Language Composition
MMNet 2015


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2013-07-15

Roadmap

- Language composition background.
- Challenges.
- Our approach.
- Concrete Example: PHP + Python.

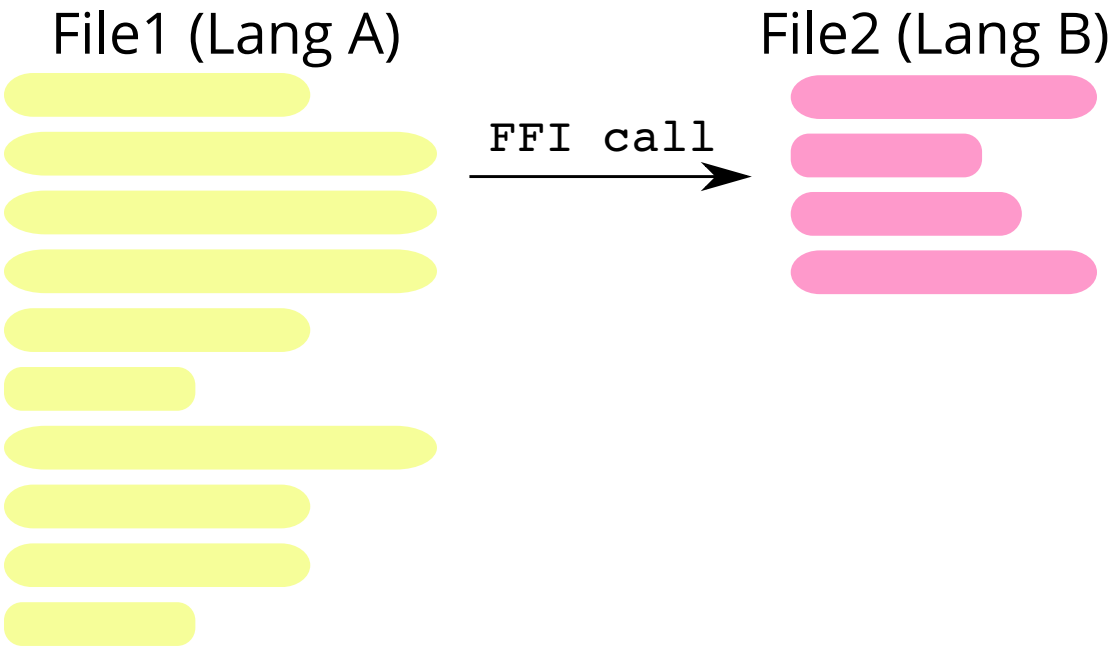
Language Composition

“The ability to write a computer program in a mix of programming languages.”

Why Compose Languages?

- Parts of a program are expressed best with different languages.
  - User Interface
  - String manipulation
  - Statistical analysis
  - Constraint solving
  - . . .
- Performance.
  - Start writing in expressive language X.
  - Port bottlenecks to fast language Y.
- Language migration.
  - Gradual reimplementation.

Most languages have a Foreign Function Interface



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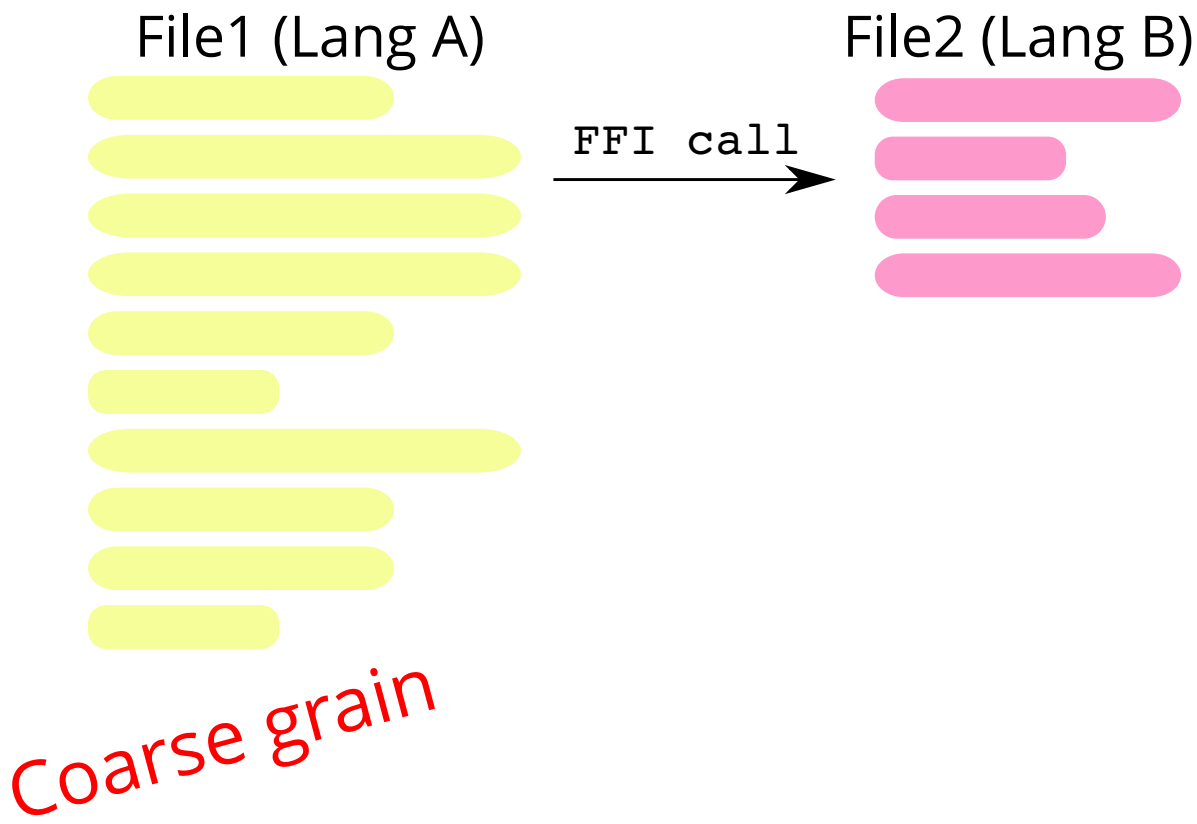

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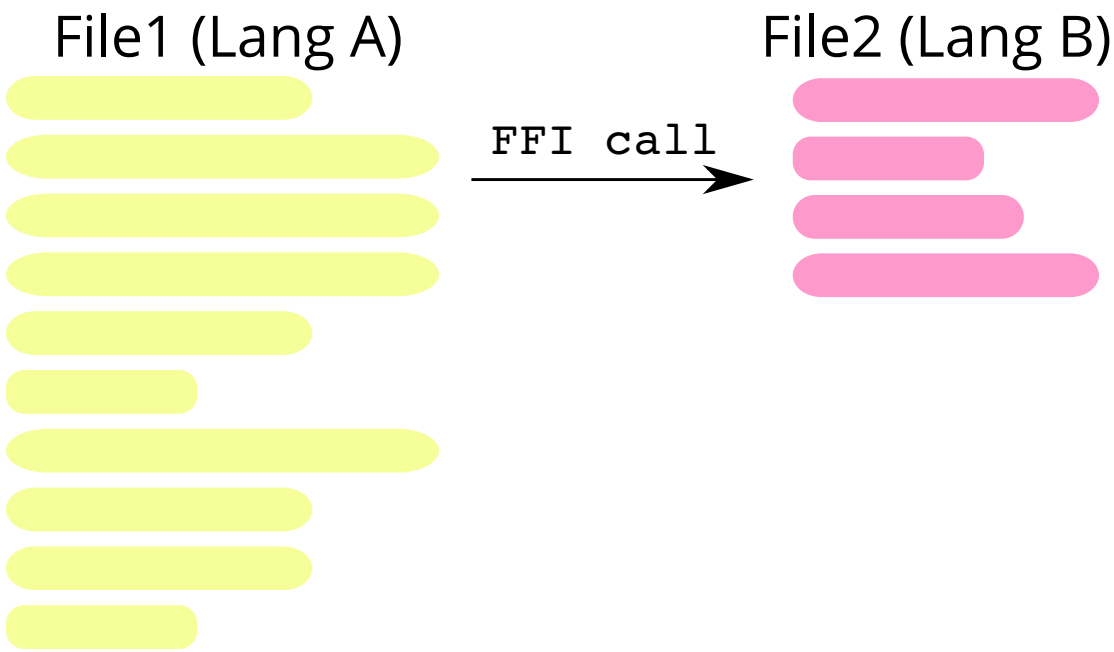
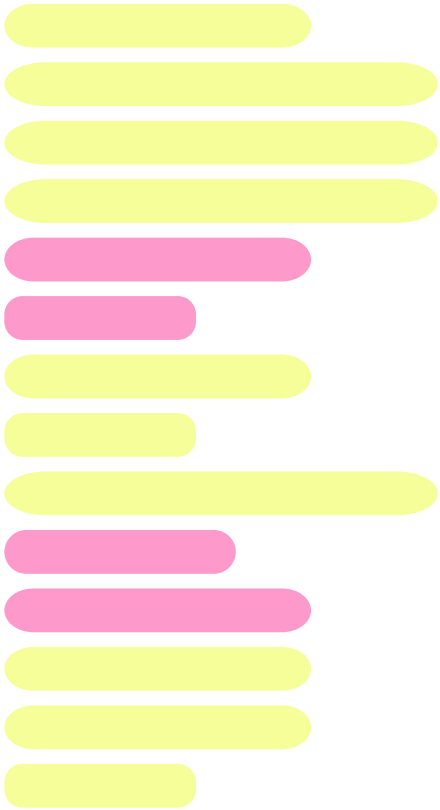


Coarse grain

Limited choice of langs

(second lang is nearly always C)

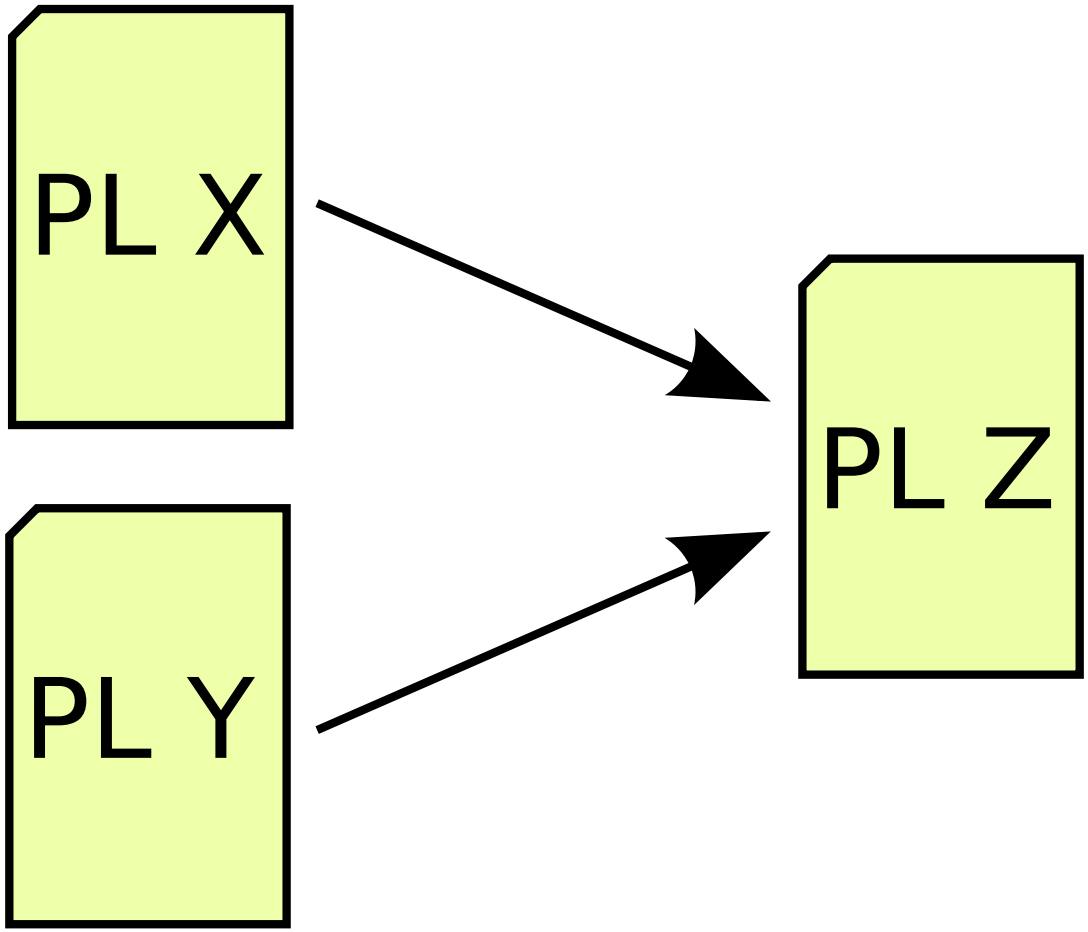
Can we do better?



