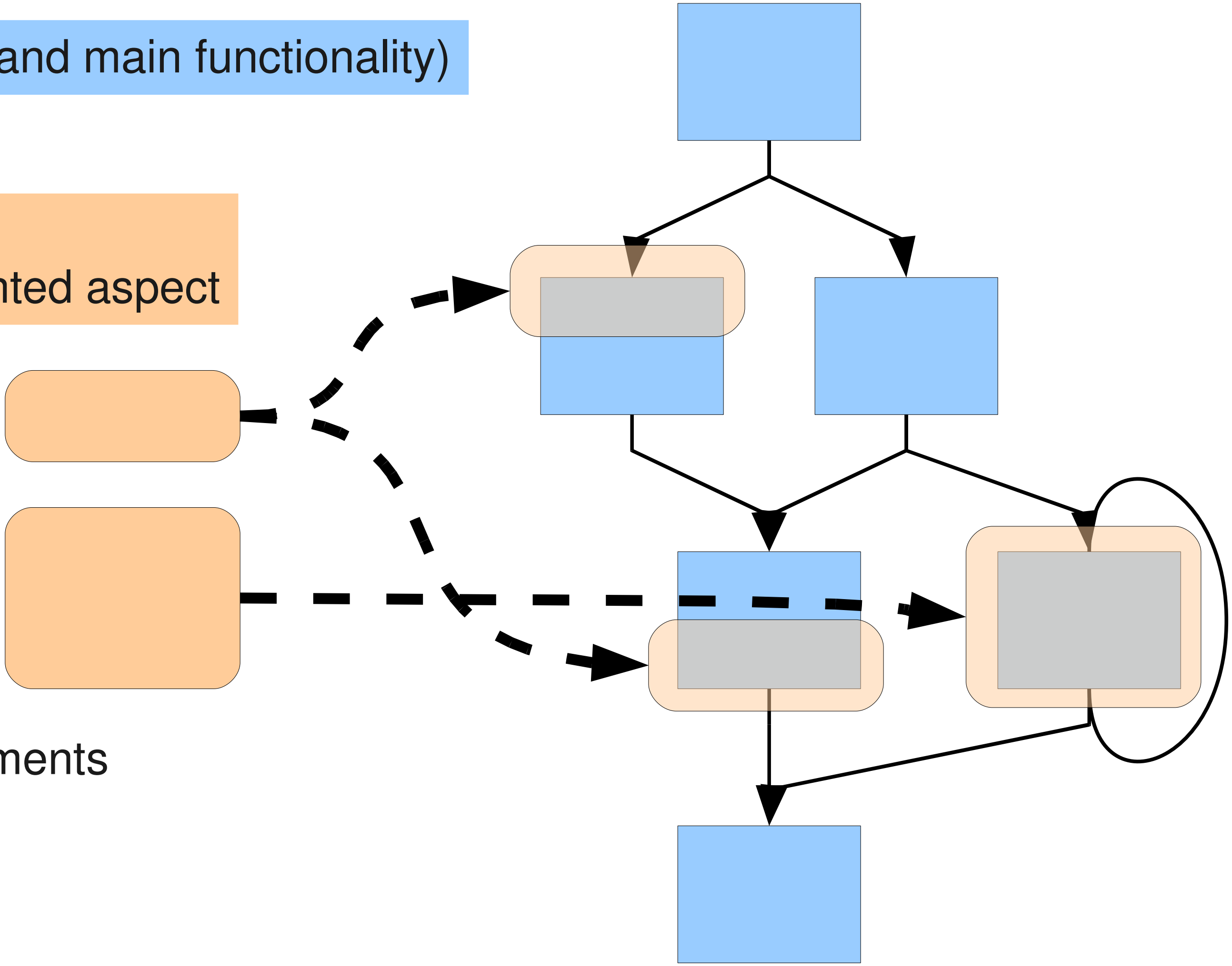


Incremental concerns:
- Contract enforcement
- Logging / Profiling
- Evolving Security Requirements

Global analysis of pointcuts to understand interaction of aspects

Producer vs Consumer Perspective

Obliviousness -> Local Reasoning?

Syntactic Obliviousness
is not enough

Syntactic Obliviousness
vs.
Semantic Obliviousness

Dantas & Walker [POPL06]:

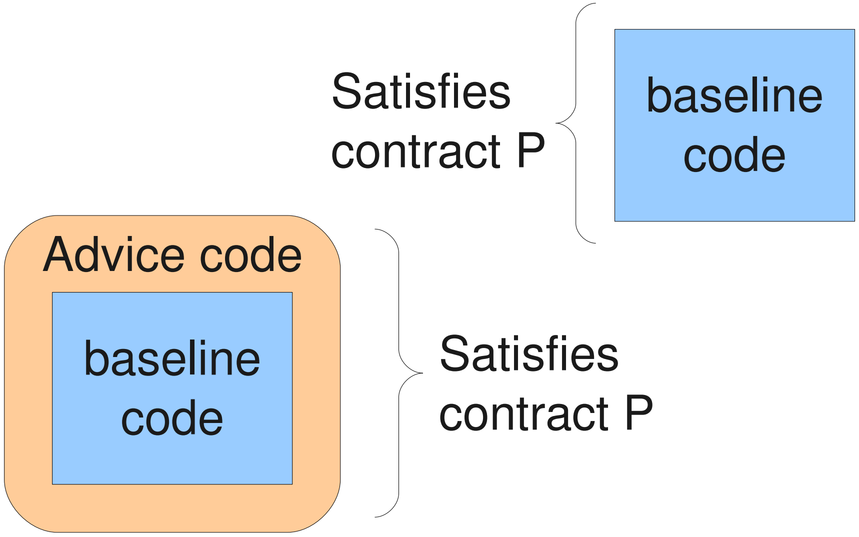
- characterize *Harmless Advices* that allow local reasoning
- information flow analysis to check advice non-interference.

PCC setting: contract enforcement

- functional properties (logic formulae)
- Absence of null pointer access
- Type Safety, etc.

Contract preserv. vs semantic preserv

weaker requirement



Satisfies
contract P

baseline
code

Advice code

baseline
code

Satisfies
contract P

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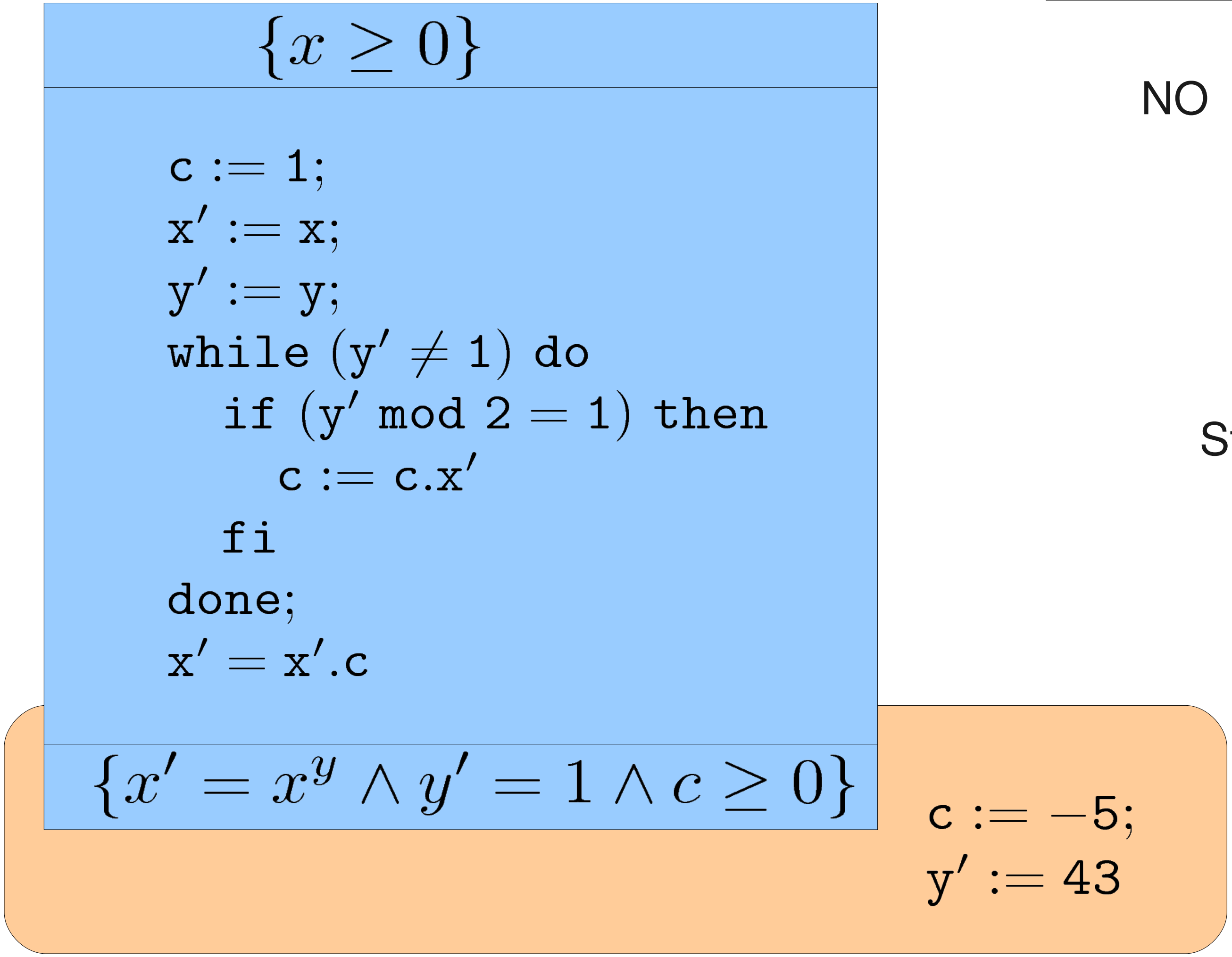
Specification Preserving Advices

Harmless	Spec. preserving
NO	NO



```
$\{x \geq 0\}$

c := 1;
x' := x;
y' := y;
while (y' ≠ 1) do
   if (y' mod 2 = 1) then
      c := c.x'
   fi
done;
x' = x'.c

$\{x' = x^y \wedge y' = 1 \wedge c \geq 0\}$
```

```
c := −5;
y' := 43
```

Strong specification

Specification Preserving Advices

Harmless	Spec. preserving
NO	YES

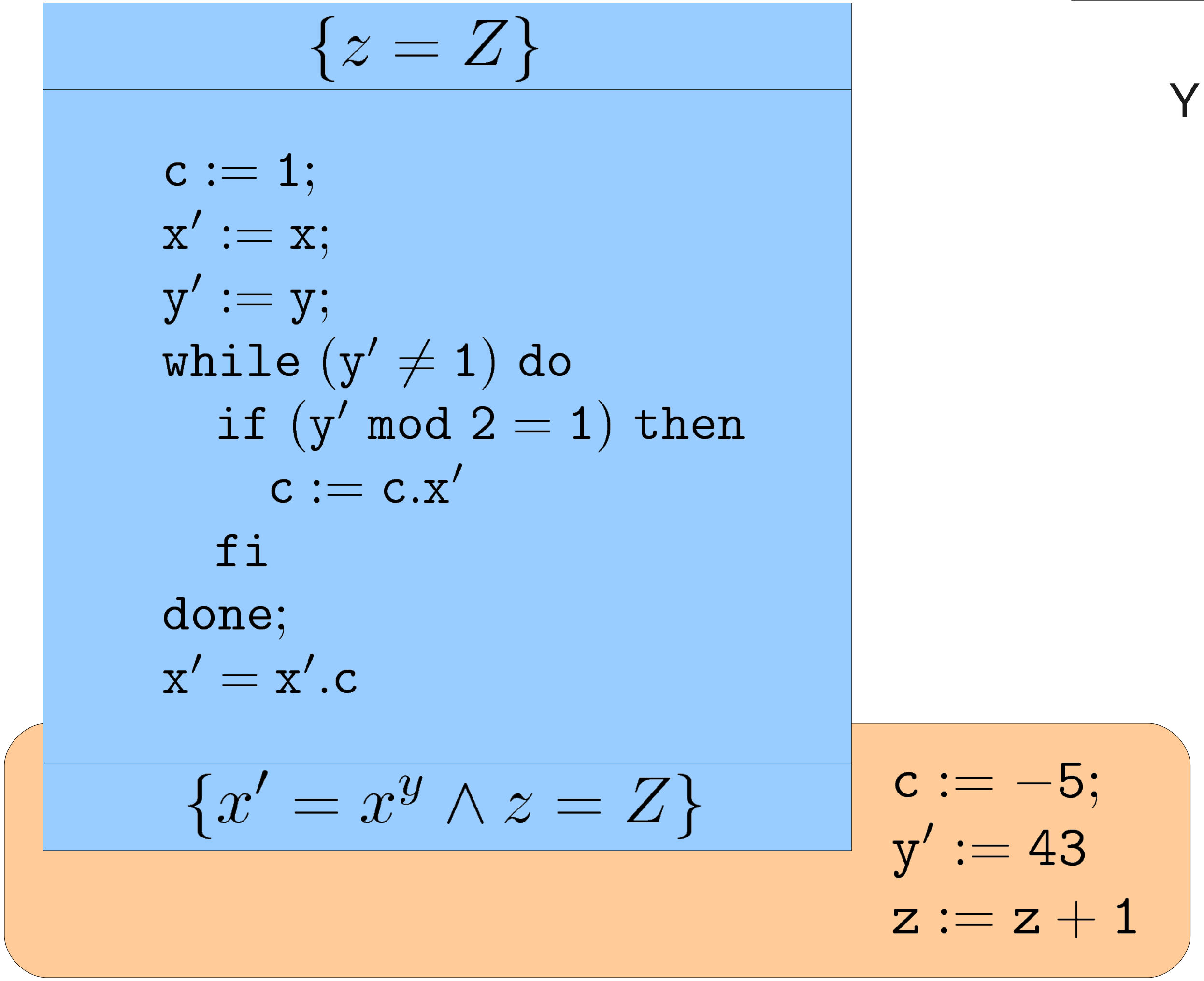
```
{True}

c := 1;
x' := x;
y' := y;
while (y' ≠ 1) do
   if (y' mod 2 = 1) then
      c := c.x'
   fi
done;
x' = x'.c

{$x' = x^y$}
```

```
c := −5;
y' := 43
```

Specification Preserving Advices



$\{z = Z\}$

```
c := 1;
x' := x;
y' := y;
while (y' ≠ 1) do
   if (y' mod 2 = 1) then
      c := c.x'
   fi
done;
x' = x'.c
```

$\{x' = x^y \wedge z = Z\}$

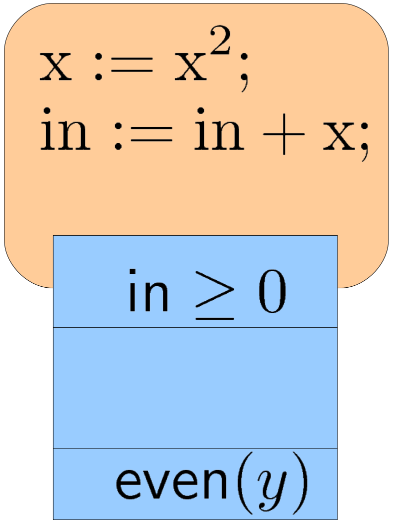
```
c := −5;
y' := 43
z := z + 1
```

Harmless	Spec. preserving
YES	NO

Specification Preserving Advices

A specification preserving advice may modify variables in the specification.