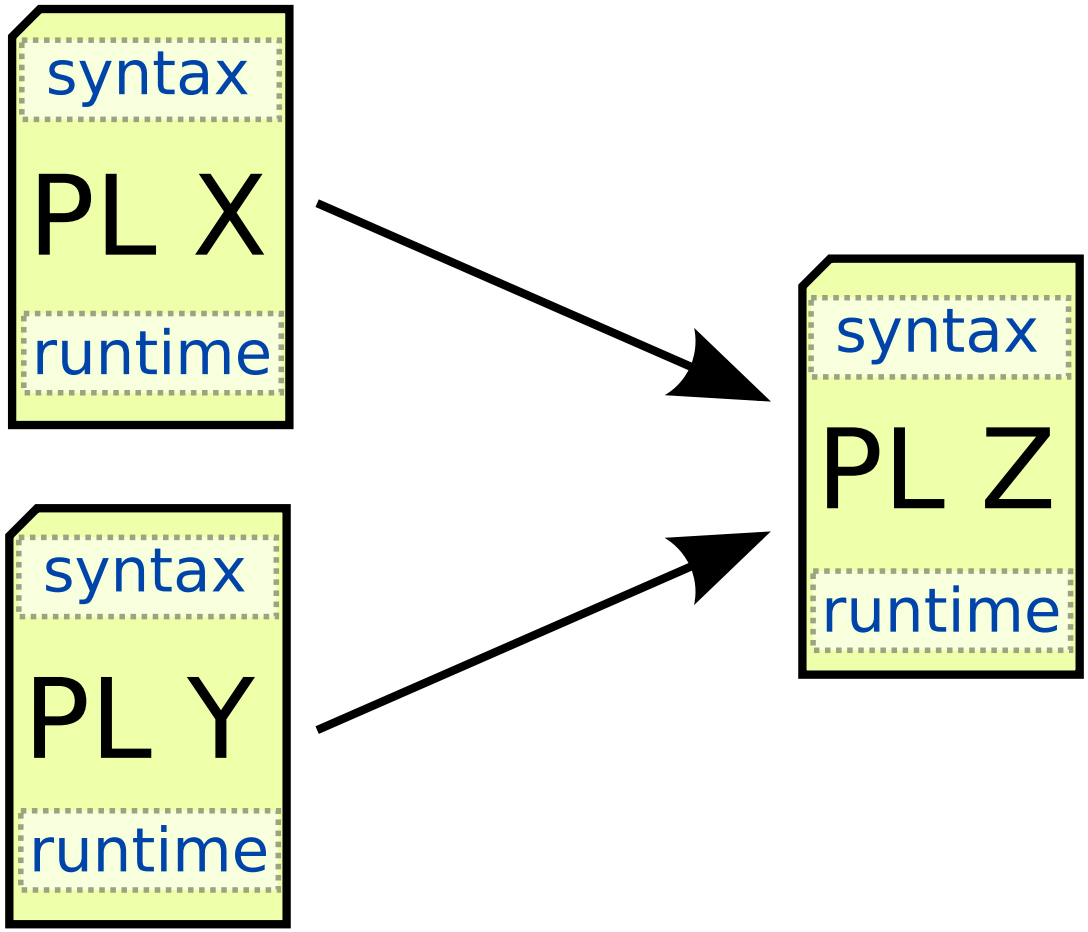
Our Aims:

- Fine-grain composition
  - Composition in the same file
  - Mix {methods, functions, expressions}
  - Integrate scoping
- Arbitrary languages
  - For now, dynamic languages.
- Make the composition fast.

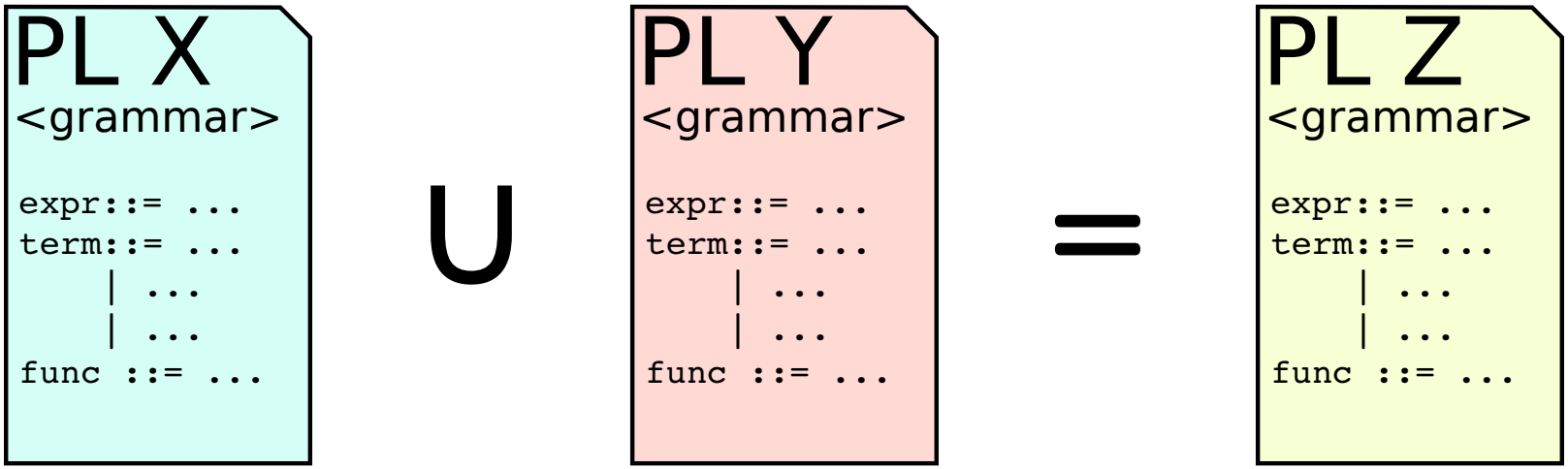
Breaking it Down



Breaking it Down



Composing Syntax

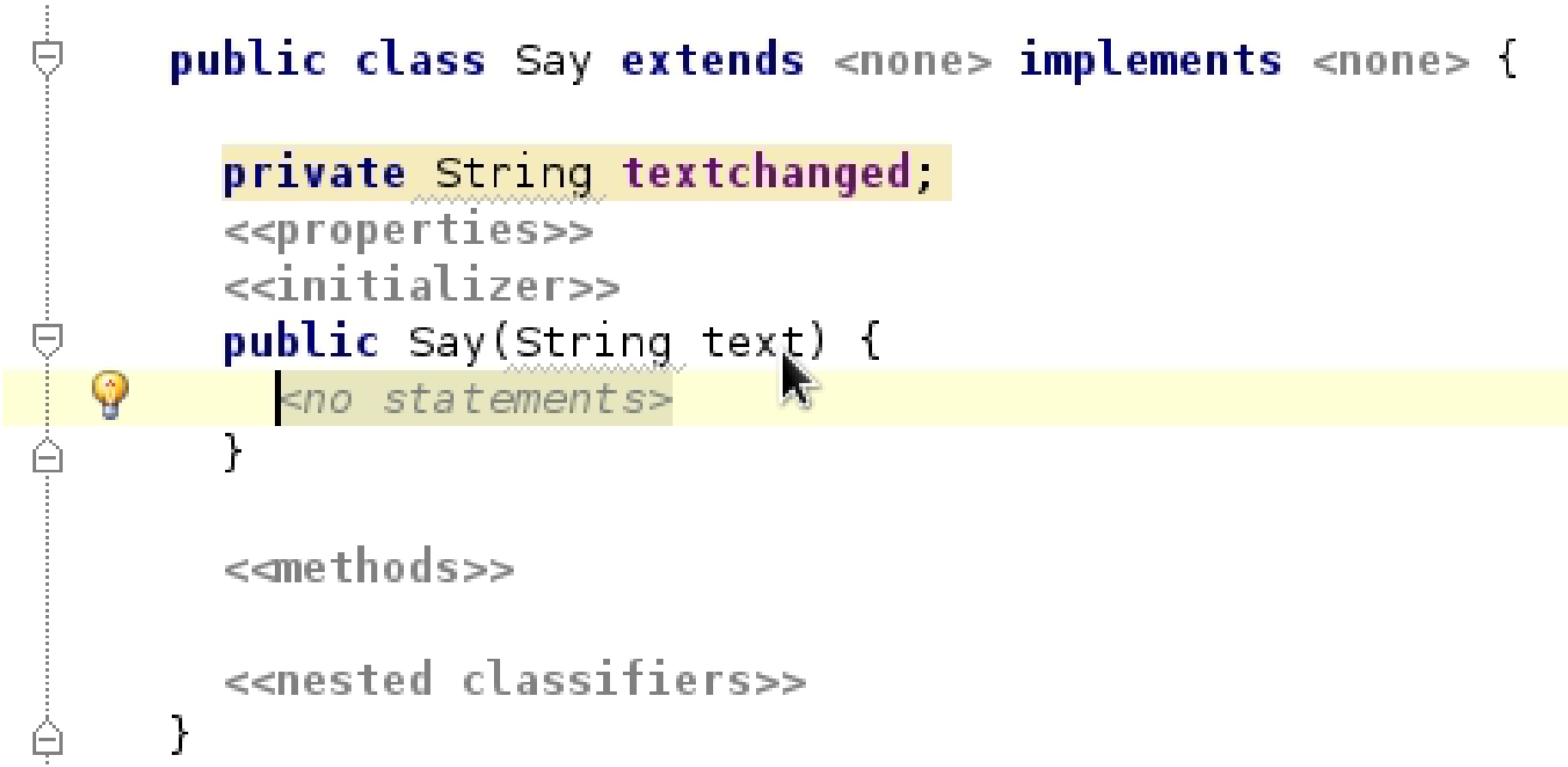


Easy?

Composing Syntax

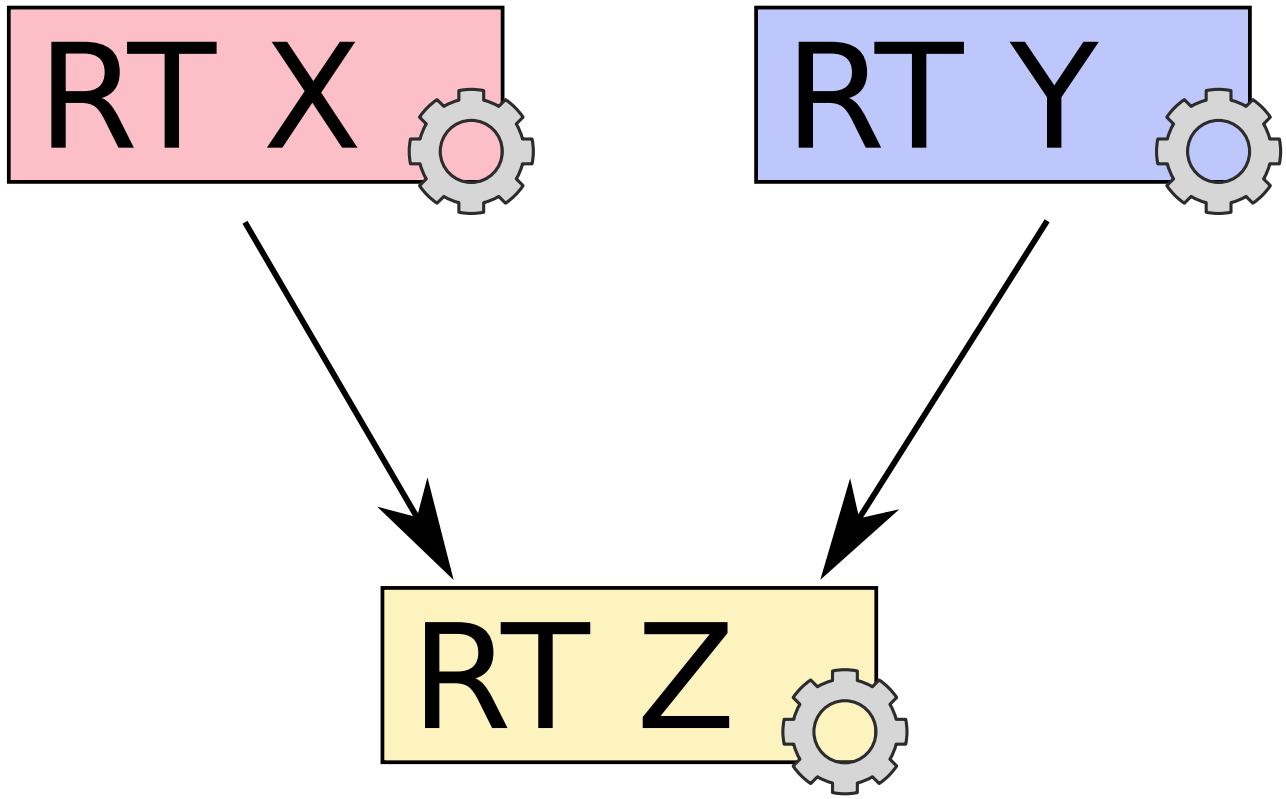
- LR $\rightarrow$ Possibly undefined.
- PEG $\rightarrow$ Shadows.
- GLR $\rightarrow$ Ambiguous.