Harmless	Spec. preserving
NO	YES



$\mathrm{x} := \mathrm{x}^2;$
$\mathrm{in} := \mathrm{in} + \mathrm{x};$

in ≥ 0

even(y)

- Output value may differ
- in ≥ 0 is not invalidated.
- even(y) is ensured.

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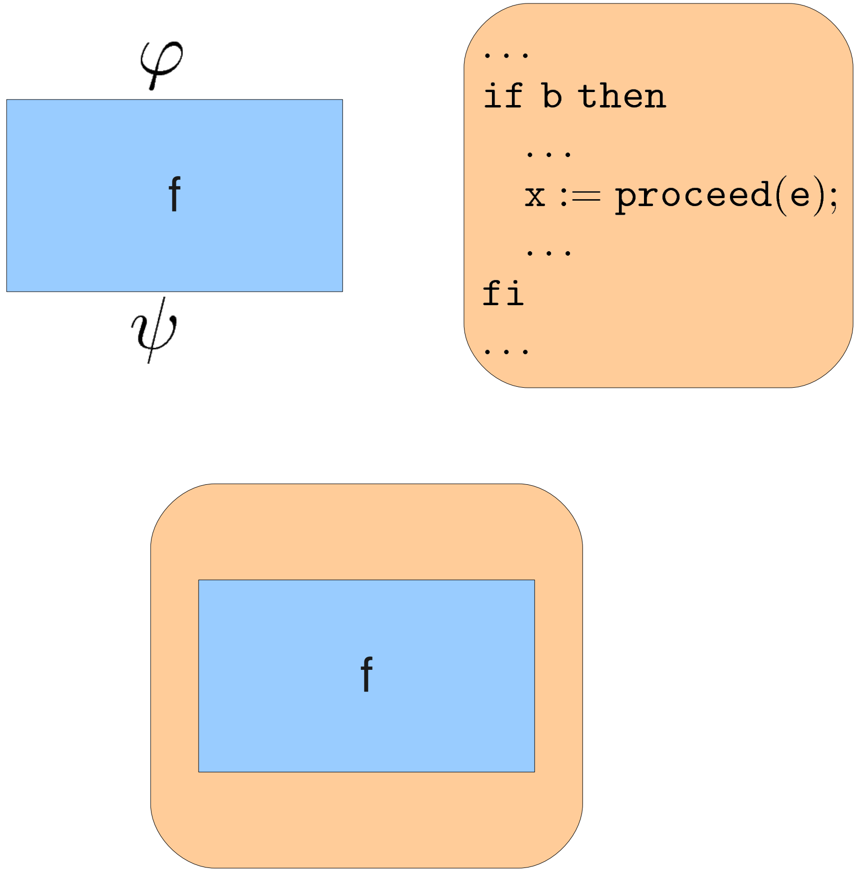
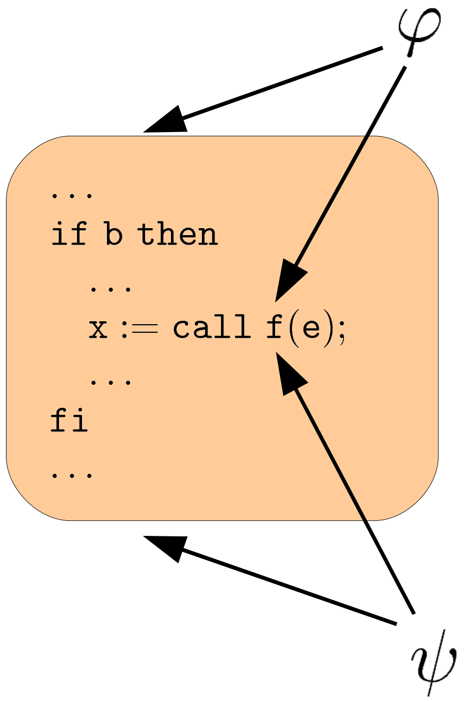
Proving spec-preservation

Baseline Code Verification: wp-based Vcgen



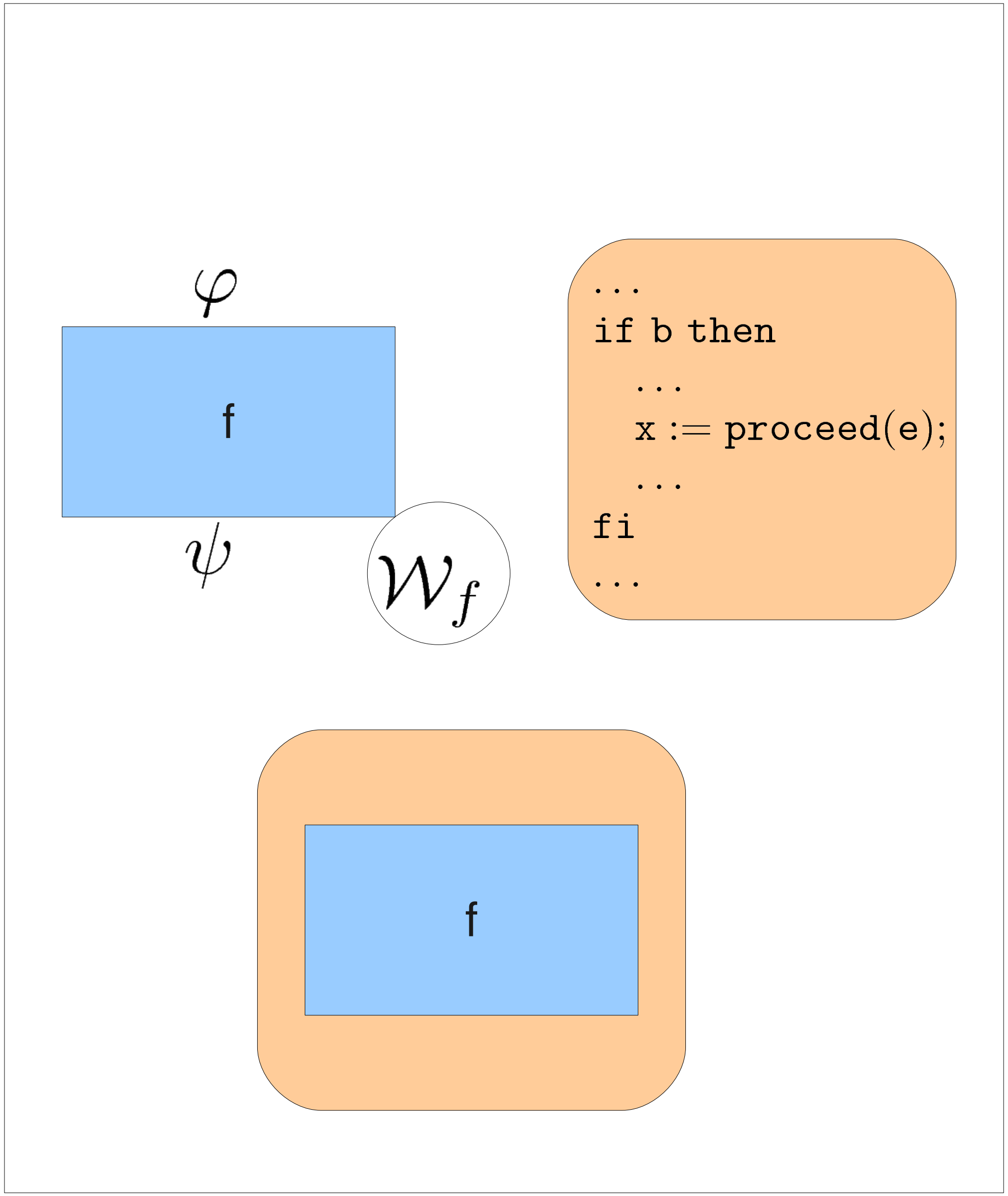
```
...
if b then
  ...
  x := proceed(e);
  ...
fi
...
```

Verification of spec. preservation: wp-based Vcgen over modified advice code.

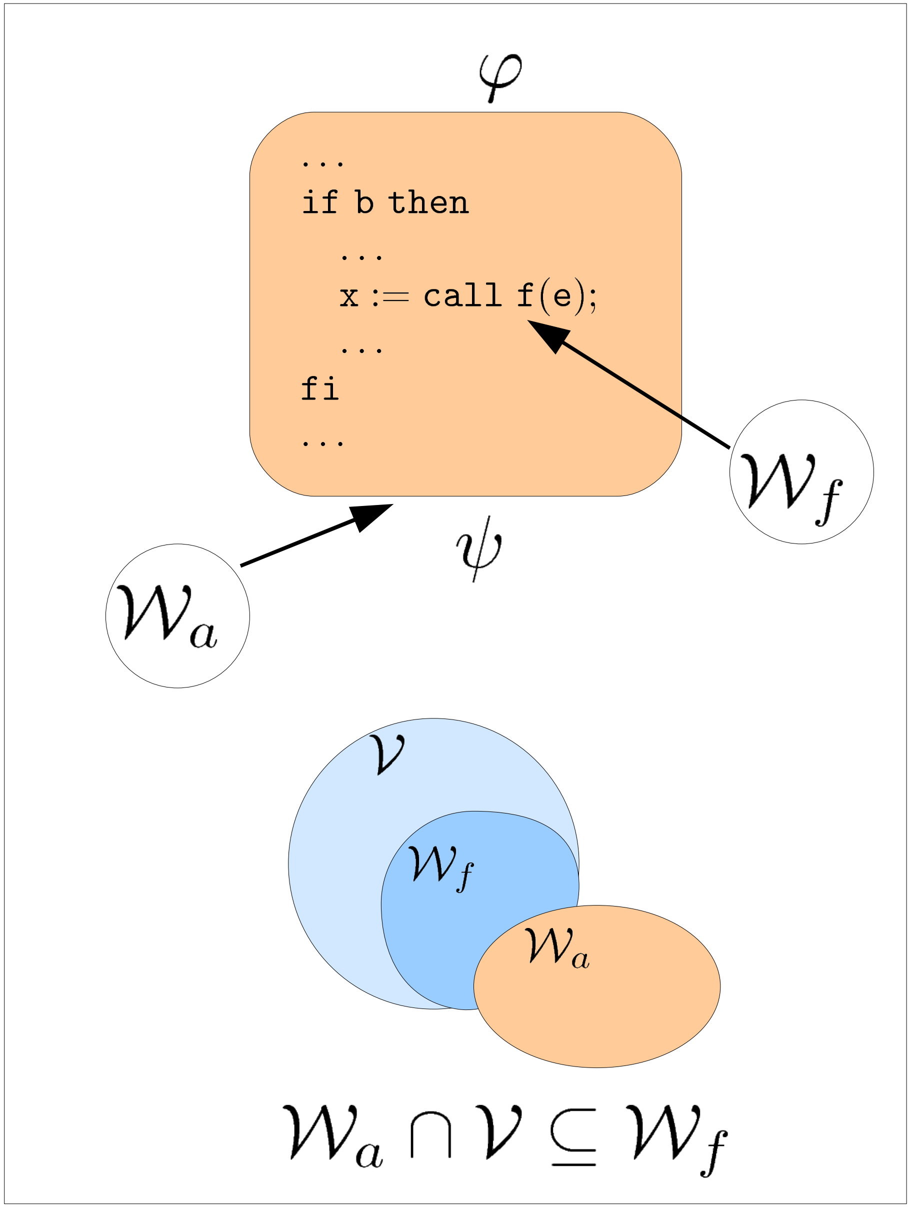


```
...
if b then
  ...
  x := call f(e);
  ...
fi
...
```

Proving spec-preservation



```
...
if b then
  ...
  x := proceed(e);
  ...
fi
...
```



```
...
if b then
  ...
  x := call f(e);
  ...
fi
...
```

$$\mathcal{W}_a \cap \mathcal{V} \subseteq \mathcal{W}_f$$

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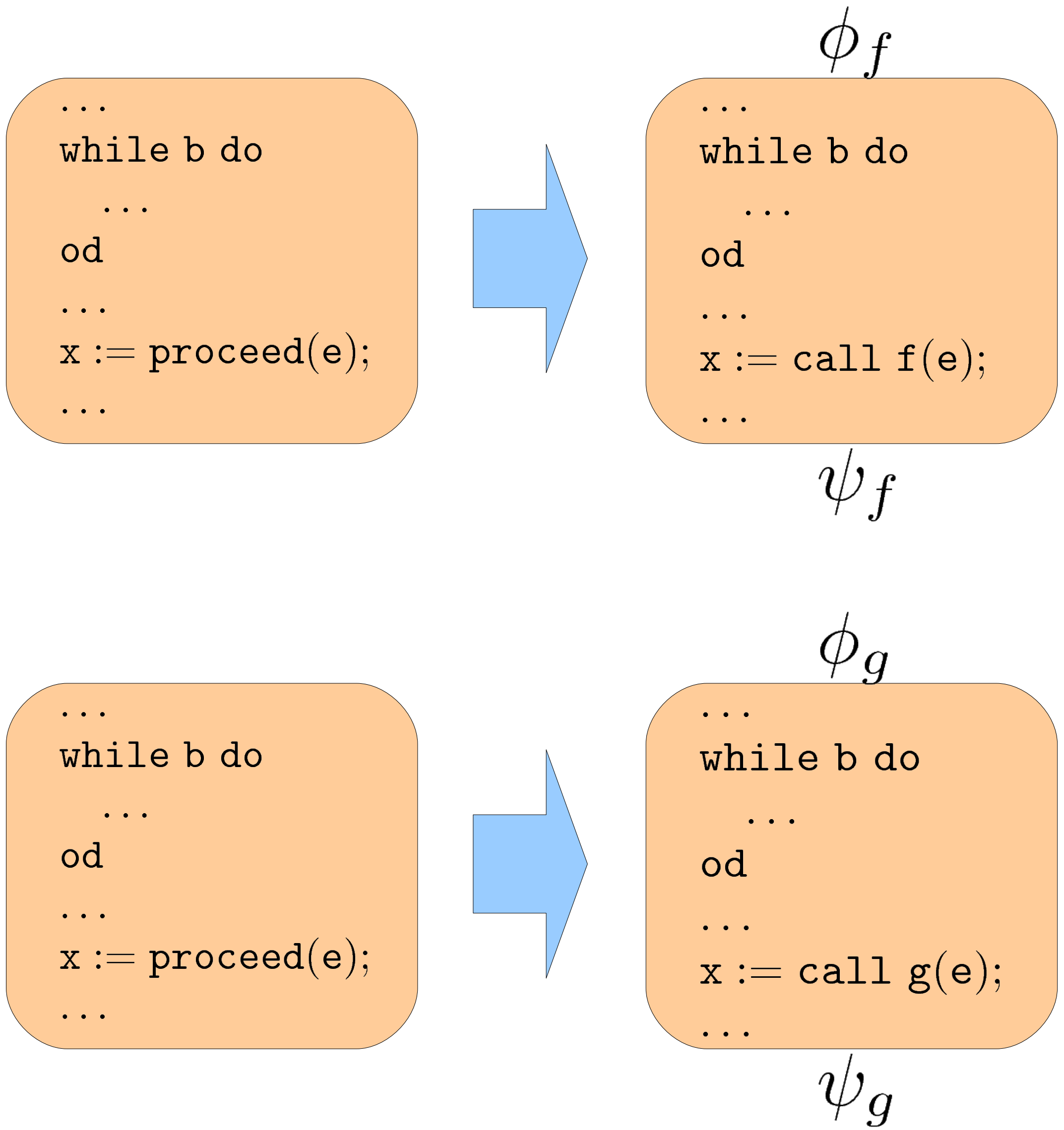
Specification Harmless Advices



$\{\phi_f\}\ f\ \{\psi_f\}$

```
...
while b do
  ...
od
...
x := proceed(e);
...
```

ϕ_f

```
...
while b do
  ...
od
...
x := call f(e);
...
```

ψ_f

$\{\phi_g\}\ g\ \{\psi_g\}$

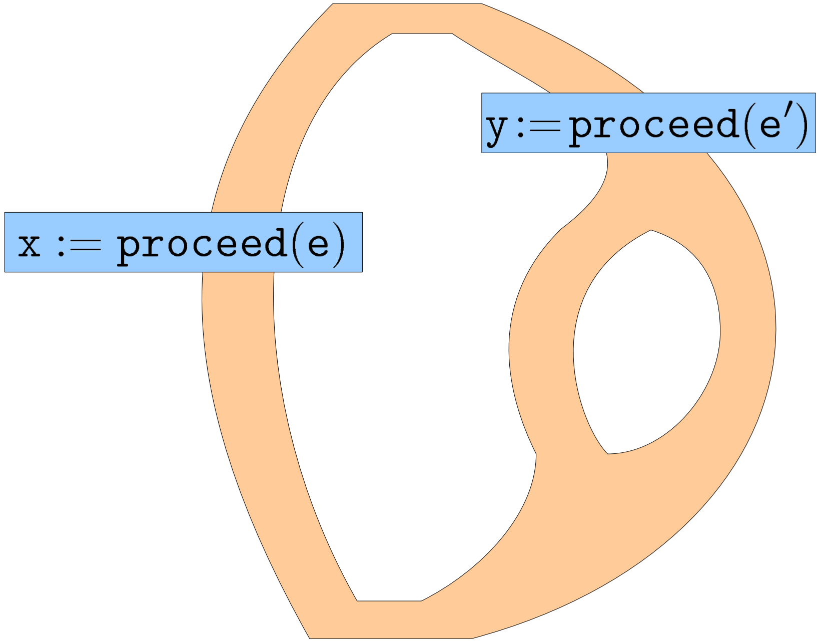
```
...
while b do
  ...
od
...
x := proceed(e);
...
```

ϕ_g

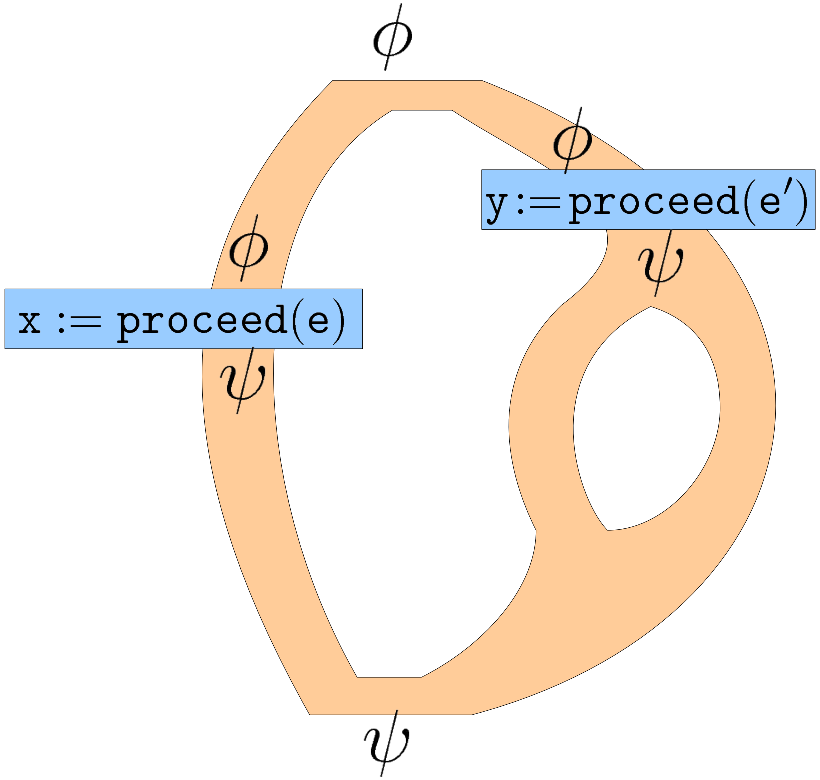
```
...
while b do
  ...
od
...
x := call g(e);
...
```

ψ_g

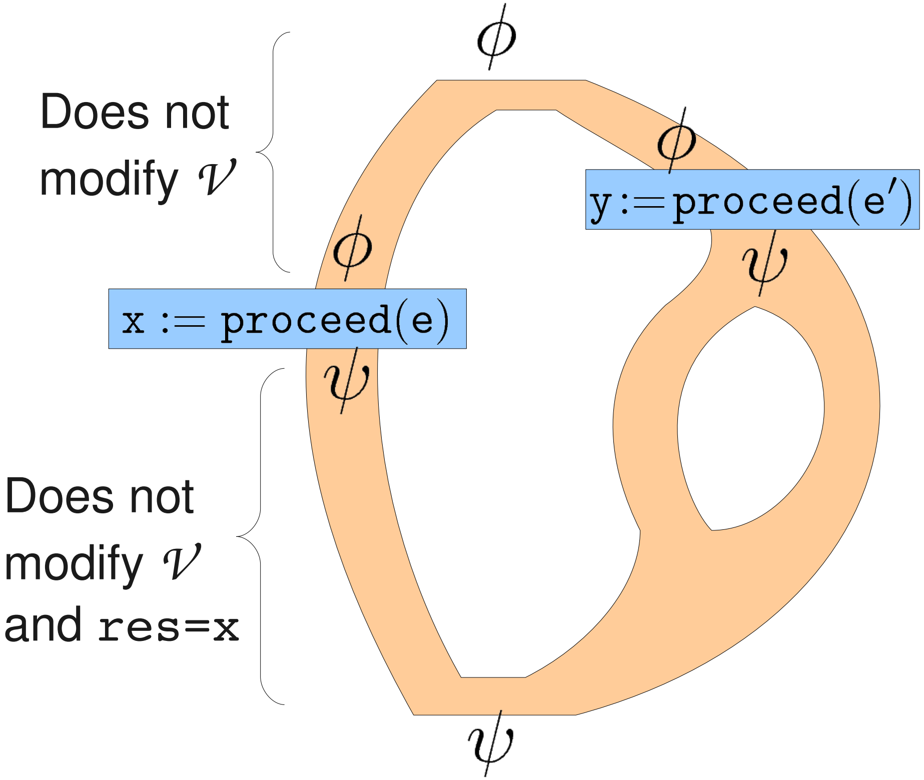
Specification Harmless Advices



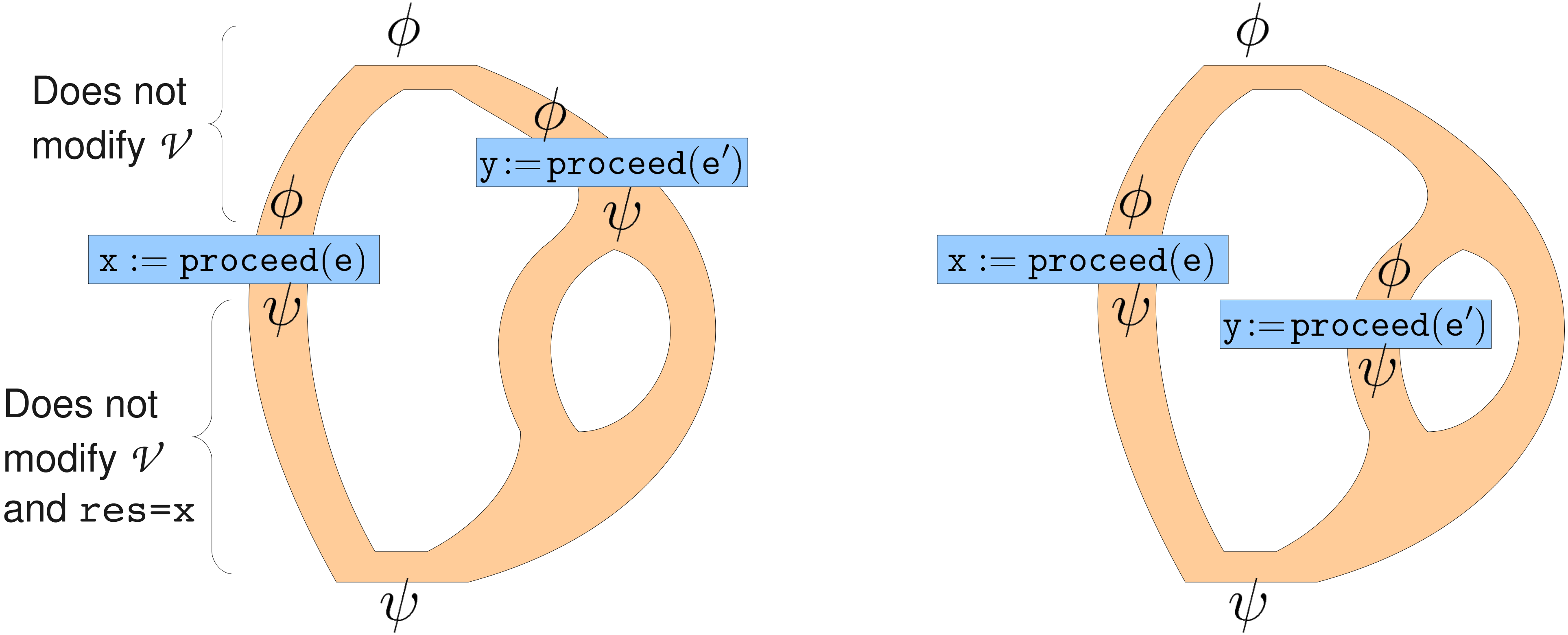
Specification Harmless Advices



Specification Harmless Advices


ϕ
Does not modify $\mathcal{V}$
ϕ
$\mathtt{y{:=}proceed(e')}$
ψ
ϕ
$\mathtt{x := proceed(e)}$
ψ
Does not modify $\mathcal{V}$ and $\mathtt{res{=}x}$
ψ