Syntax Directed Editing



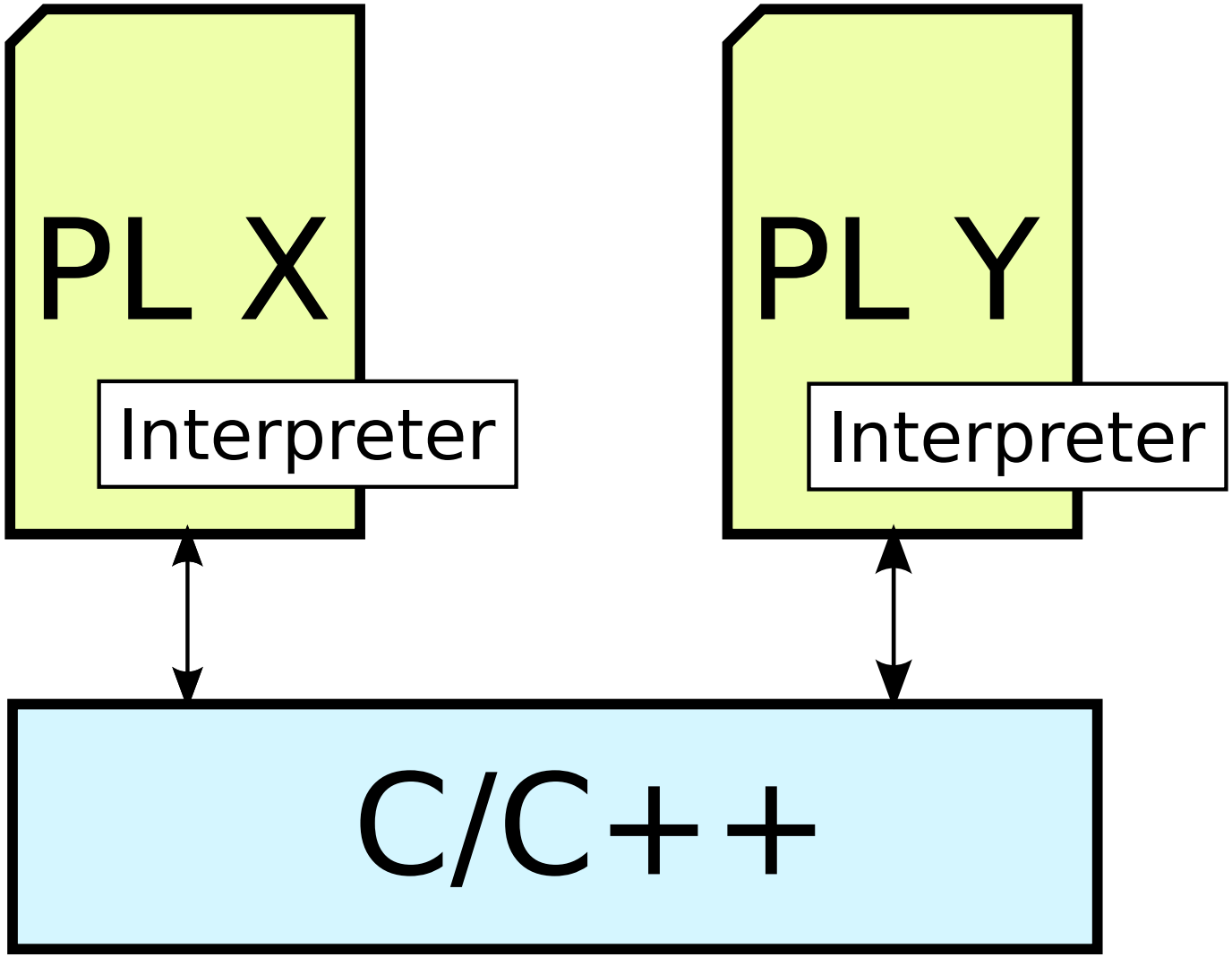
Poor editing experience.

Composing Runtimes

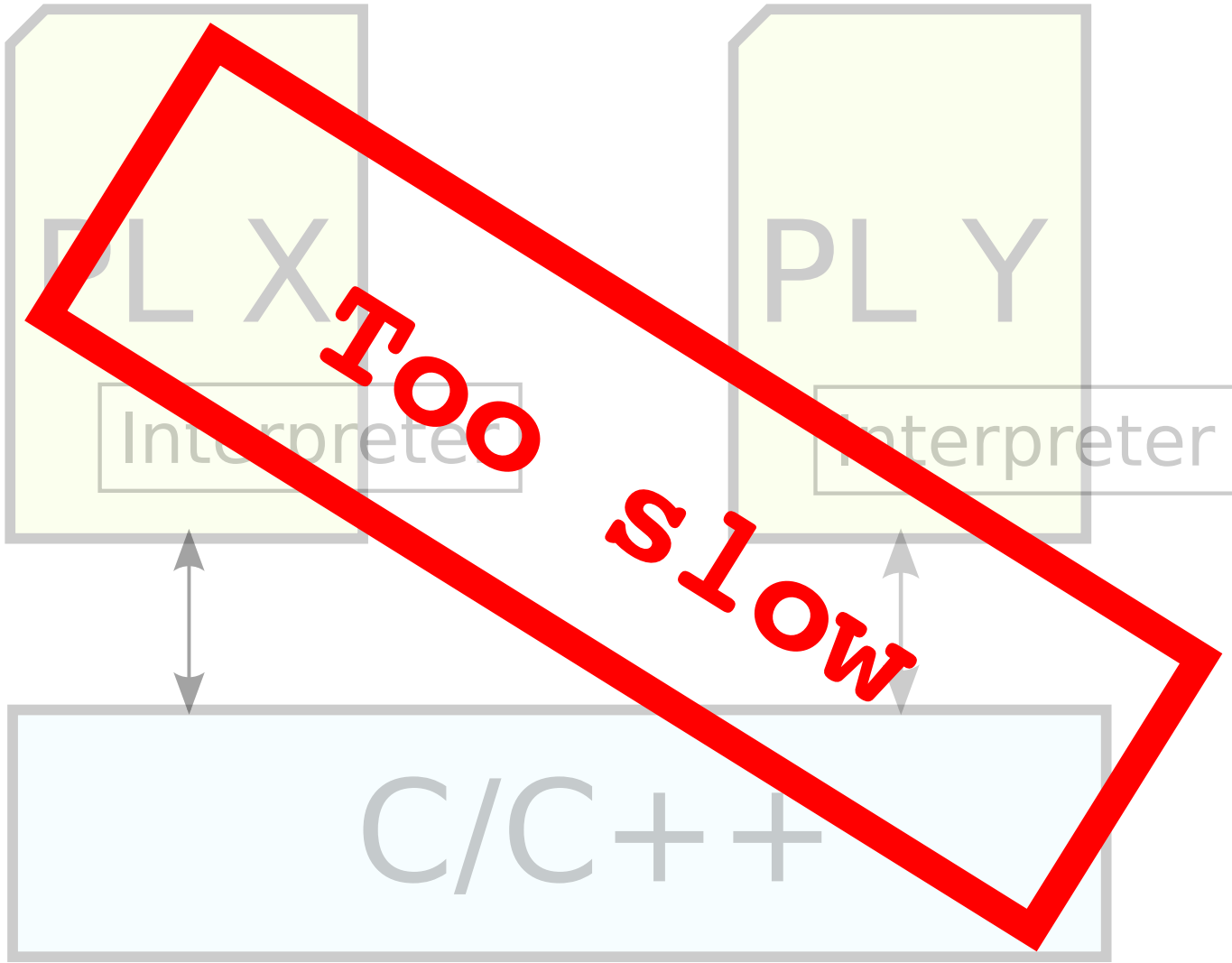


Easy?

Runtime composition



Runtime composition



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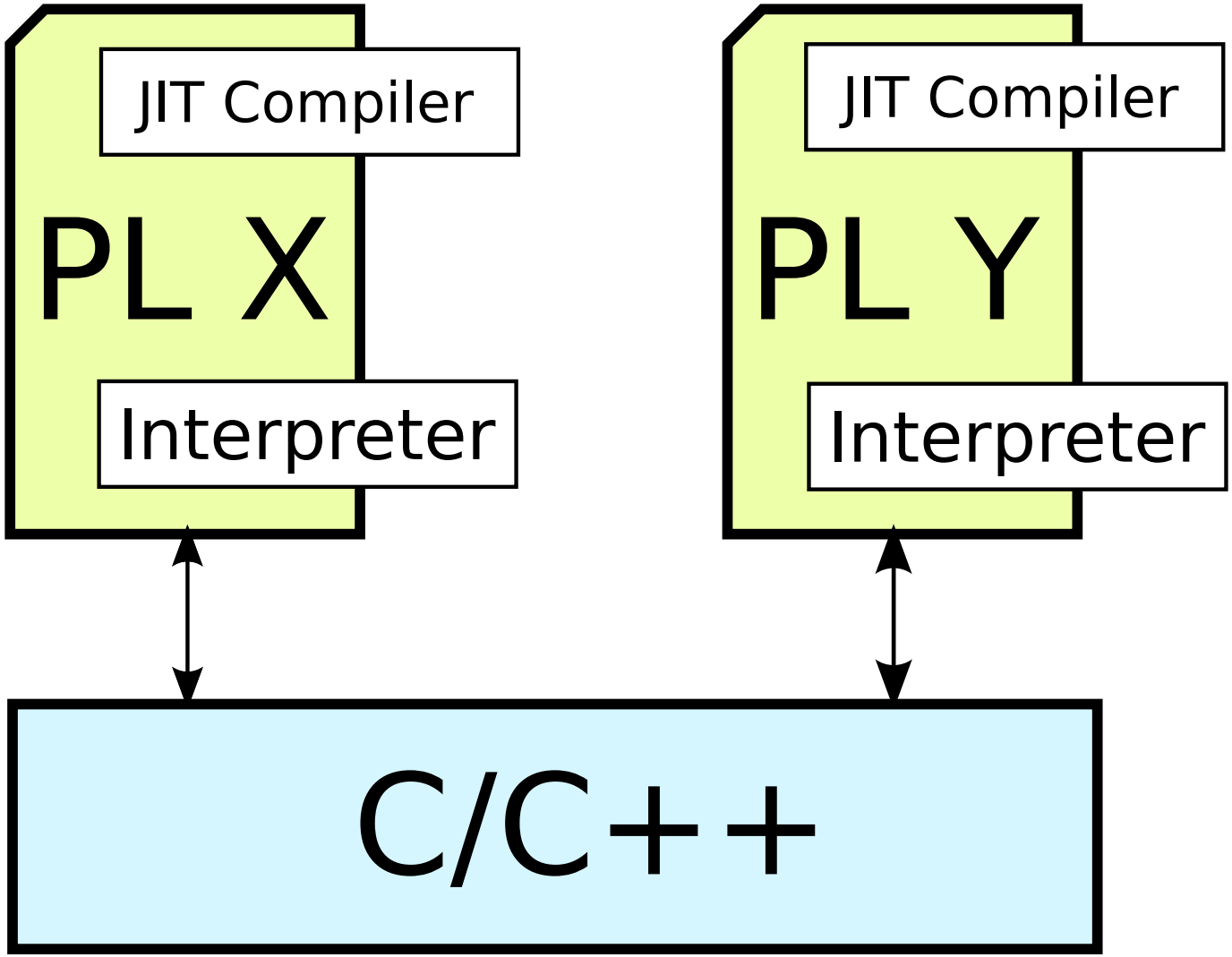
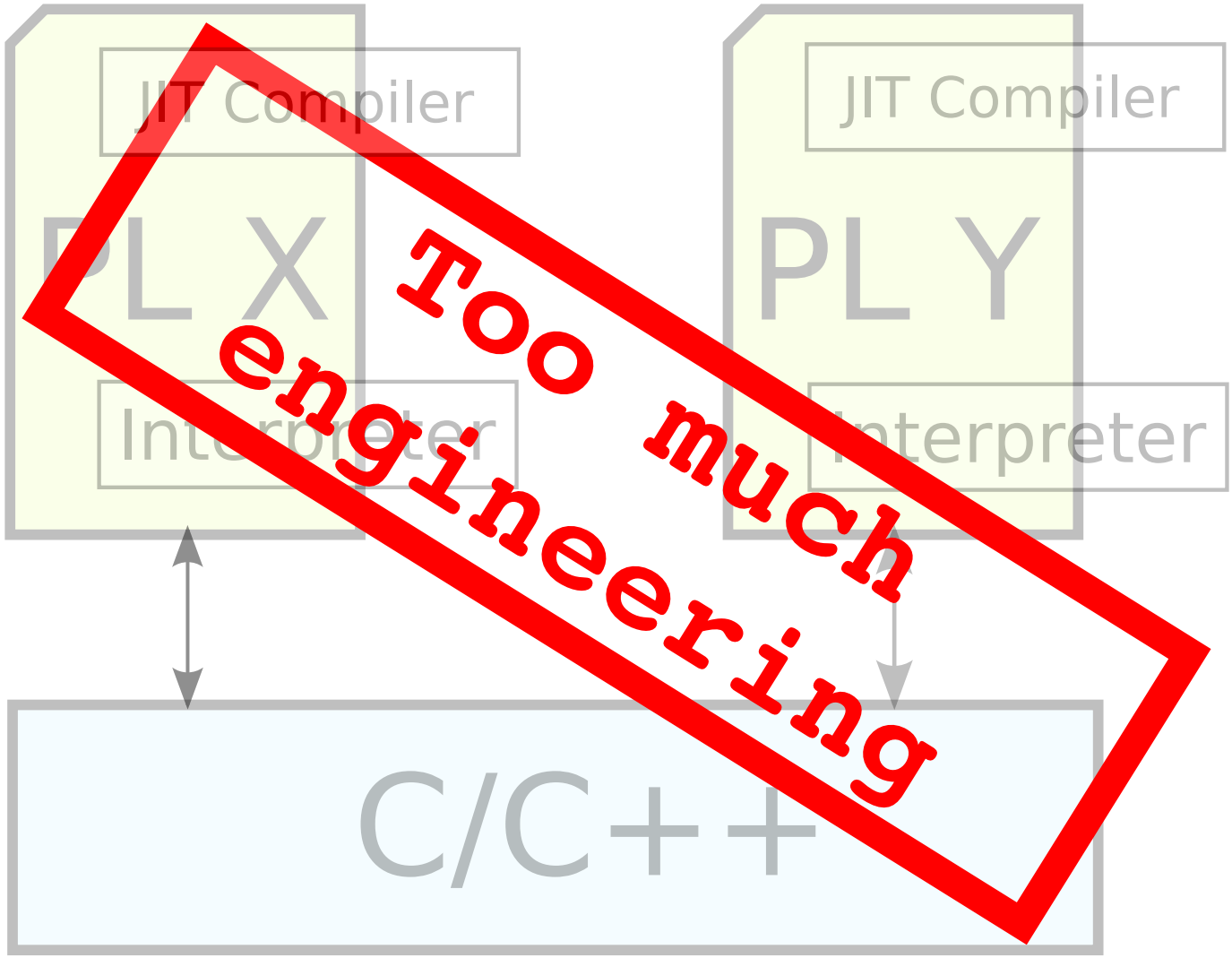