Specification Harmless Advices



Does not modify $\mathcal{V}$

Does not modify $\mathcal{V}$ and `res=x`

ϕ

ϕ

`x := proceed(e)`

ψ

ϕ

`y:=proceed(e')`

ψ

ψ

ϕ

ϕ

`x := proceed(e)`

ψ

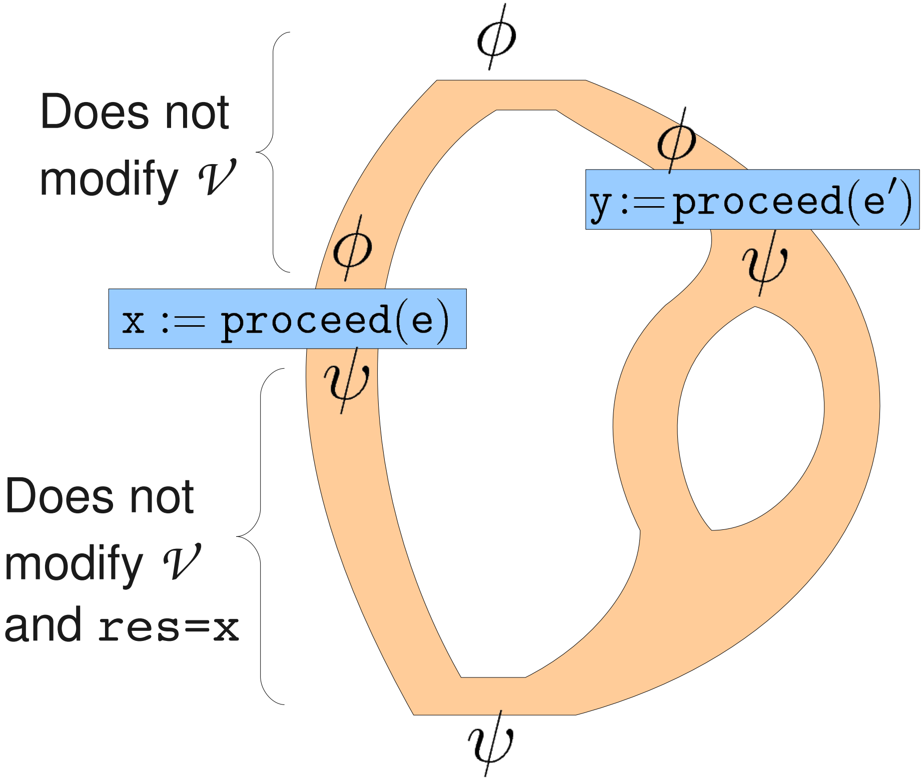
ϕ

`y:=proceed(e')`

ψ

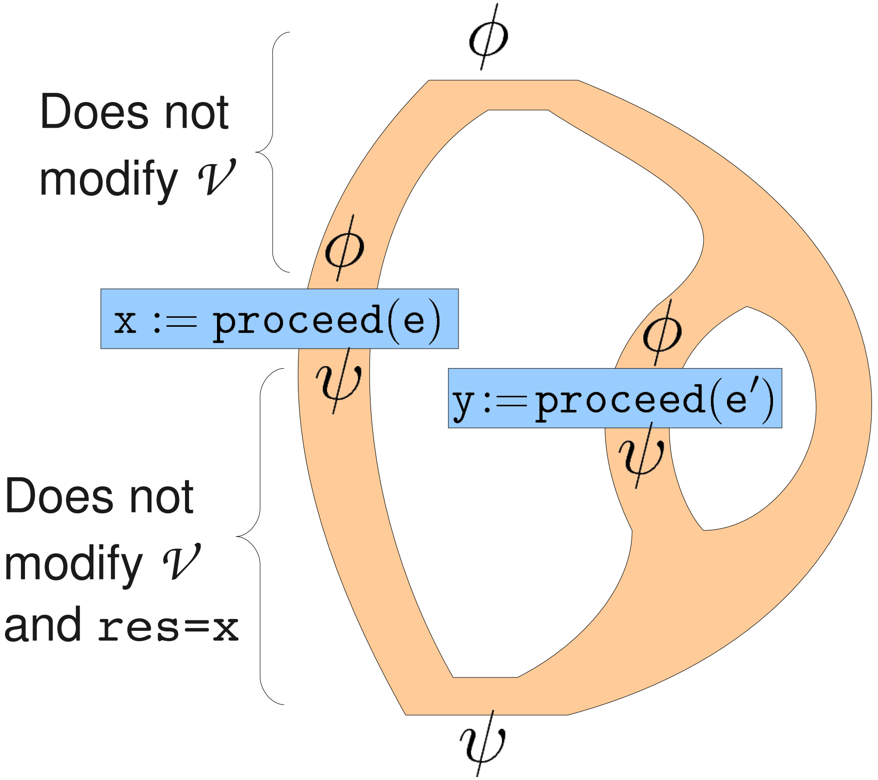
ψ

Specification Harmless Advices



Does not modify $\mathcal{V}$

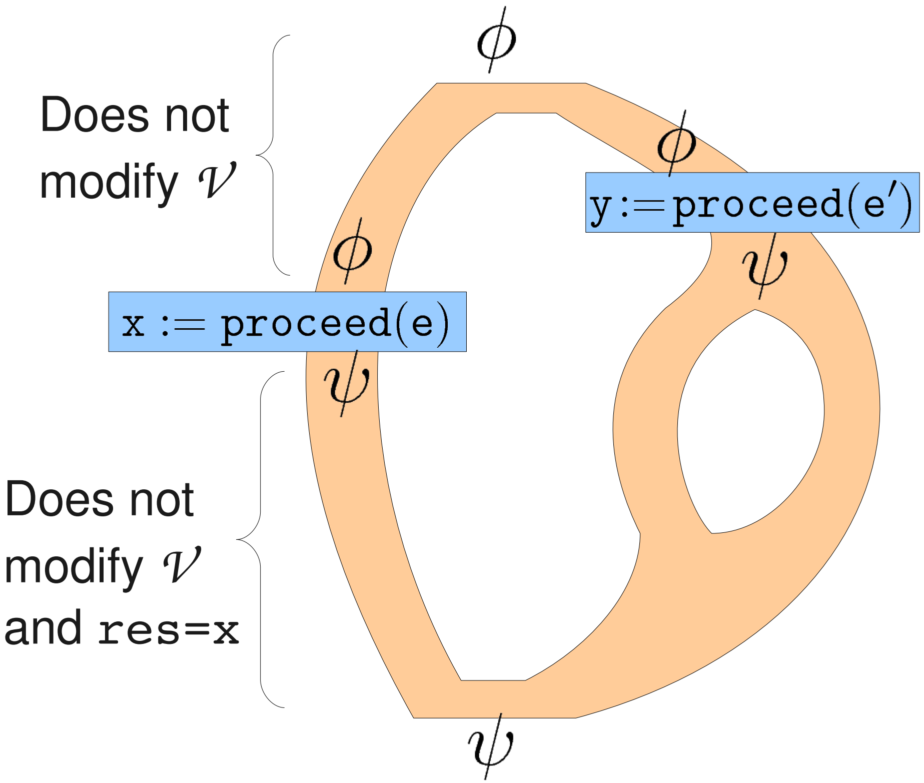
Does not modify $\mathcal{V}$ and `res=x`



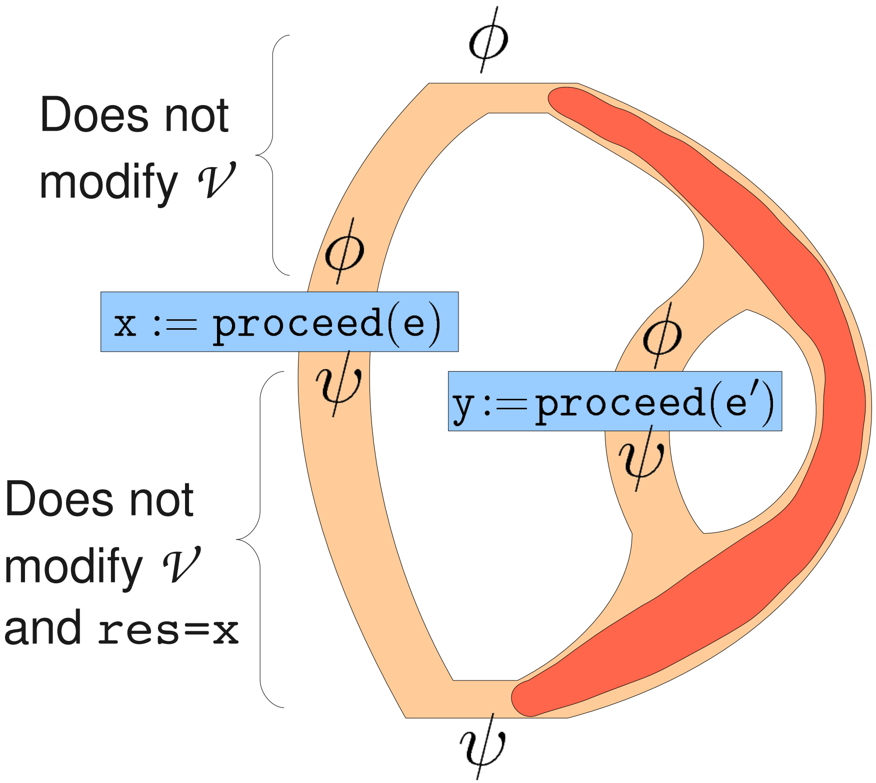
Does not modify $\mathcal{V}$

Does not modify $\mathcal{V}$ and `res=x`

Specification Harmless Advices


Does not modify $\mathcal{V}$

Does not modify $\mathcal{V}$ and `res=x`


Does not modify $\mathcal{V}$

Does not modify $\mathcal{V}$ and `res=x`

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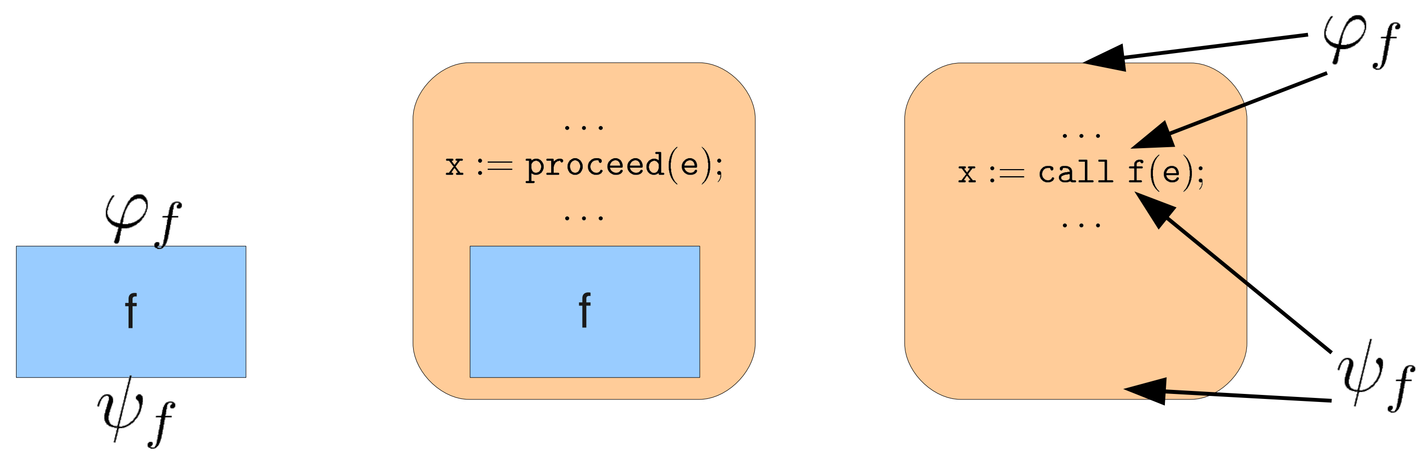
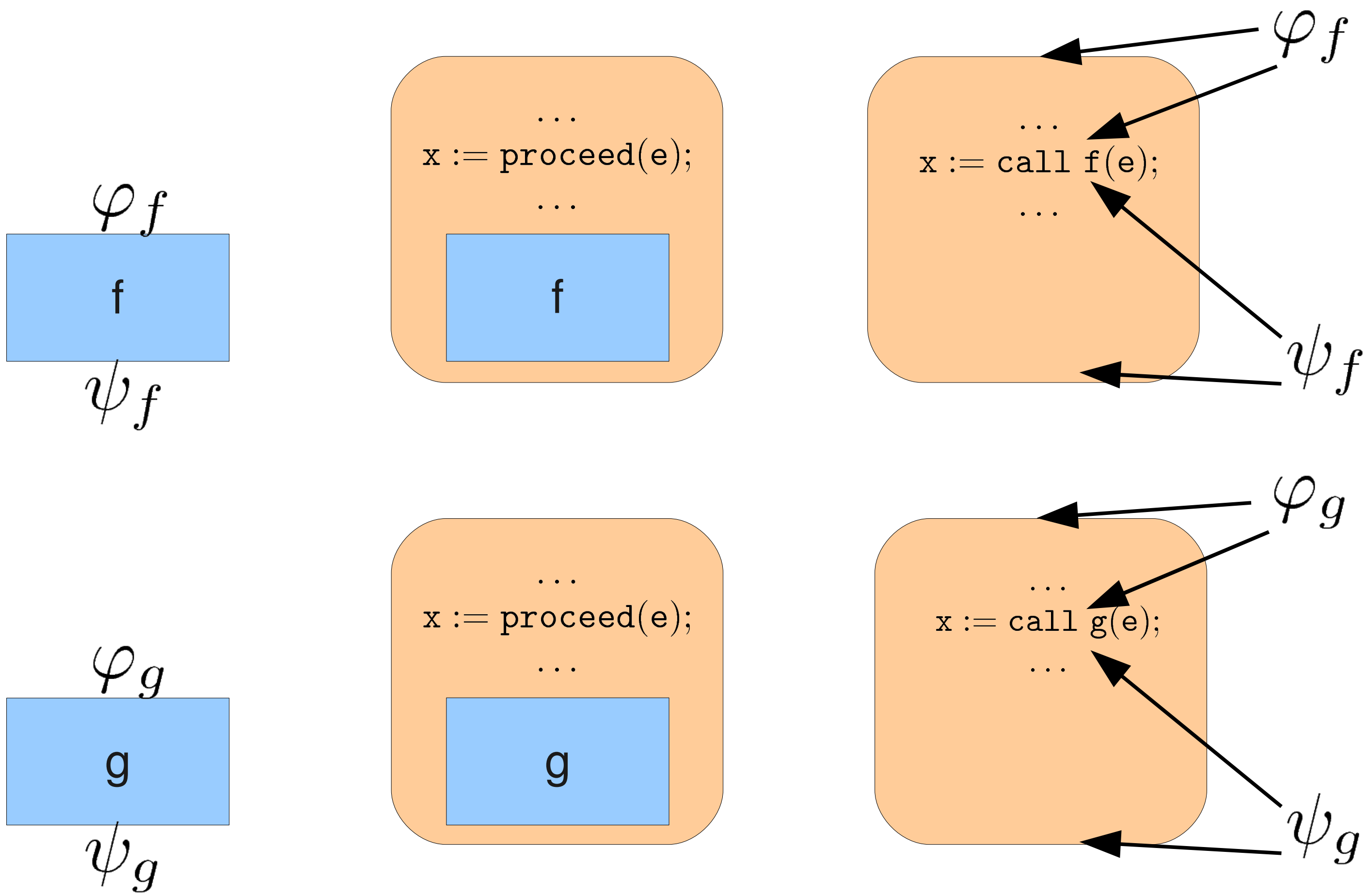
IMPROVING THE VERIFICATION POWER



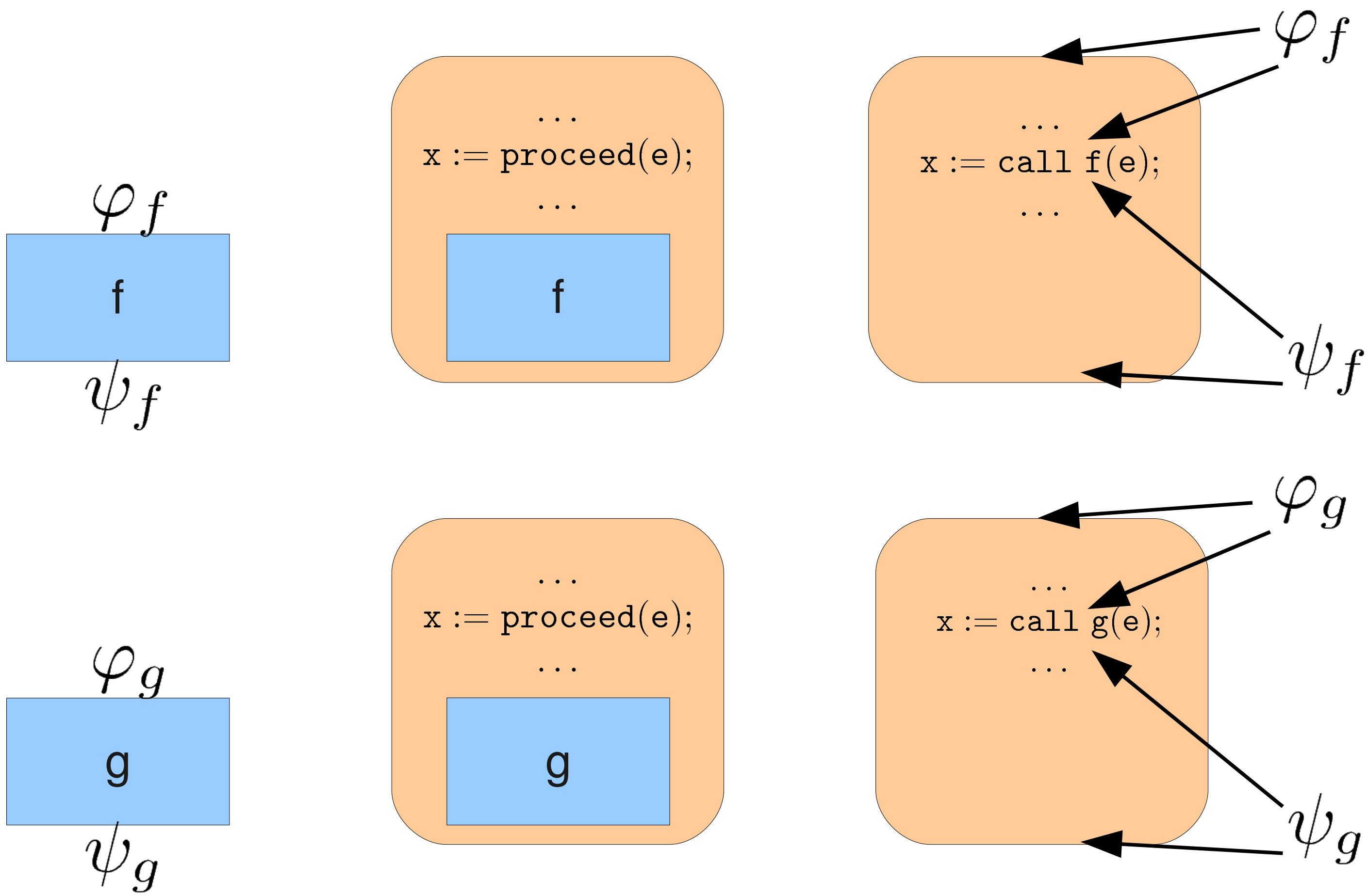
IMPROVING THE VERIFICATION POWER



IMPROVING THE VERIFICATION POWER

Drawback

Multiple advised procedures = multiple verification invariants.



```
...
x := proceed(e);
...
```

```
...
x := call f(e);
...
```

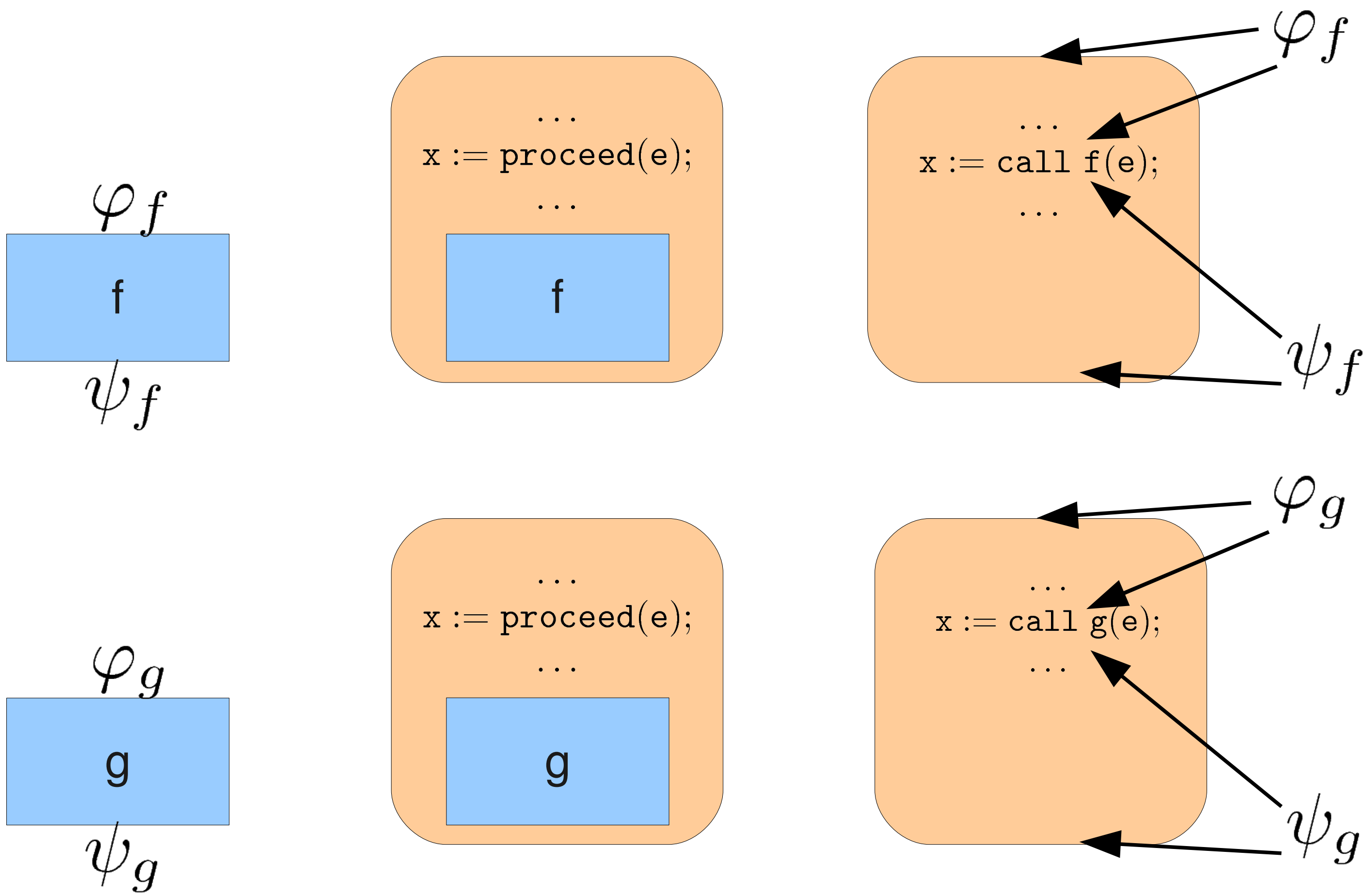
```
...
x := proceed(e);
...
```

```
...
x := call g(e);
...
```

IMPROVING THE VERIFICATION POWER

Drawback

Multiple advised procedures = multiple verification invariants.

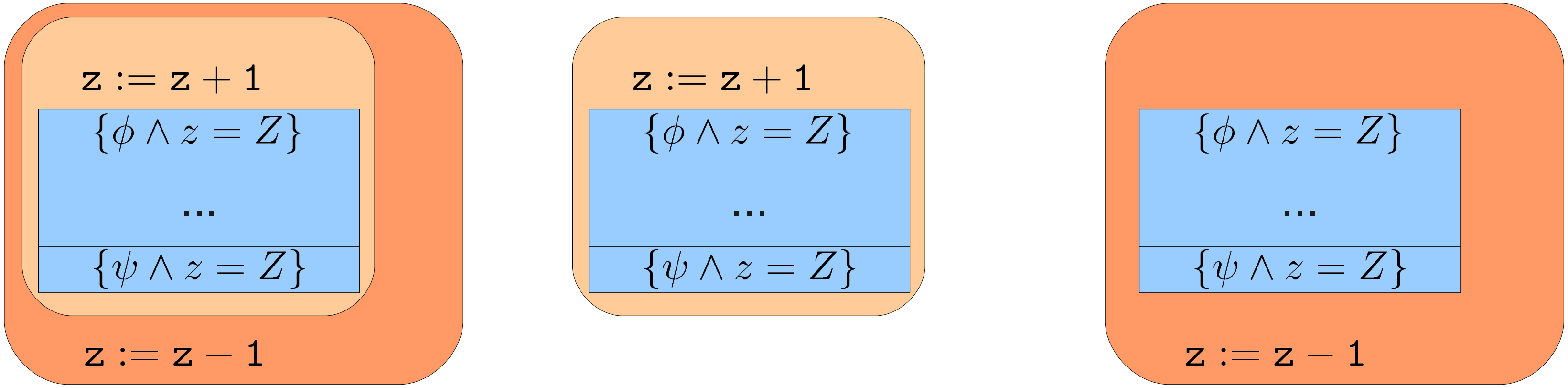


(specification of proceed improves modularity)

IMPROVING THE VERIFICATION POWER

Interference is not always a bad thing.

Some advices are be spec-preserving when combined but not when analyzed in isolation



IMPROVING THE VERIFICATION POWER

$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

$(\Phi_1, \Psi_1, \mathcal{W}_1)$

a_1

$(\Phi_1^p, \Psi_1^p, \mathcal{W}_1^p)$

$(\Phi_2, \Psi_2, \mathcal{W}_2)$

a_2

$(\Phi_2^p, \Psi_2^p, \mathcal{W}_2^p)$

...

$(\Phi_n, \Psi_n, \mathcal{W}_n)$

a_n

$(\Phi_n^p, \Psi_n^p, \mathcal{W}_n^p)$

IMPROVING THE VERIFICATION POWER

$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

$(\Phi_1, \Psi_1, \mathcal{W}_1)$

a_1

$(\Phi_1^p, \Psi_1^p, \mathcal{W}_1^p)$

$(\Phi_2, \Psi_2, \mathcal{W}_2)$

a_2

$(\Phi_2^p, \Psi_2^p, \mathcal{W}_2^p)$

...

$(\Phi_n, \Psi_n, \mathcal{W}_n)$

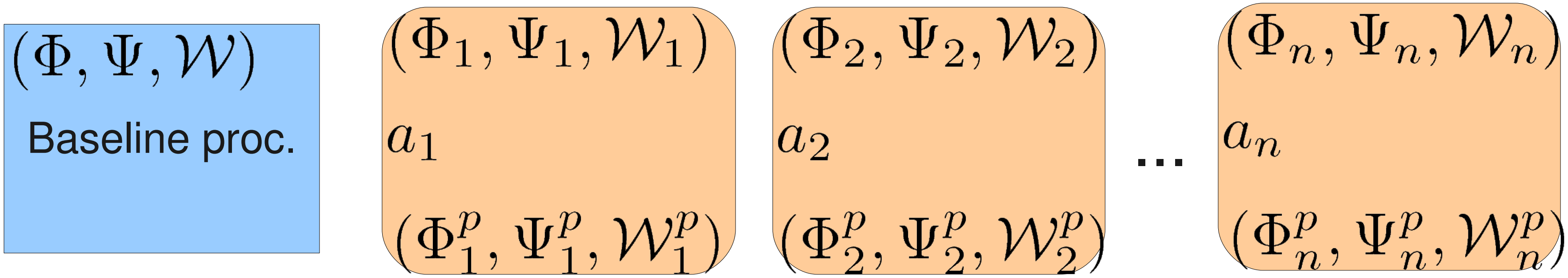
a_n

$(\Phi_n^p, \Psi_n^p, \mathcal{W}_n^p)$

$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

IMPROVING THE VERIFICATION POWER



$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

$(\Phi_1, \Psi_1, \mathcal{W}_1)$

a_1

$(\Phi_1^p, \Psi_1^p, \mathcal{W}_1^p)$

$(\Phi_2, \Psi_2, \mathcal{W}_2)$

a_2

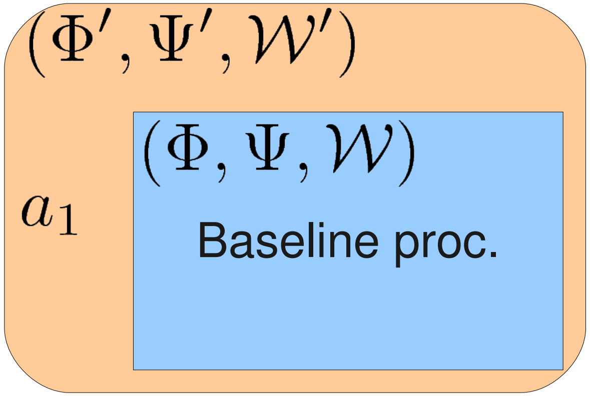
$(\Phi_2^p, \Psi_2^p, \mathcal{W}_2^p)$

...