Runtime composition



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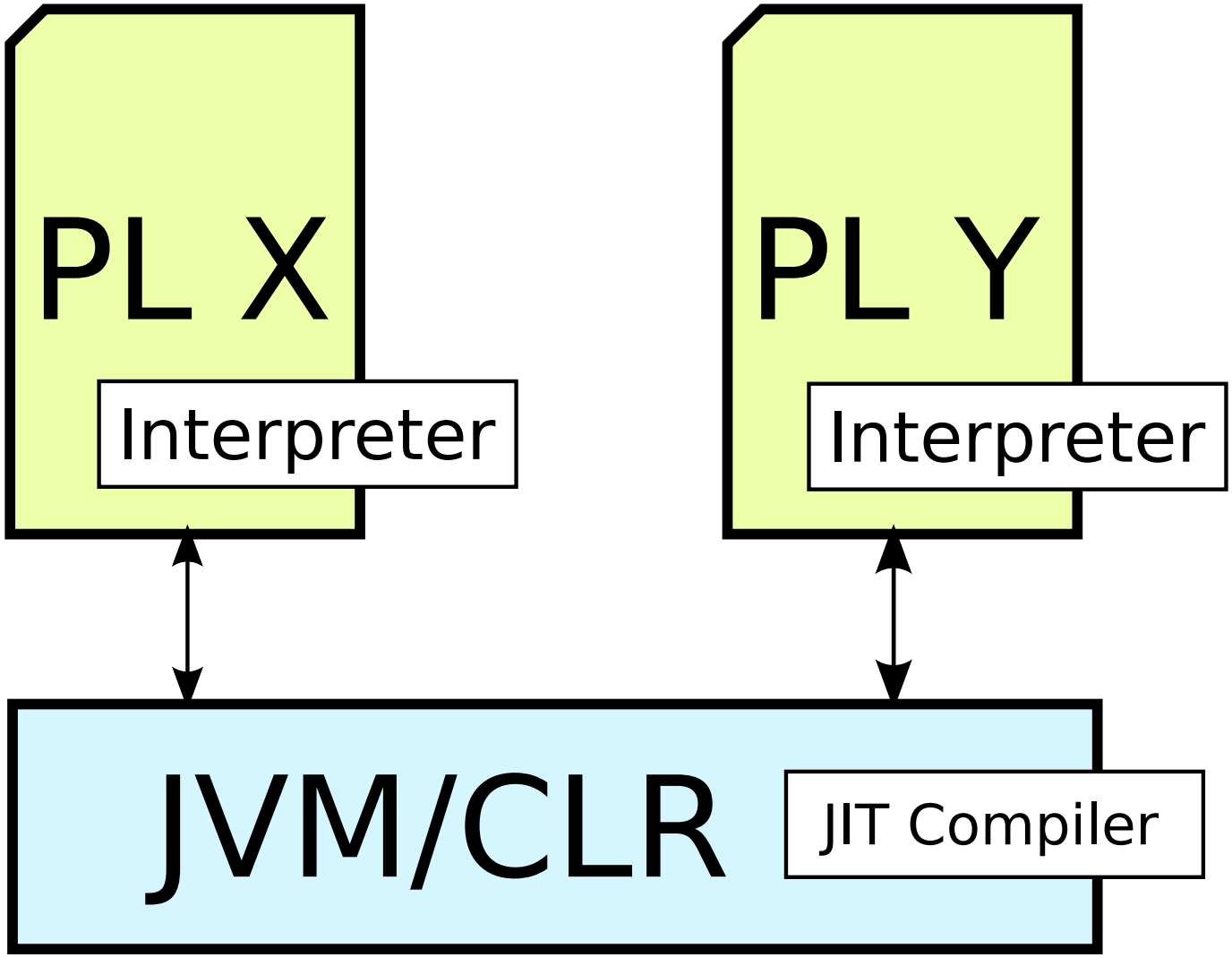

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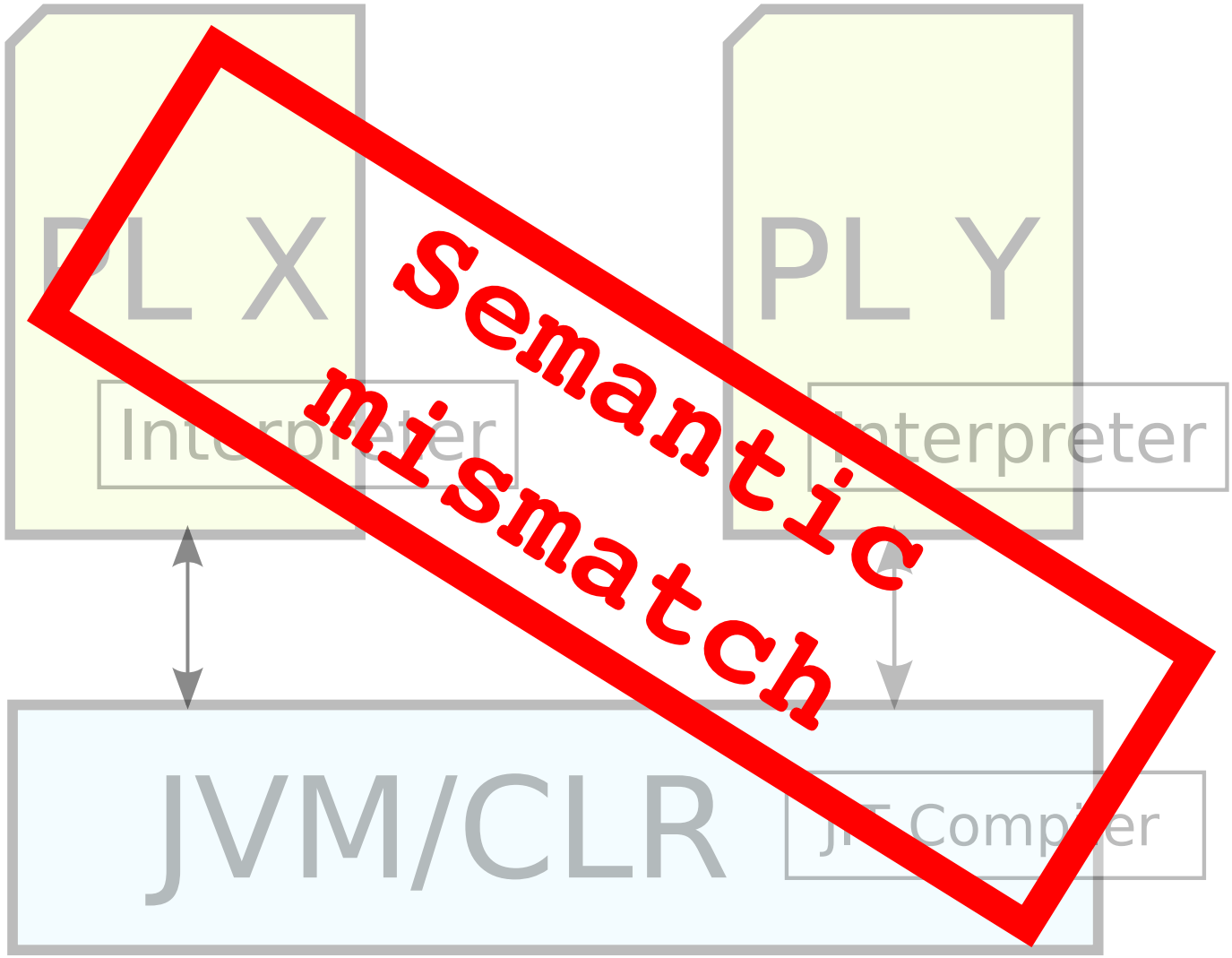

Summary:

We need a practical way of composing syntax and runtimes.

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Language Boxes + Meta-tracing

Language Boxes

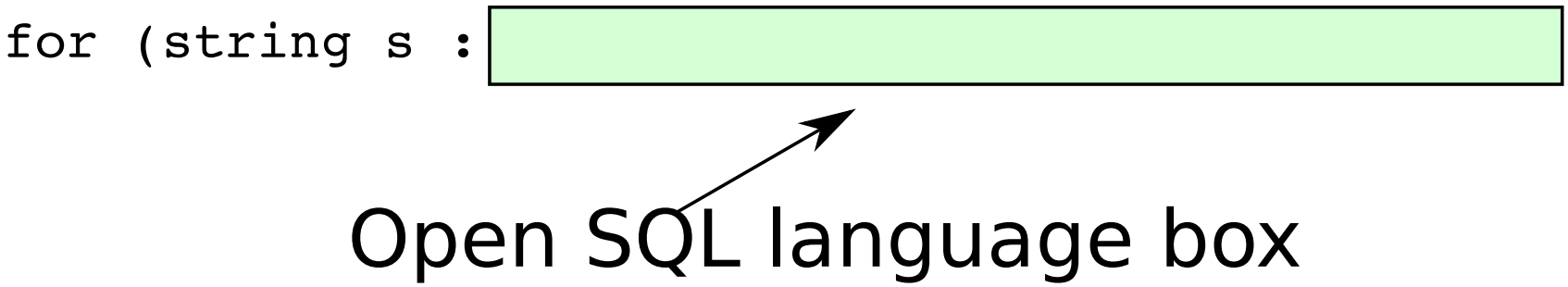
- Borrows ideas from SDE.
- Palatable editing experience.
- Simple and practical way to compose grammars.