$(\Phi_n, \Psi_n, \mathcal{W}_n)$

a_n

$(\Phi_n^p, \Psi_n^p, \mathcal{W}_n^p)$



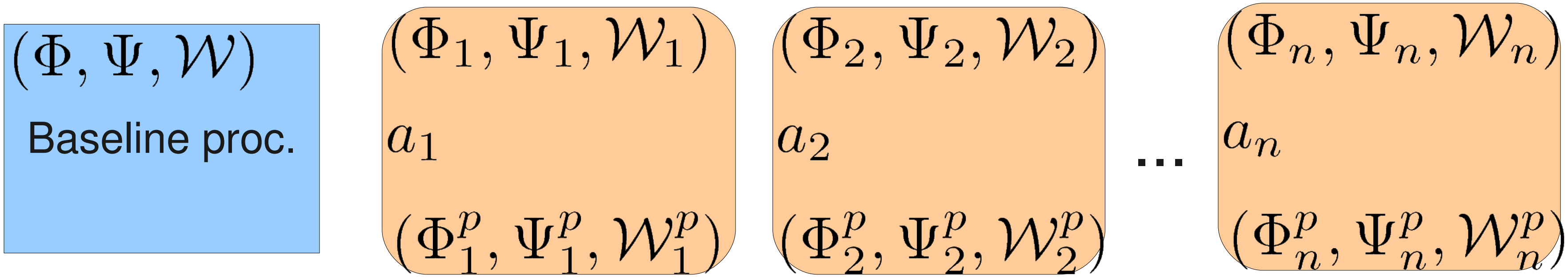
$(\Phi', \Psi', \mathcal{W}')$

a_1

$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

IMPROVING THE VERIFICATION POWER



$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

$(\Phi_1, \Psi_1, \mathcal{W}_1)$

a_1

$(\Phi_1^p, \Psi_1^p, \mathcal{W}_1^p)$

$(\Phi_2, \Psi_2, \mathcal{W}_2)$

a_2

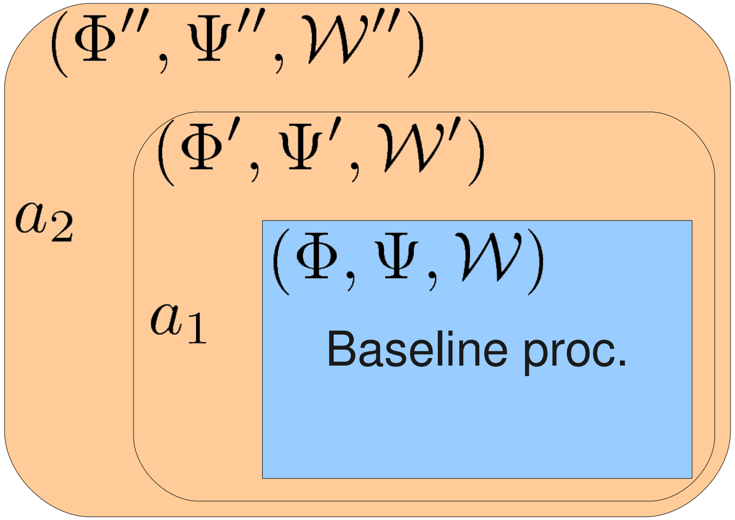
$(\Phi_2^p, \Psi_2^p, \mathcal{W}_2^p)$

...

$(\Phi_n, \Psi_n, \mathcal{W}_n)$

a_n

$(\Phi_n^p, \Psi_n^p, \mathcal{W}_n^p)$



$(\Phi'', \Psi'', \mathcal{W}'')$

a_2

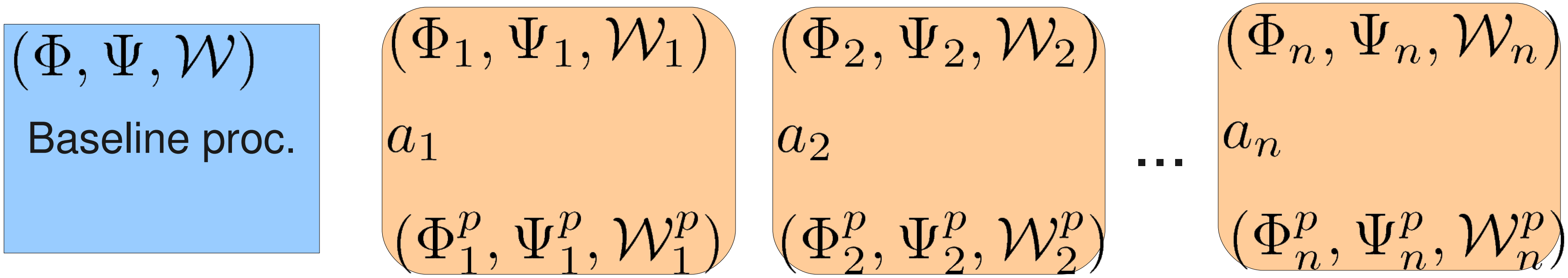
$(\Phi', \Psi', \mathcal{W}')$

a_1

$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

IMPROVING THE VERIFICATION POWER



$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

$(\Phi_1, \Psi_1, \mathcal{W}_1)$

a_1

$(\Phi_1^p, \Psi_1^p, \mathcal{W}_1^p)$

$(\Phi_2, \Psi_2, \mathcal{W}_2)$

a_2

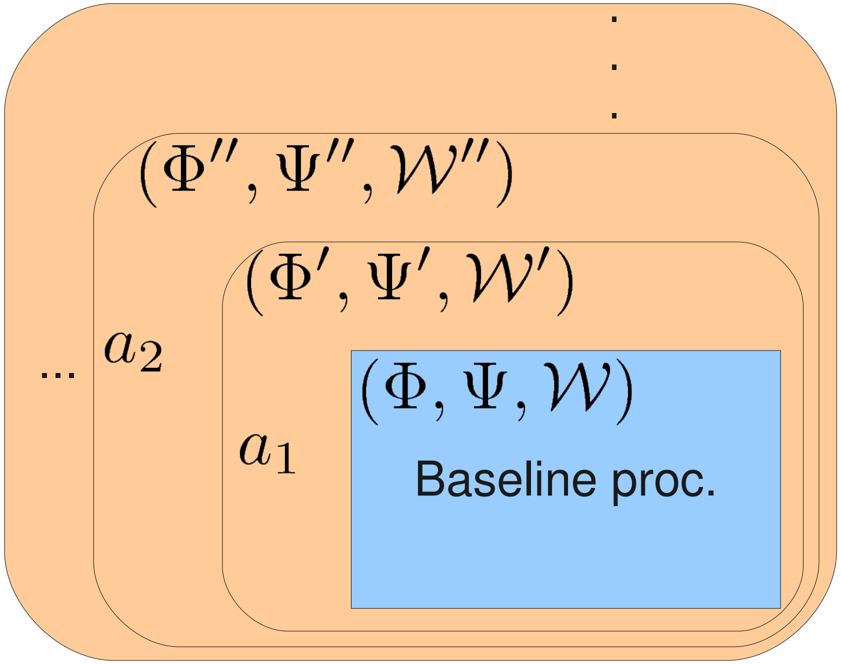
$(\Phi_2^p, \Psi_2^p, \mathcal{W}_2^p)$

...

$(\Phi_n, \Psi_n, \mathcal{W}_n)$

a_n

$(\Phi_n^p, \Psi_n^p, \mathcal{W}_n^p)$



$\vdots$

$(\Phi'', \Psi'', \mathcal{W}'')$

$(\Phi', \Psi', \mathcal{W}')$

...

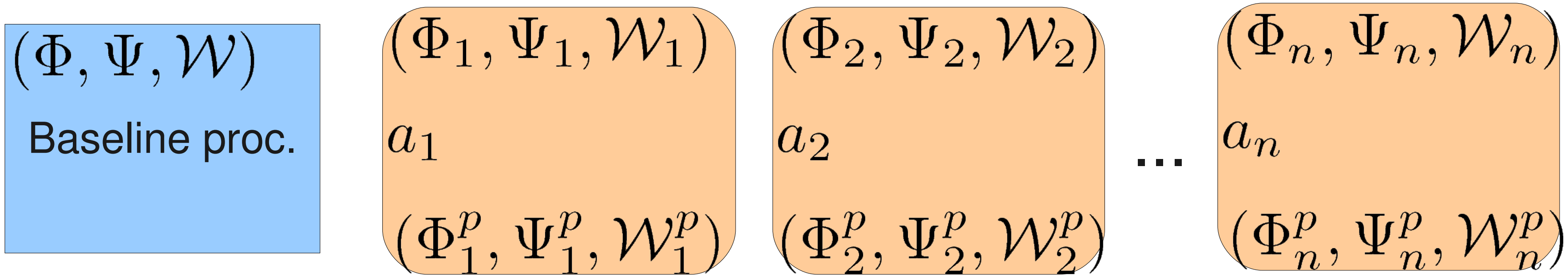
a_2

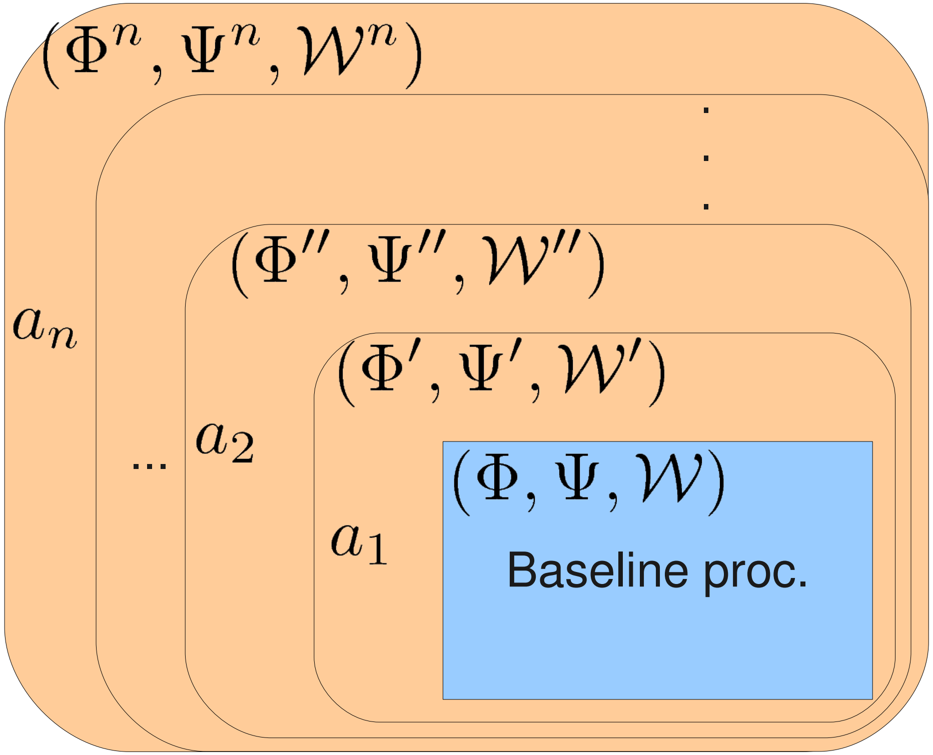
a_1

$(\Phi, \Psi, \mathcal{W})$

Baseline proc.

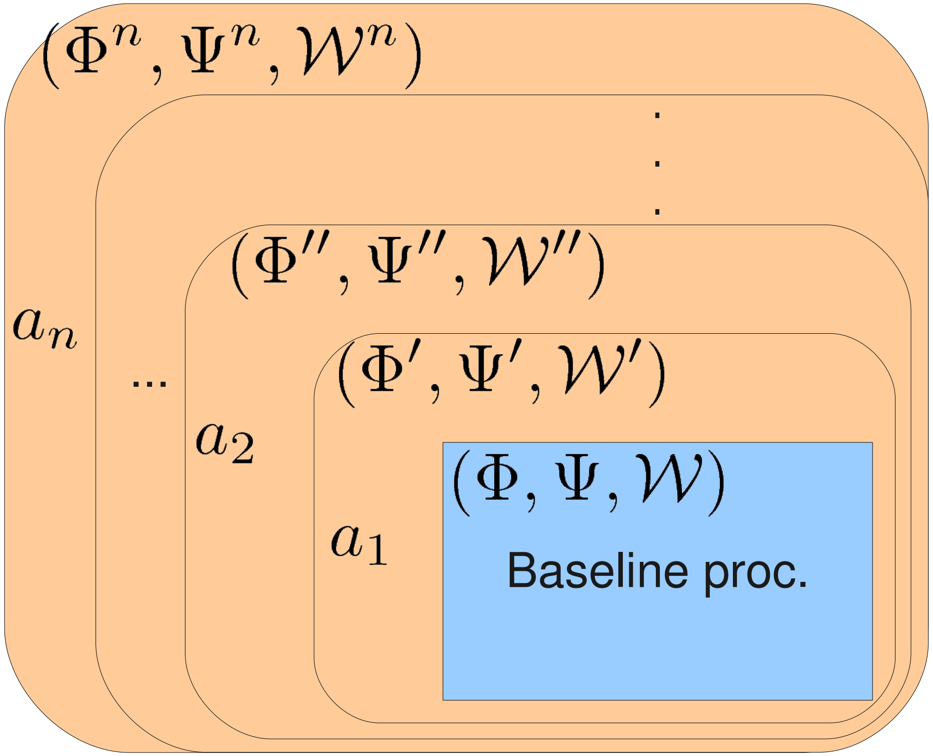
IMPROVING THE VERIFICATION POWER


$(\Phi, \Psi, \mathcal{W})$
Baseline proc.
$(\Phi_1, \Psi_1, \mathcal{W}_1)$
a_1
$(\Phi^p_1, \Psi^p_1, \mathcal{W}^p_1)$
$(\Phi_2, \Psi_2, \mathcal{W}_2)$
a_2
$(\Phi^p_2, \Psi^p_2, \mathcal{W}^p_2)$
...
$(\Phi_n, \Psi_n, \mathcal{W}_n)$
a_n
$(\Phi^p_n, \Psi^p_n, \mathcal{W}^p_n)$


$(\Phi^n, \Psi^n, \mathcal{W}^n)$
$\vdots$
$(\Phi'', \Psi'', \mathcal{W}'')$
$(\Phi', \Psi', \mathcal{W}')$
a_n
...
a_2
a_1
$(\Phi, \Psi, \mathcal{W})$
Baseline proc.