Language Boxes: E.g. Java + SQL

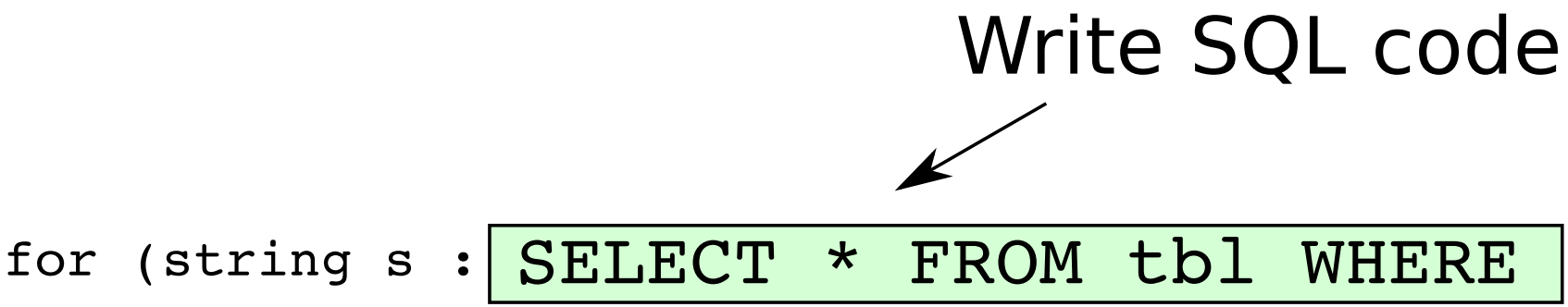
Begin writing Java code

```
for (string s :
```

Language Boxes: E.g. Java + SQL



Language Boxes: E.g. Java + SQL

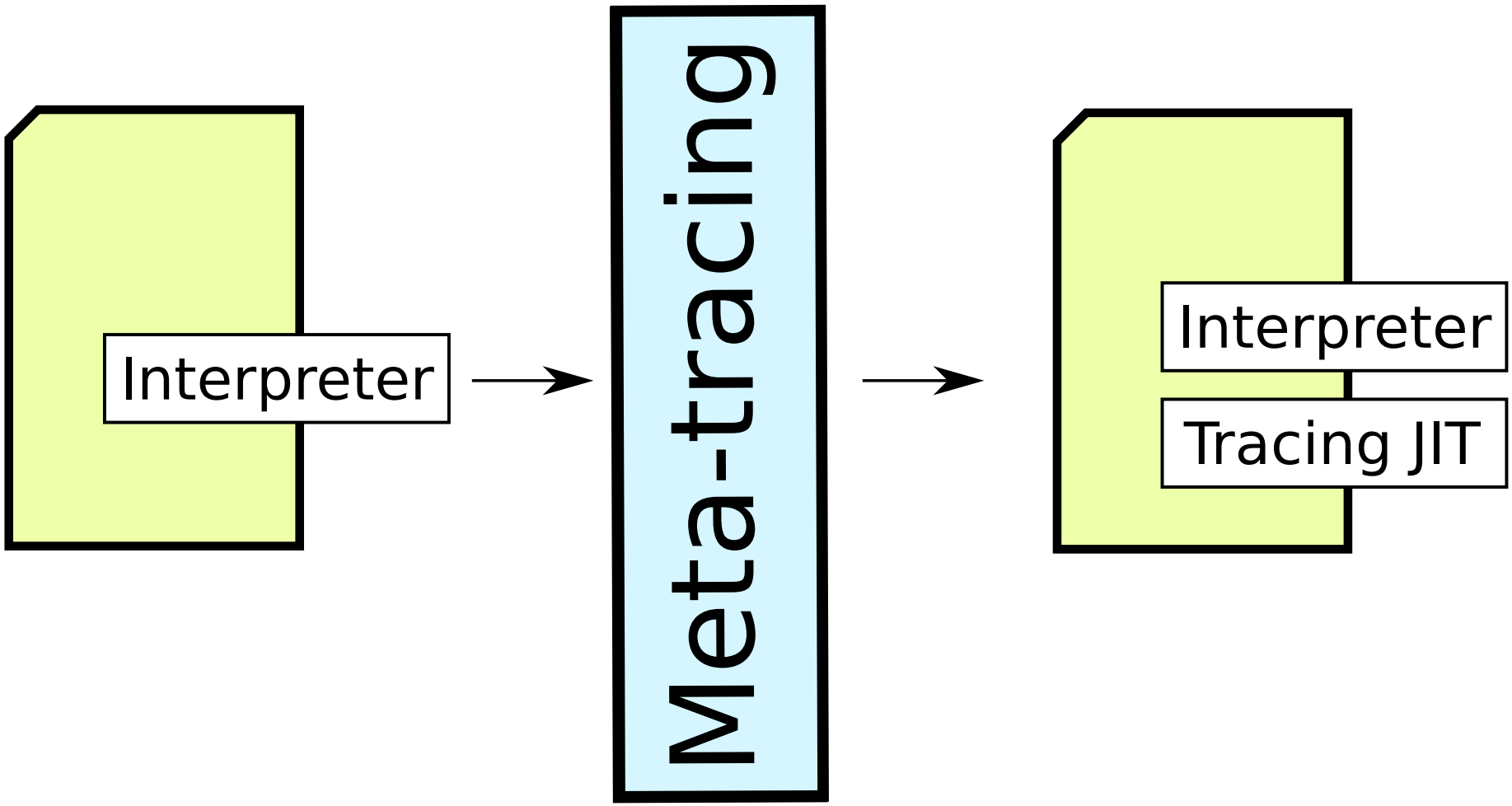


Language Boxes: E.g. Java + SQL

```
for (string s : SELECT * FROM tbl WHERE
name = this.name;) {
```

Java code

Meta-tracing



How Does this Apply to VM Composition?

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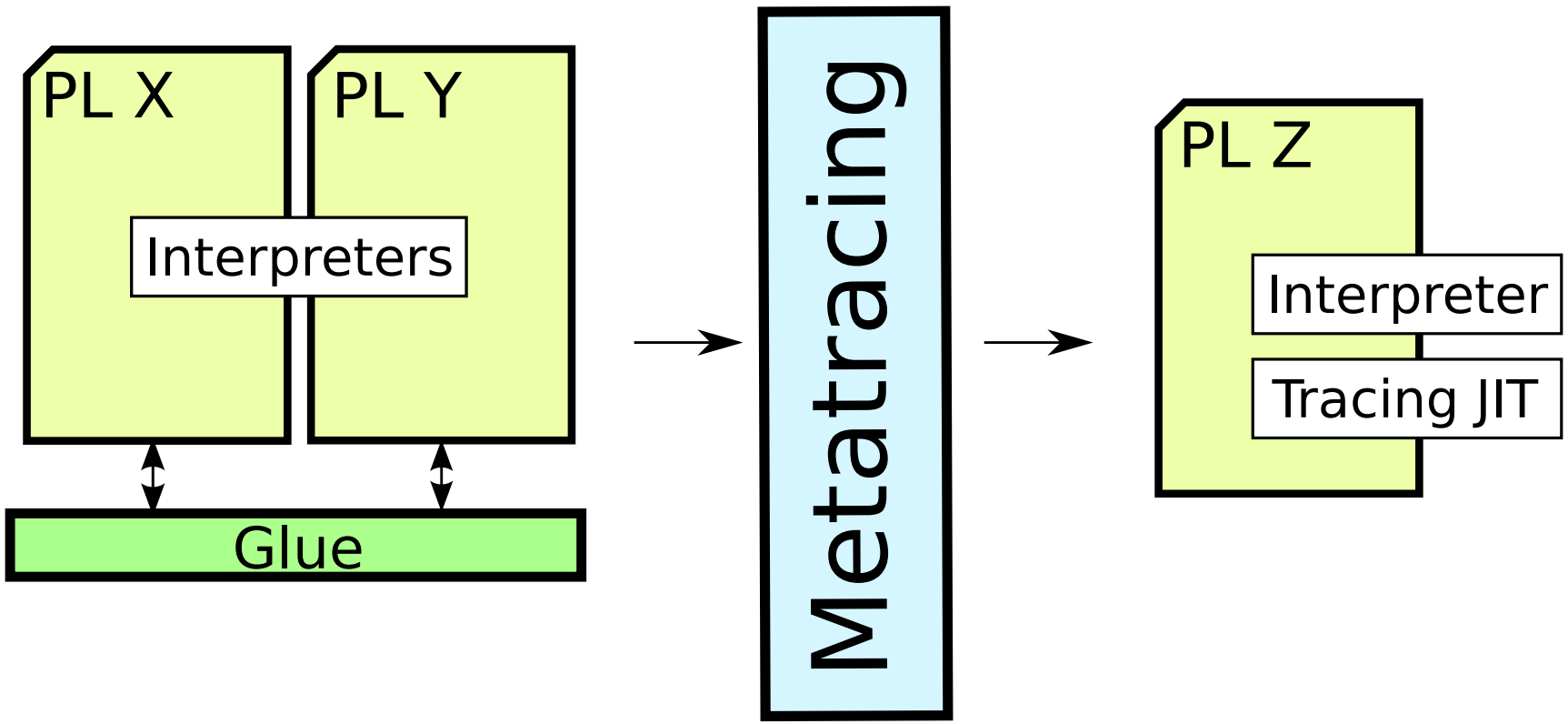


Summarising our Approach

- Editing with Language boxes.
  - Traditional “code editor” look and feel.
  - Practical syntactic composition.

- Interpreter Composition with Meta-tracing
  - Relatively little engineering effort.
  - Compose any two languages written in RPython.
  - Language agnostic JIT optimisations.

Our Compositions

Our Language Compositions

Eco + RPython

Our Language Compositions

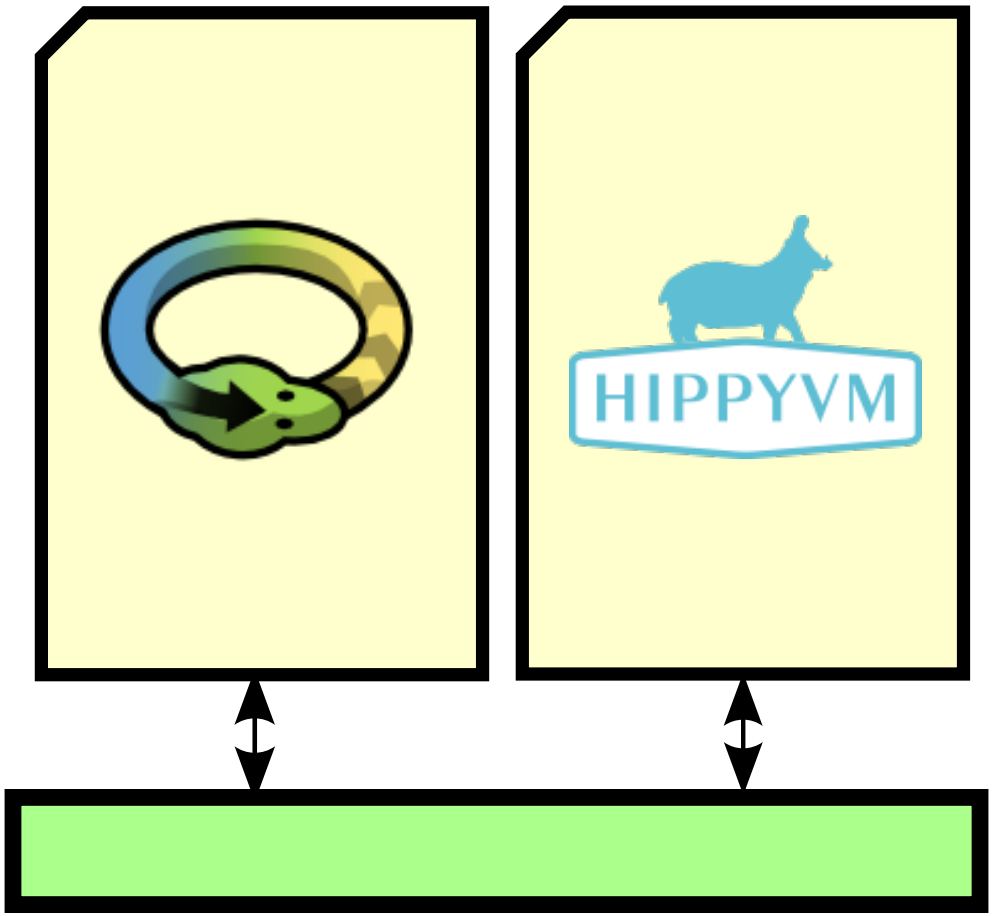
- Python + Prolog
- Python + PHP
- Python + SQLite

Our Language Compositions

- Python + Prolog
- Python + PHP = PyHyp
- Python + SQLite

PyHyp

PyHyp

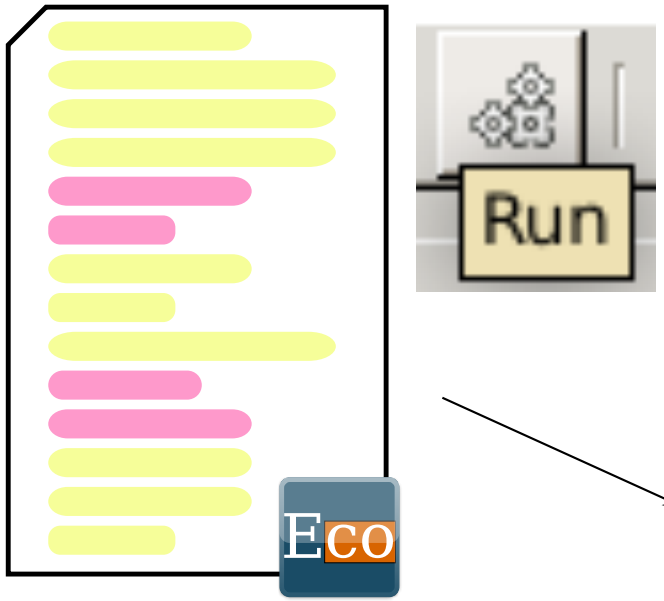


Features of PyHyp

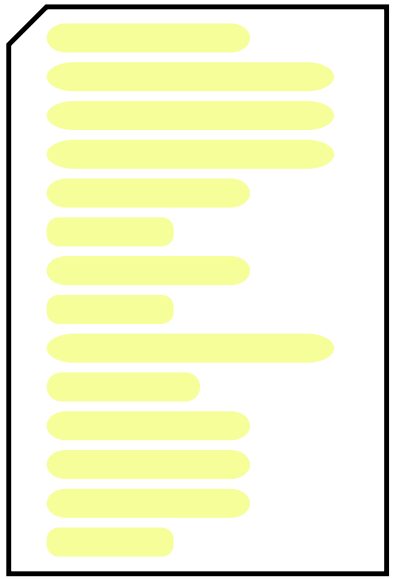
- FFI-like features
  - Calling Python functions and methods from PHP
  - Calling PHP functions and methods from Python
  - Automatic type “conversion”

- Advanced features
  - Adds support for references to Python
  - Arbitrary nesting of foreign functions
  - Cross-language scoping
  - Python expressions in PHP
  - “Embedding” Python methods inside PHP classes
  - Access modifiers

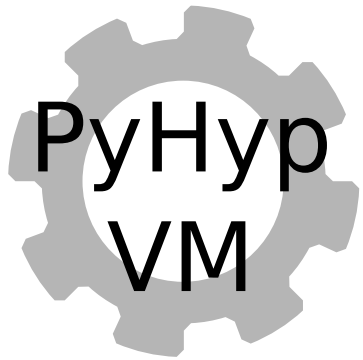
Edit/Execute



PHP + Python
Code



Intermediate
(x-lang interfaces)



“Semantic Friction”

Implementing desired behaviour: relatively easy

Deciding the correct behaviours: hard

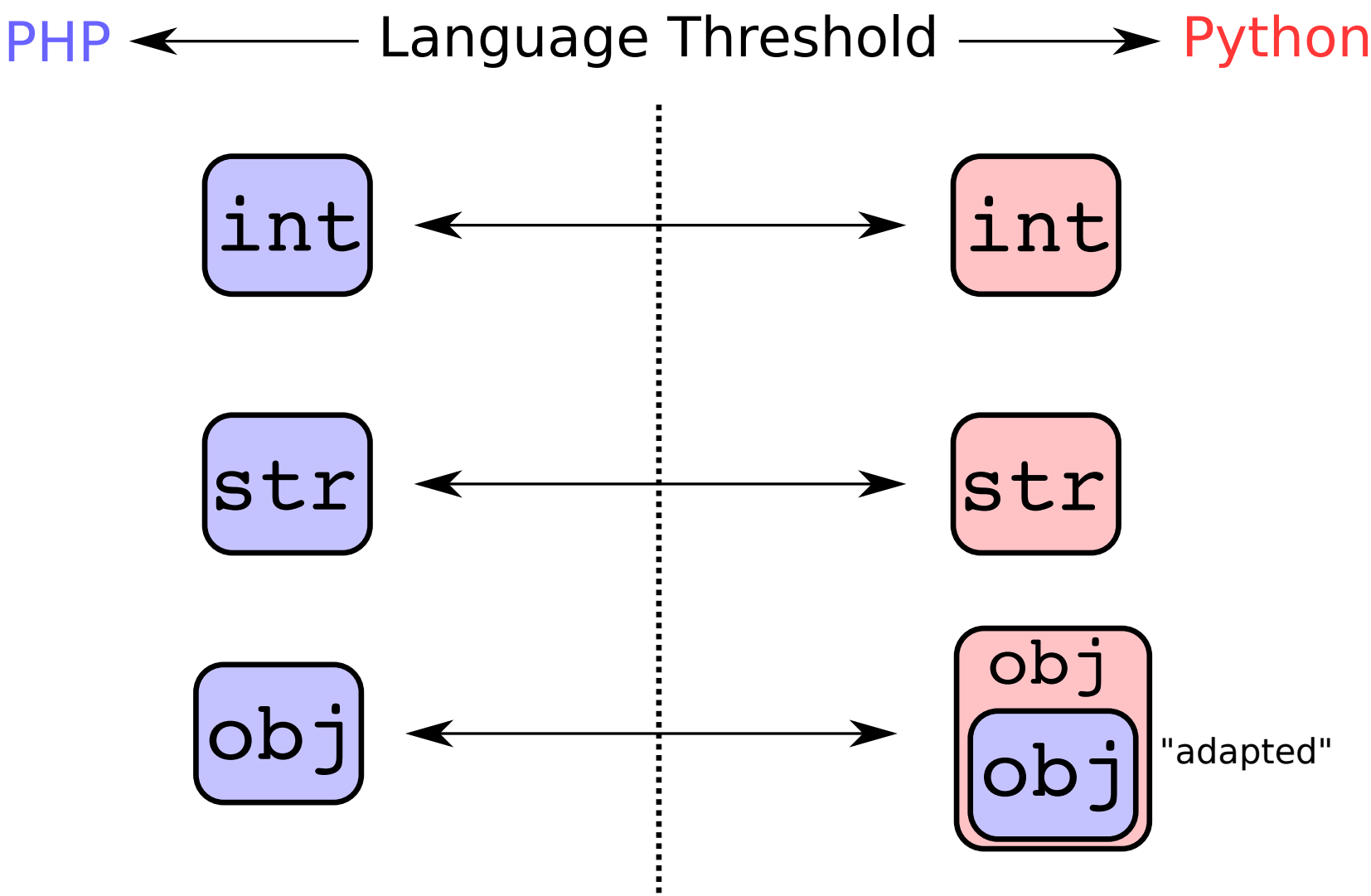
“Semantic friction”

Compromises sometimes must be made.

“Semantic Friction”

Example: Collection types across languages.

Semantic Friction: Array/Dict/List Conversions



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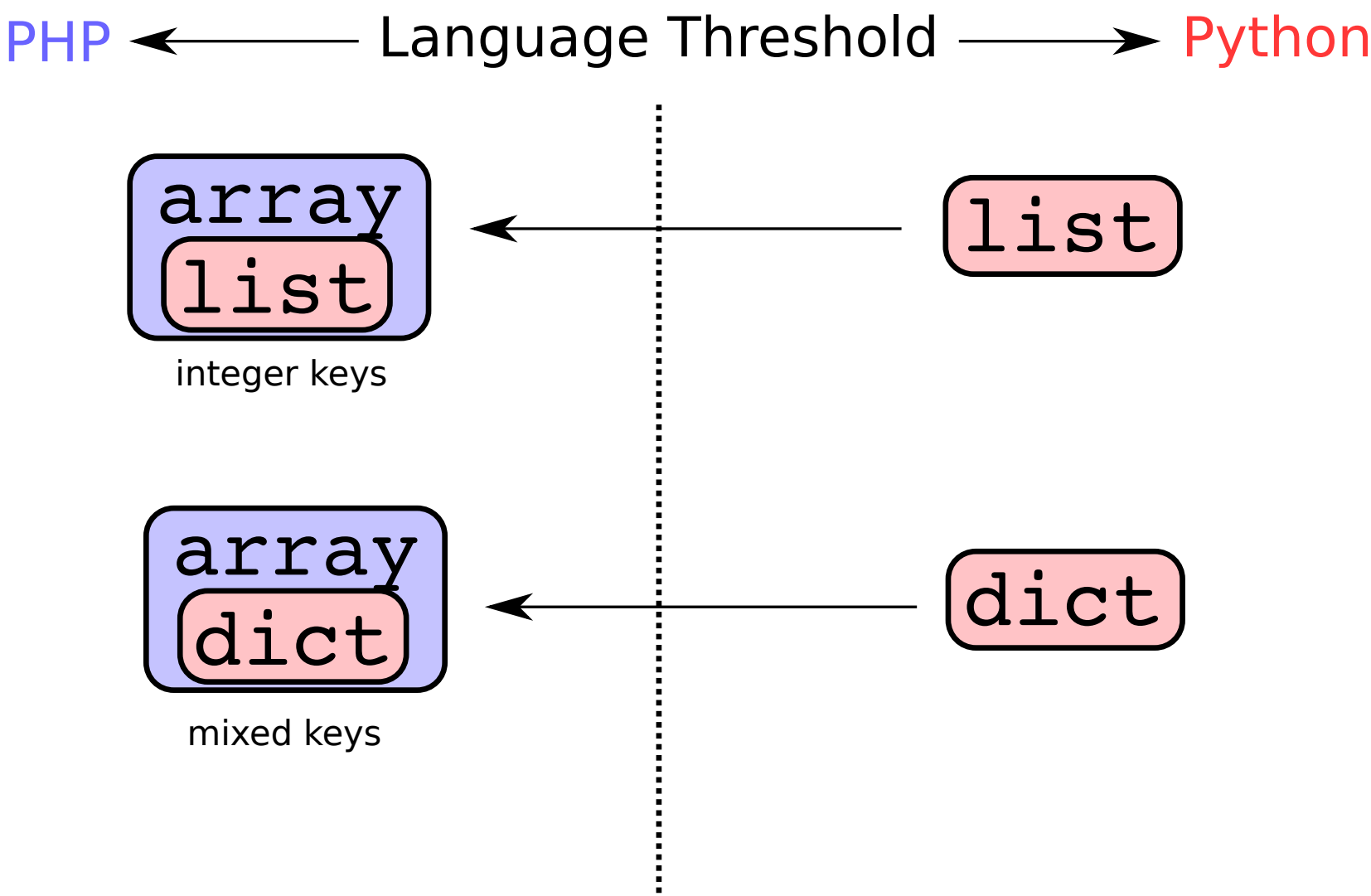

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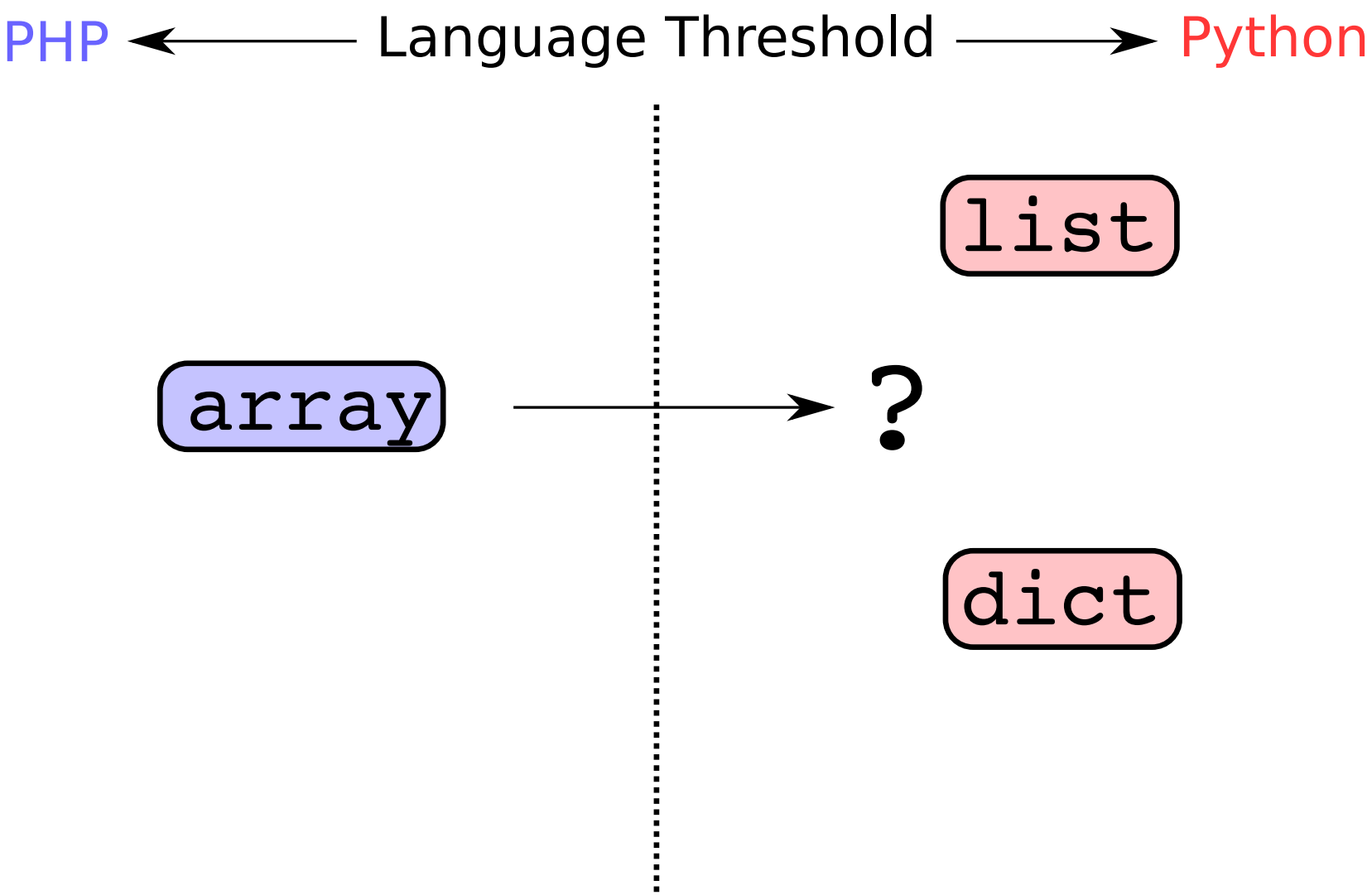