IMPROVING THE VERIFICATION POWER

$$\Phi \Rightarrow \Phi^n \qquad \Psi^n \Rightarrow \Psi \qquad \mathcal{W}^n \cap \mathcal{V} \subseteq \mathcal{W}$$


$(\Phi^n, \Psi^n, \mathcal{W}^n)$
$\vdots$
$(\Phi'', \Psi'', \mathcal{W}'')$
a_n
...
$(\Phi', \Psi', \mathcal{W}')$
a_2
$(\Phi, \Psi, \mathcal{W})$
a_1
Baseline proc.

Specification Refinement instead of Specification Preservation

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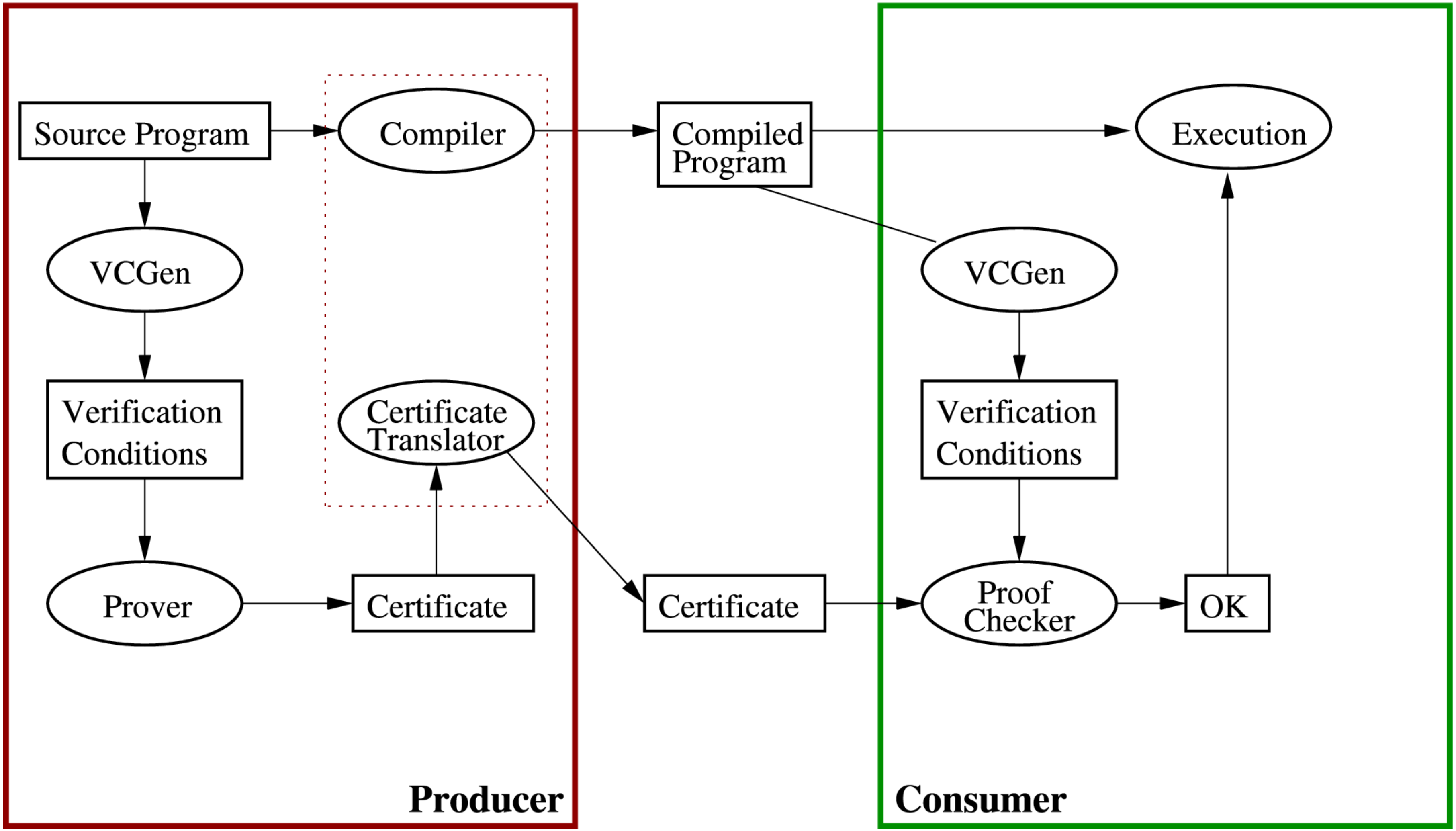
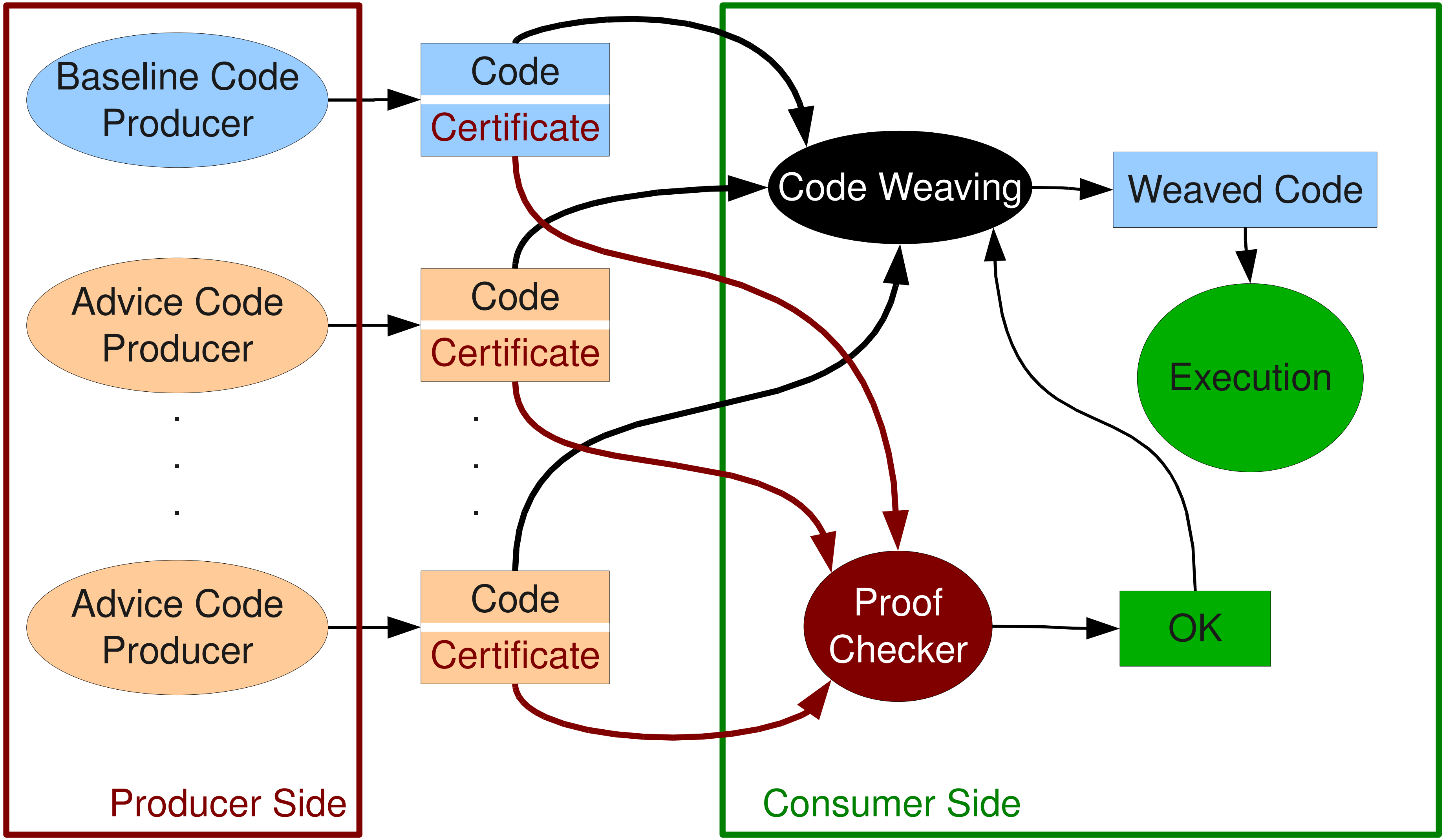


Certificate Translation

Consider the situation:

- Client verification and execution environment not AOP-oriented
- Code generated by multiple producers is weaved before execution



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•Client verification and execution environment not AOP-oriented

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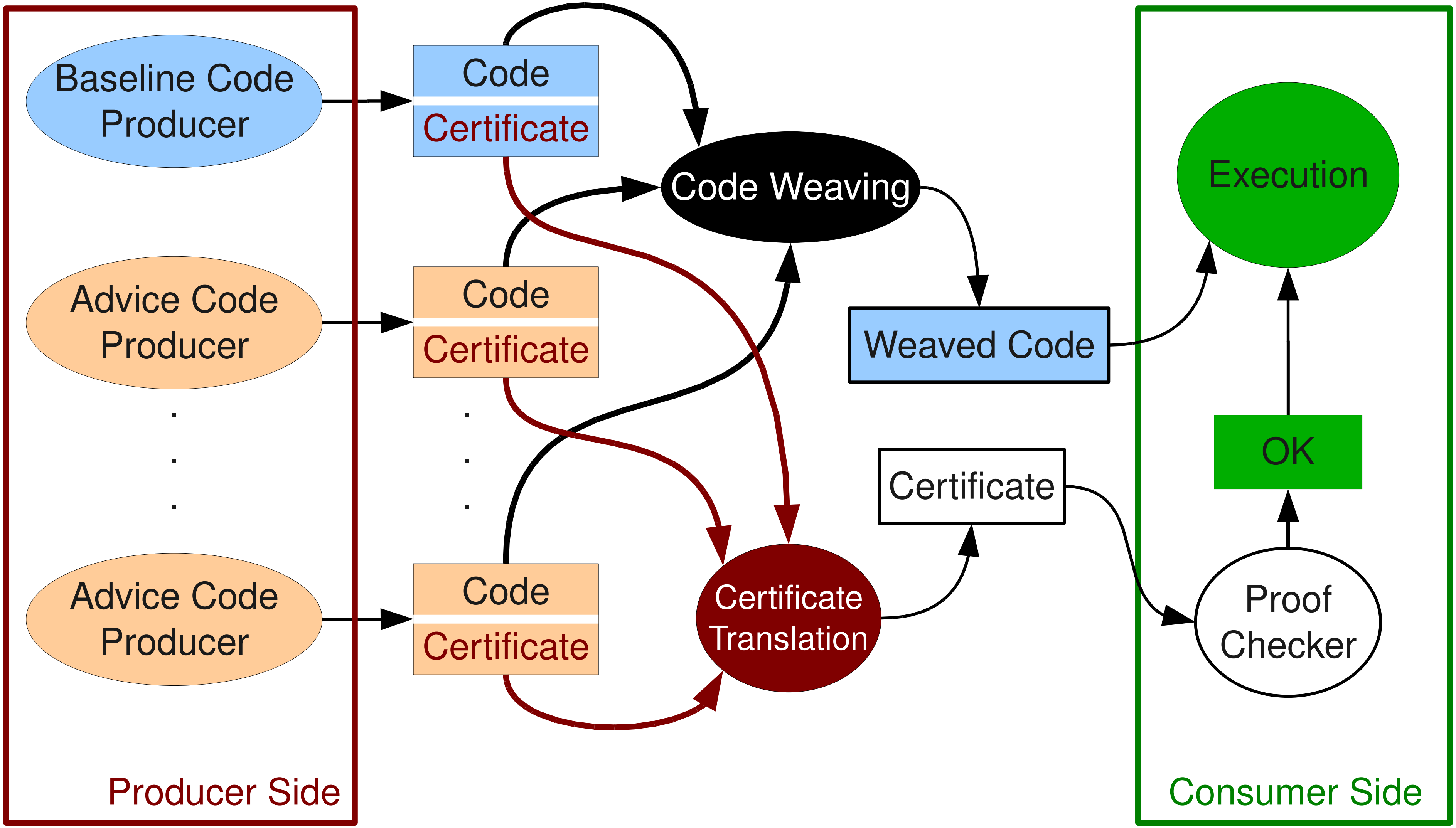

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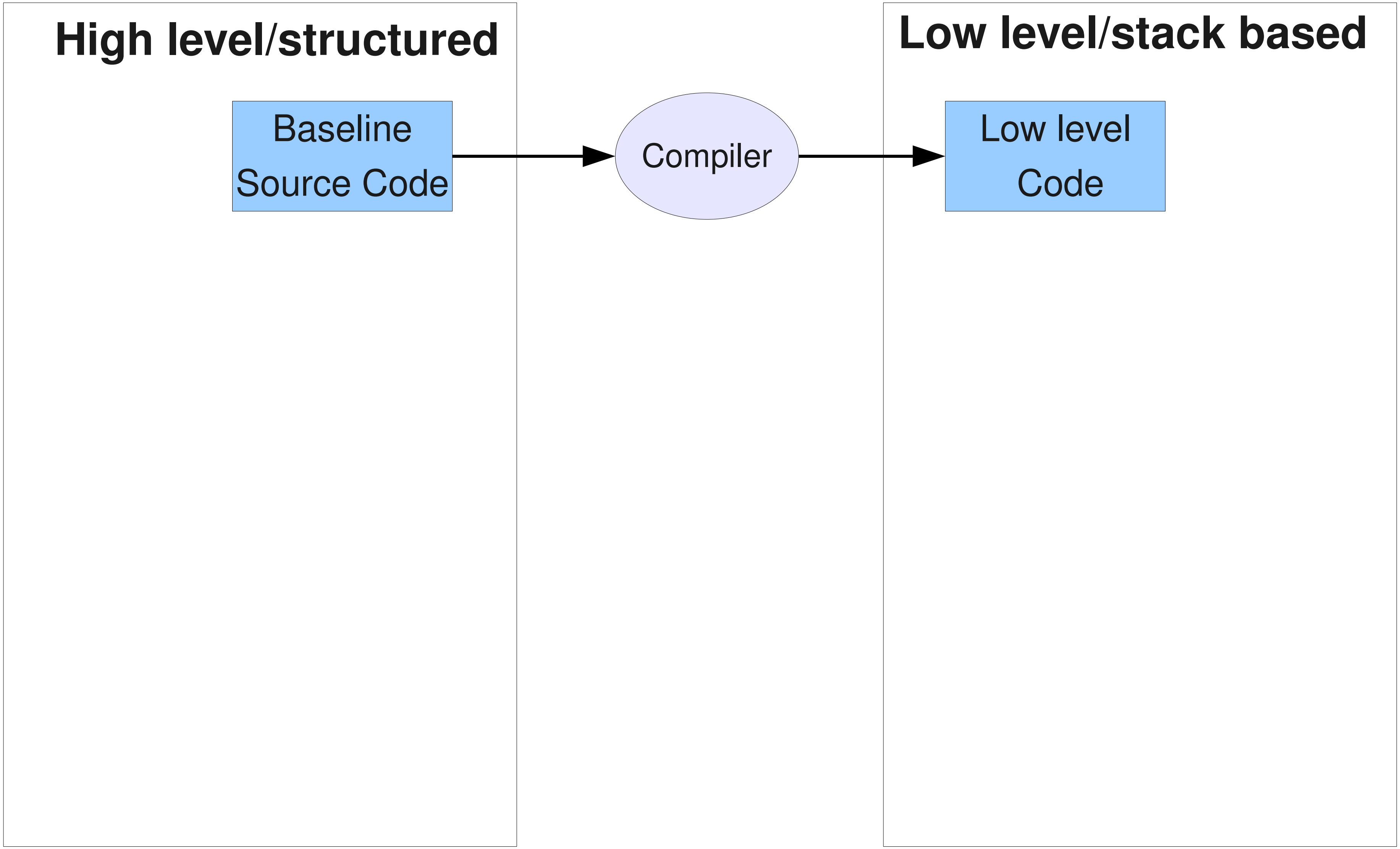

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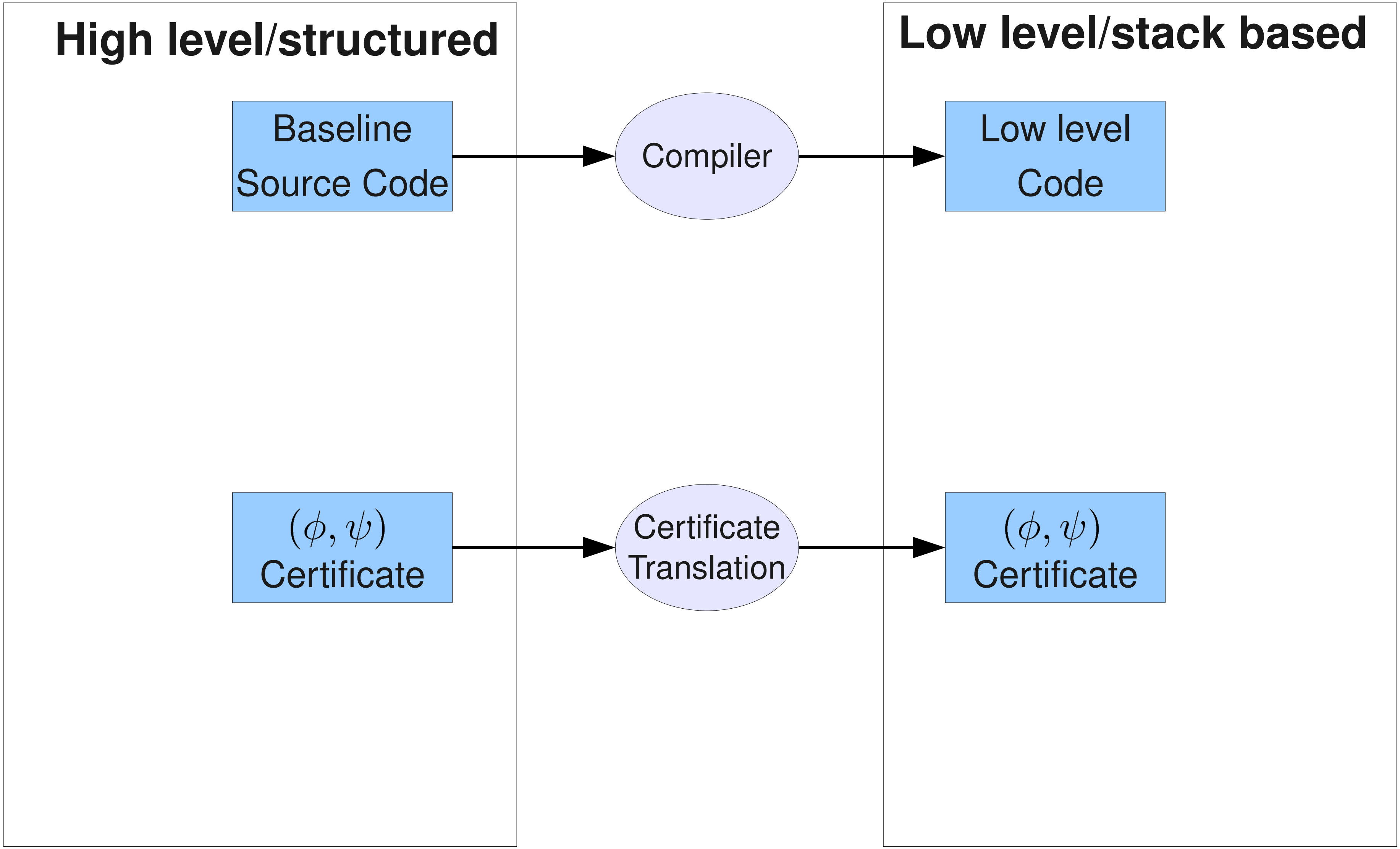

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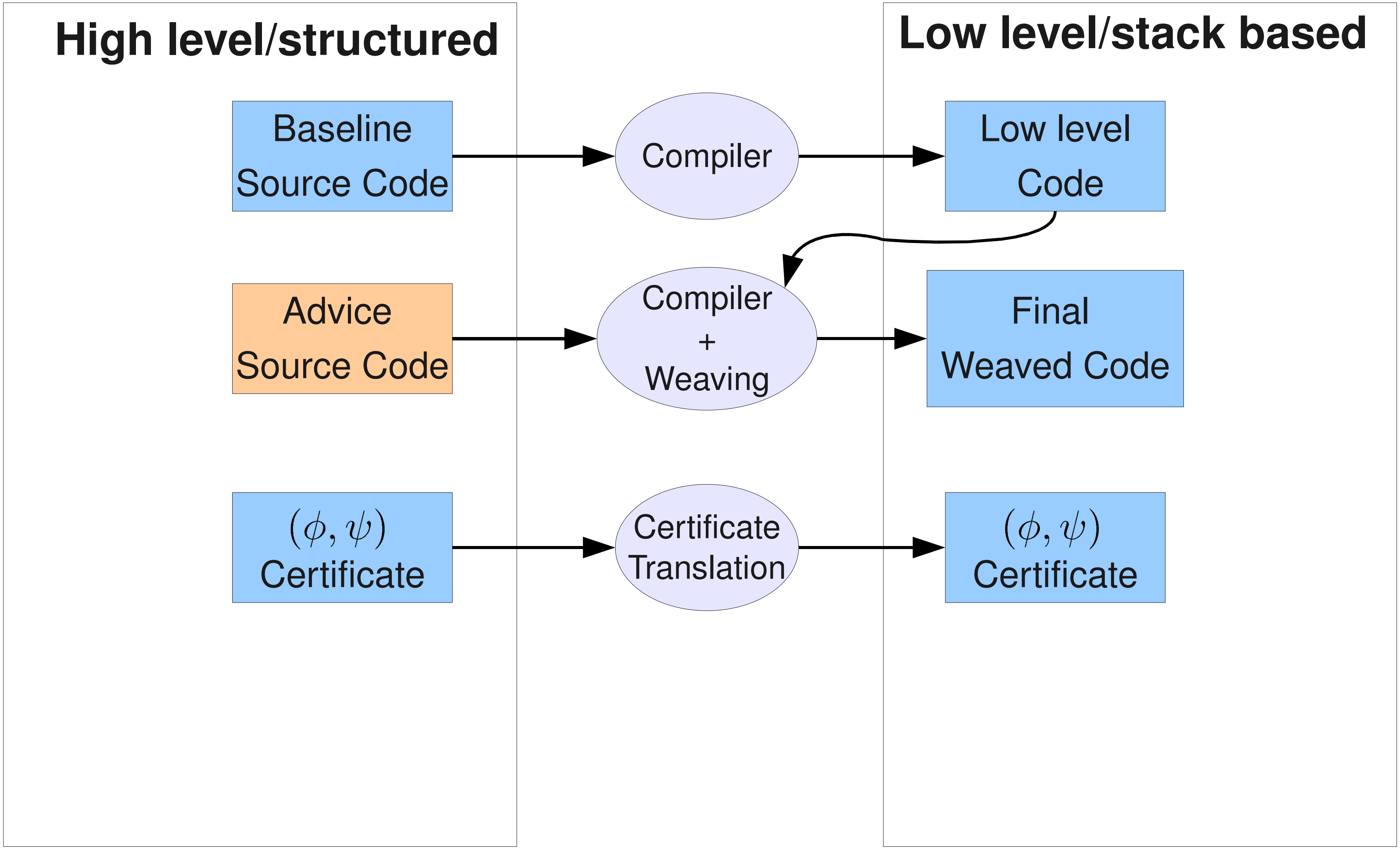
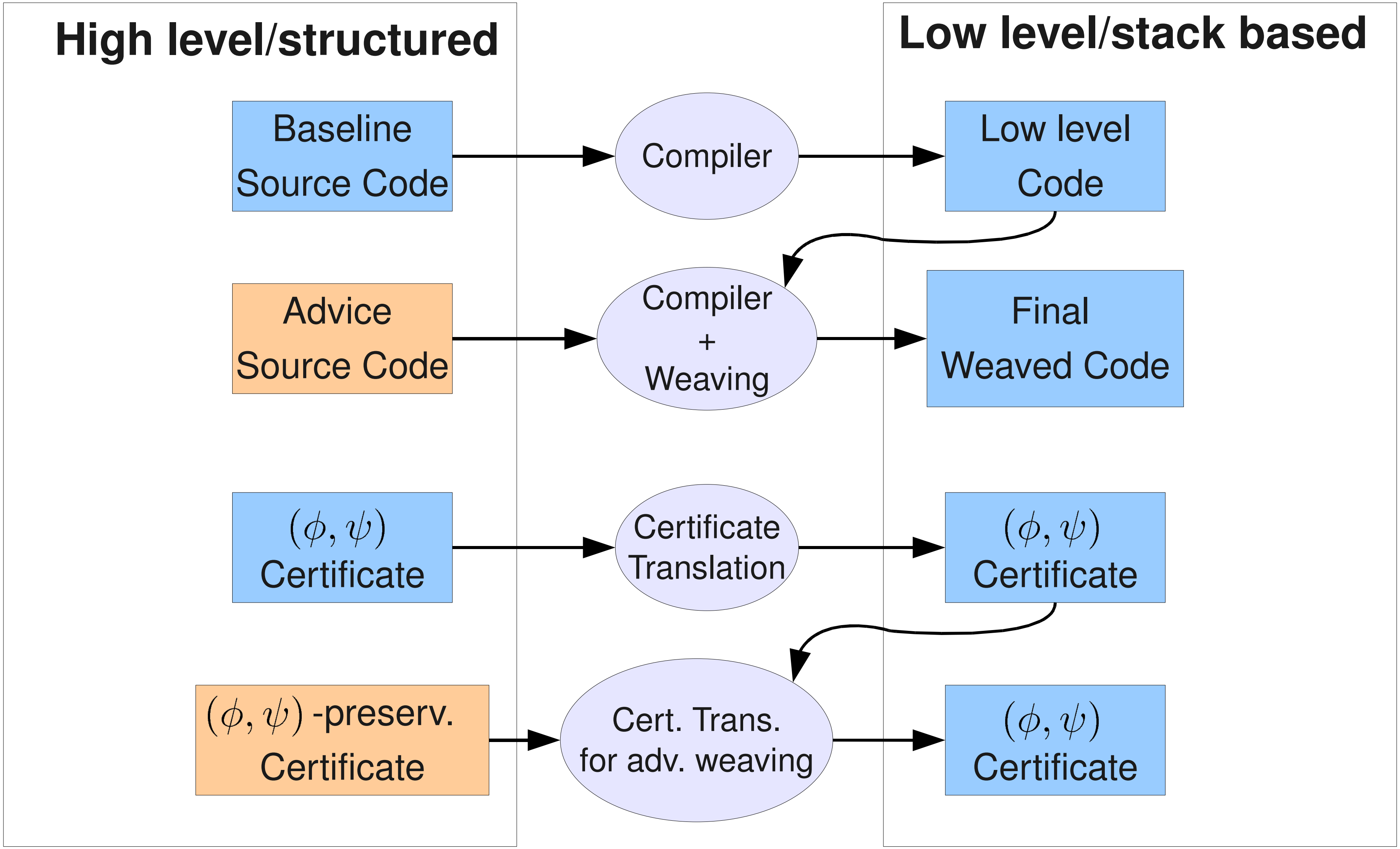


Certificate Translation



Conclusions

- A more flexible notion of non-interfering advices
- Stronger non-interference analyses reduce proof obligations
- Certificate translation targetting a typical backend