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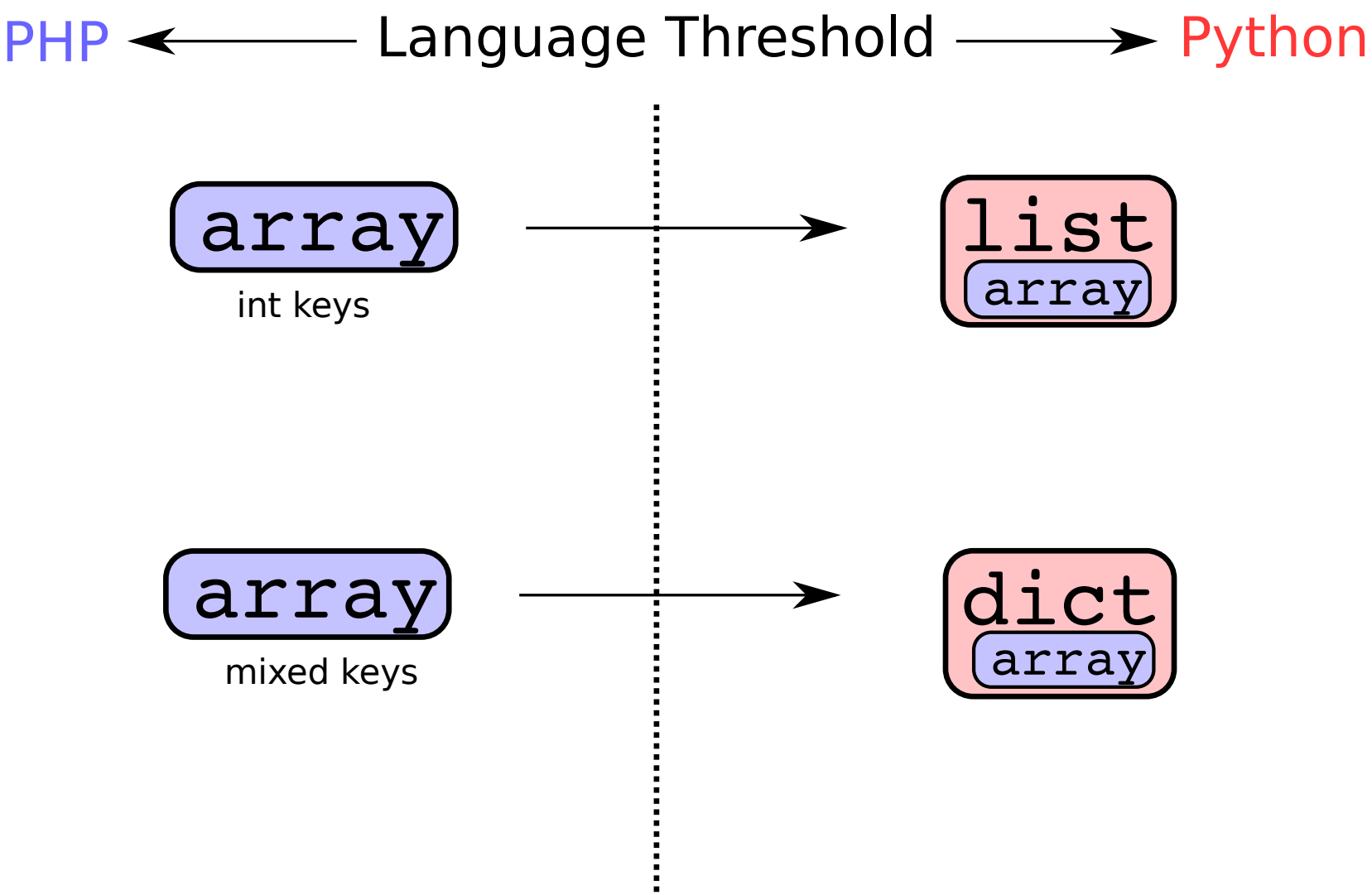

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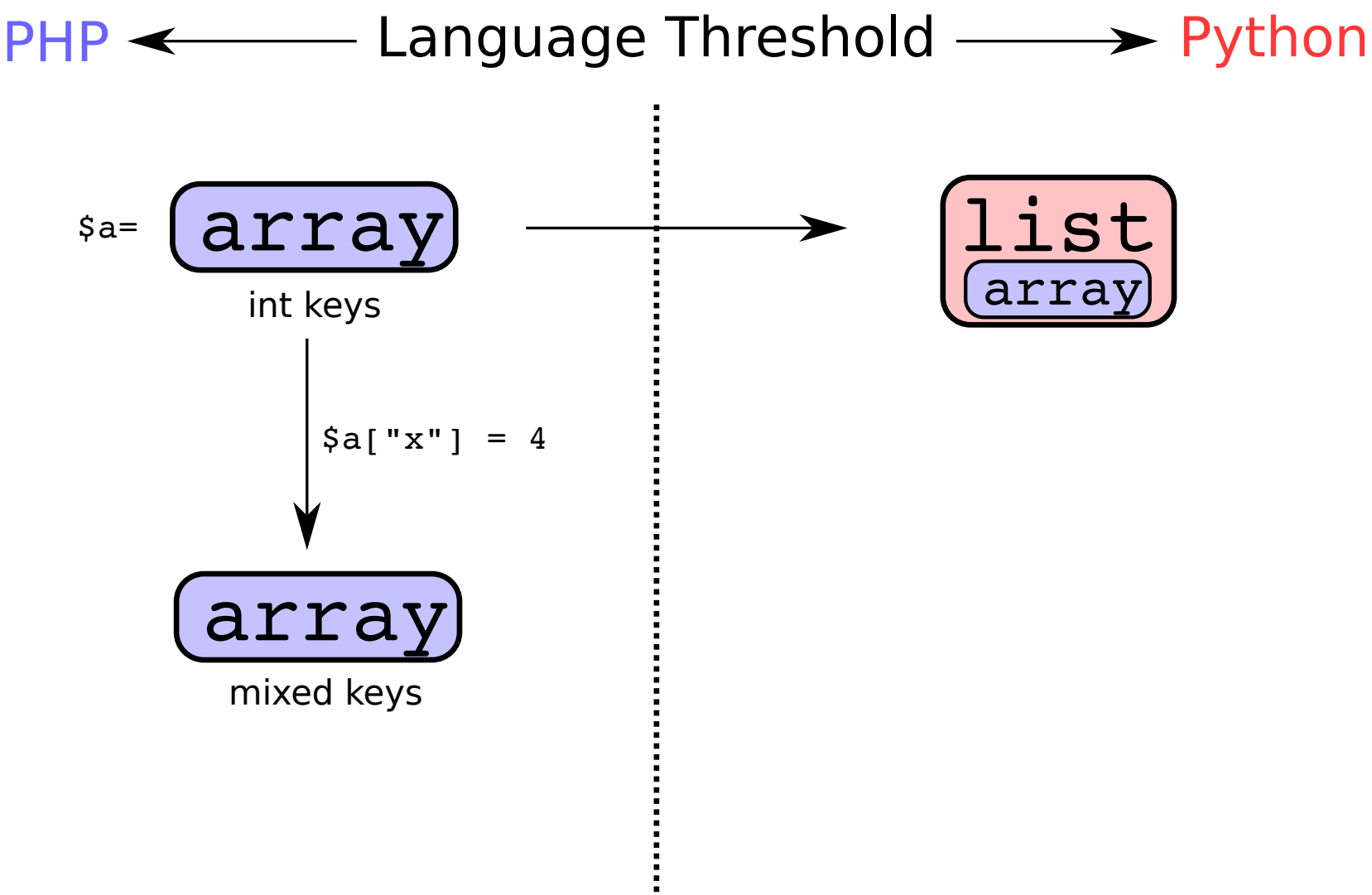

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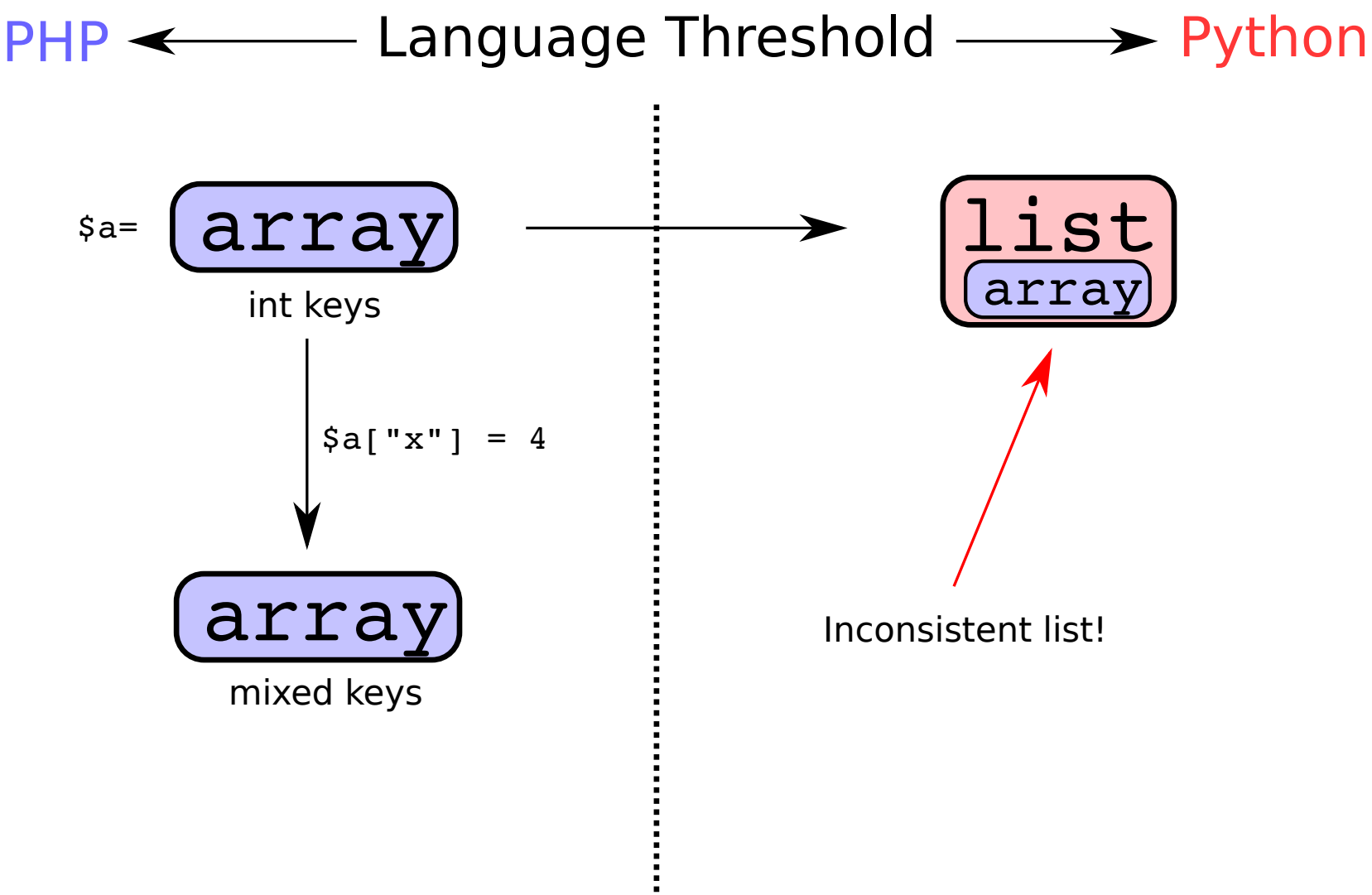

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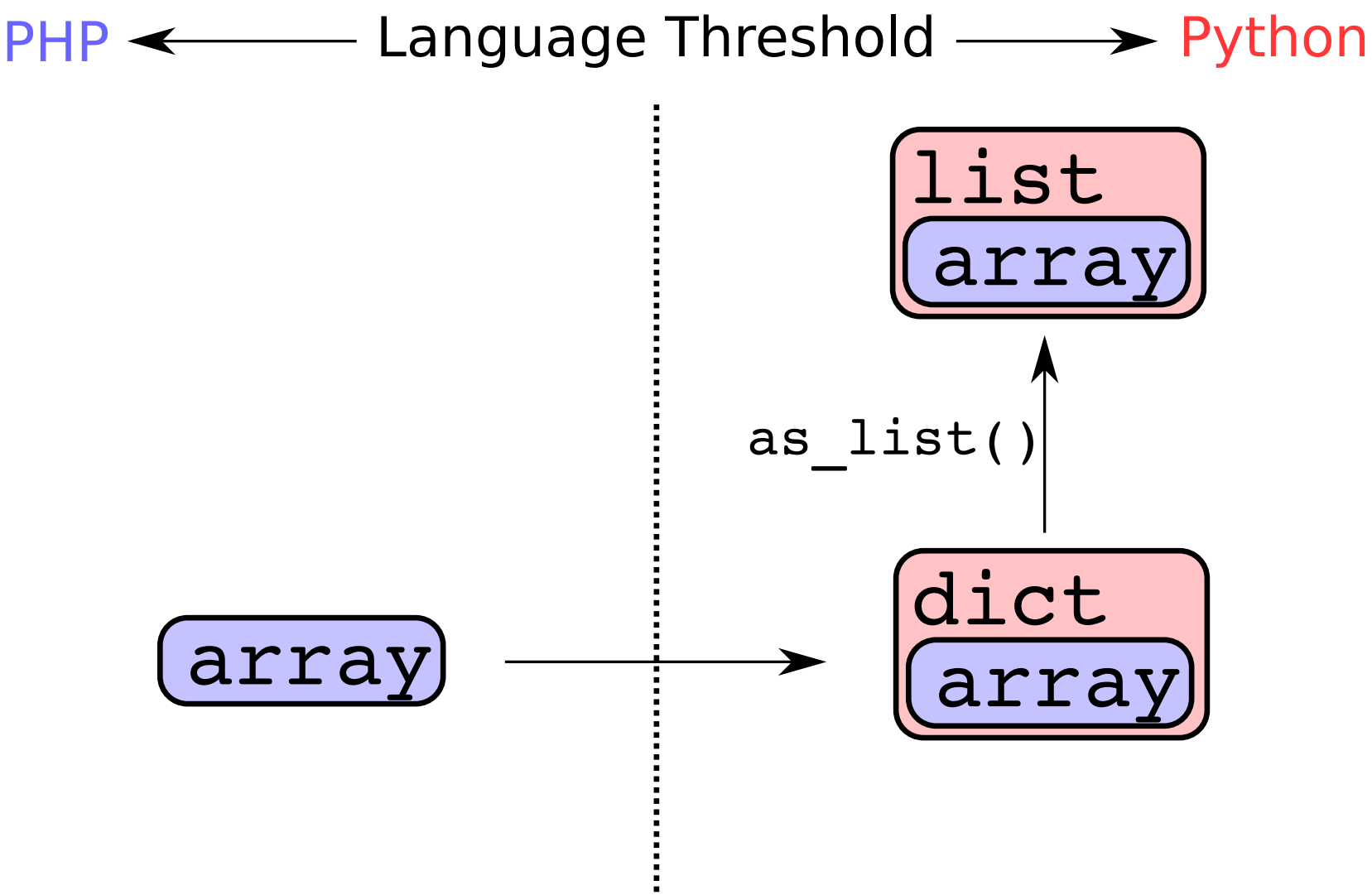


Experimental Evaluation

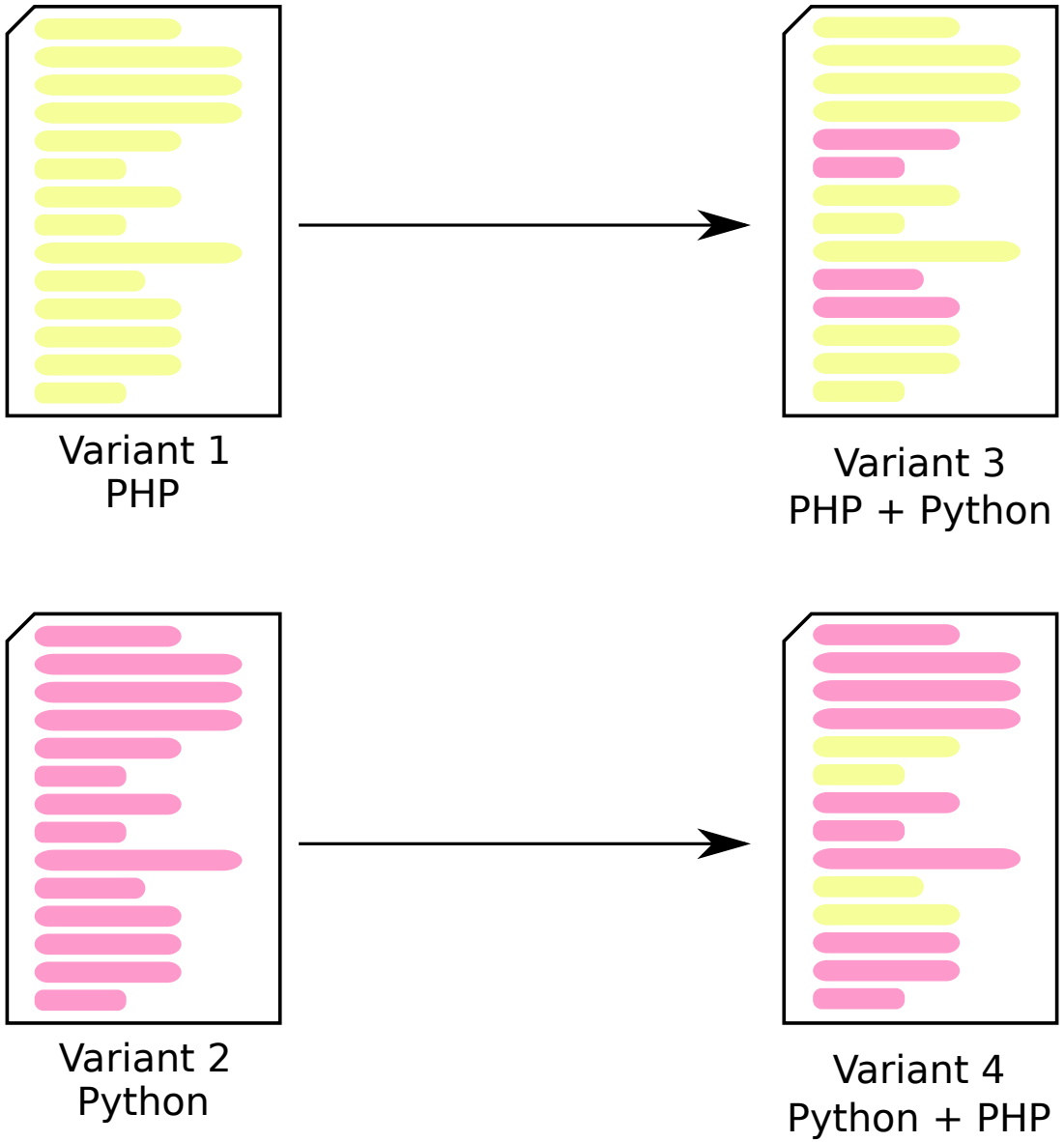
Benchmarks

Microbenchmarks

“Larger” benchmarks

Benchmark Variants

Benchmarks


Variant 1
PHP
Variant 3
PHP + Python
Variant 2
Python
Variant 4
Python + PHP

“Good Performance”

Composed variant on PyHyp should perform “close” to mono variants on constituent interpreters.

Aim for between 1-2x slower. 3x is too slow.

For completeness, benchmark against other PHP and Python implementations too.

Microbenchmarks: Relative to PyHyp Variant3

Benchmark	CPython	HHVM	HippyVM	PyHyp$_m$	PyPy	Zend
instchain	22.172 ±0.0859	6.209 ±0.0234	0.969 ±0.0036	0.967 ±0.0039	0.477 ±0.0019	24.248 ±0.1191
l1a0r	71.633 ±1.4869	3.770 ±0.0793	1.230 ±0.0255	1.230 ±0.0256	1.231 ±0.0298	37.752 ±1.1719
l1a1r	76.171 ±0.1207	3.000 ±0.0038	1.285 ±0.0003	1.285 ±0.0002	1.144 ±0.0077	41.052 ±0.3498
lists	7.485 ±0.0227	0.879 ±0.0072	0.966 ±0.0037	0.977 ±0.0041	0.520 ±0.0018	16.106 ±0.0736
ref_swap		6.911 ±0.0054	1.000 ±0.0003	1.000 ±0.0003		55.360 ±0.7395
return_simple	108.576 ±0.2690	6.915 ±0.0009	1.000 ±0.0001	1.000 ±0.0002	0.889 ±0.0002	83.708 ±0.7264
scopes	123.284 ±1.5081	14.969 ±0.0391	4.528 ±0.0099	4.512 ±0.0588	1.000 ±0.0003	156.443 ±0.5742
smallfunc	184.778 ±0.3071	12.818 ±0.0099	1.000 ±0.0003	1.000 ±0.0003	1.000 ±0.0003	243.318 ±0.8453
sum	299.582 ±0.3659	19.083 ±0.0172	1.000 ±0.0005	1.000 ±0.0005	0.874 ±0.0003	427.513 ±2.6441
sum_meth	328.894 ±1.2870	23.714 ±0.0955	0.998 ±0.0030	0.999 ±0.0030	0.873 ±0.0026	456.739 ±2.9270
sum_meth_attr	127.800 ±0.1907	17.819 ±0.2655	1.001 ±0.0019	1.116 ±0.0015	0.925 ±0.0016	148.167 ±0.6554
total_list	14.266 ±0.0248	2.080 ±0.0031	0.695 ±0.0005	0.696 ±0.0019	0.510 ±0.0014	30.356 ±0.1679
walk_list	4.869 ±0.0340	0.373 ±0.0025	0.773 ±0.0060	0.774 ±0.0107	1.099 ±0.0082	10.700 ±0.0846

Larger Benchmarks: Relative to PyHyp Variant3

Benchmark	CPython	HHVM	HippyVM	PyHyp$_m$	PyPy	Zend
deltablue	19.199 ±0.6900	860.108 ±31.1392	4.739 ±0.1684	4.888 ±0.1766	0.405 ±0.0151	181.209 ±6.7871
fannkuch	18.616 ±0.0362	3.212 ±0.0133	1.869 ±0.0034	1.879 ±0.0024	1.009 ±0.0046	14.998 ±0.1032
mandel		0.883 ±0.0006	1.013 ±0.0089	1.003 ±0.0011		8.290 ±0.0623
richards	28.291 ±0.1091	12.726 ±0.1296	0.745 ±0.0036	0.766 ±0.0044	0.531 ±0.0026	27.081 ±0.1445

Overall: Relative to PyHyp Variant3

Benchmark	CPython	HHVM	HippyVM	PyHyp$_m$	PyPy	Zend
Geometric Mean	48.575 ±0.1493	6.698 ±0.0188	1.206 ±0.0032	1.218 ±0.0035	0.785 ±0.0024	56.521 ±0.1833

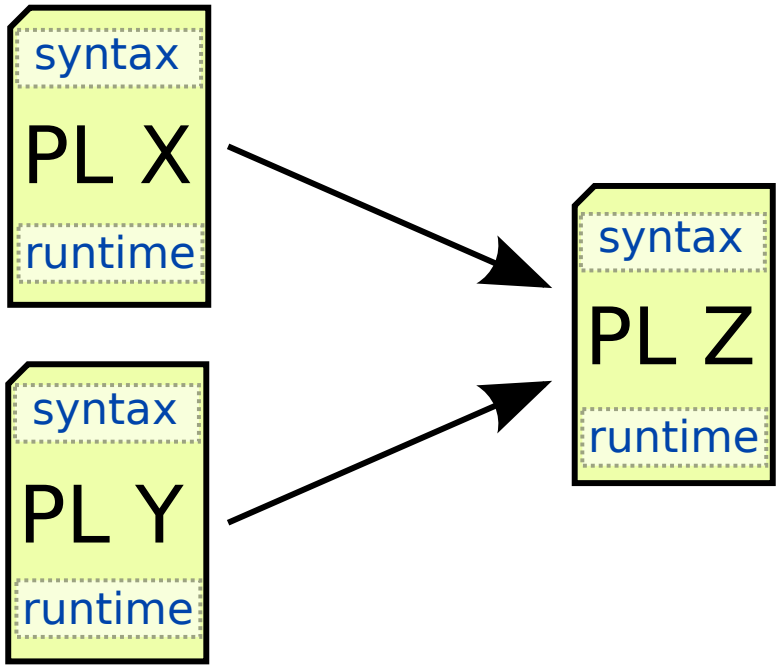
Conclusions

- Language boxes:
  - Practical composition of PL syntax.
  - Decent editor experience.
- Meta-tracing:
  - Compositions with relatively little effort.
  - Overall good performance.
- Implementing x-lang behaviours is easy.
- Designing x-lang behaviours is hard.
  - Thanks to semantic friction.

Future Work

- Debugging
  - ~~Proper backtrace information.~~
  - Cross-language debugger.
- Compositions with >2 languages involved.
- Statically typed languages.

Thanks



Language Boxes + Meta-tracing