Fine-grained language composition





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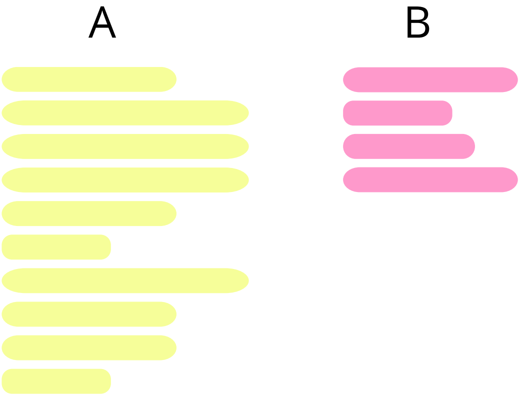
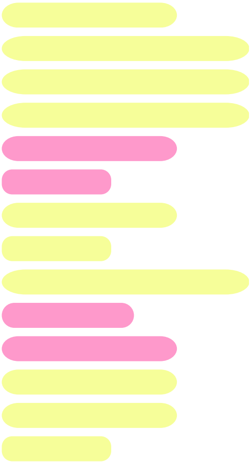
What to expect from this talk

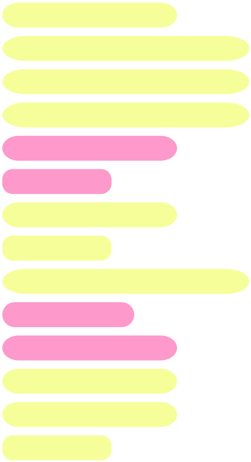


What to expect from this talk

$A \cup B$

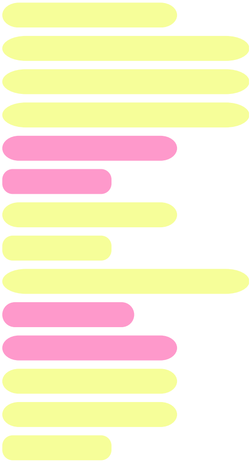


Python $\cup$ Prolog



What to expect from this talk

Python $\cup$ PHP



Two levels of challenge

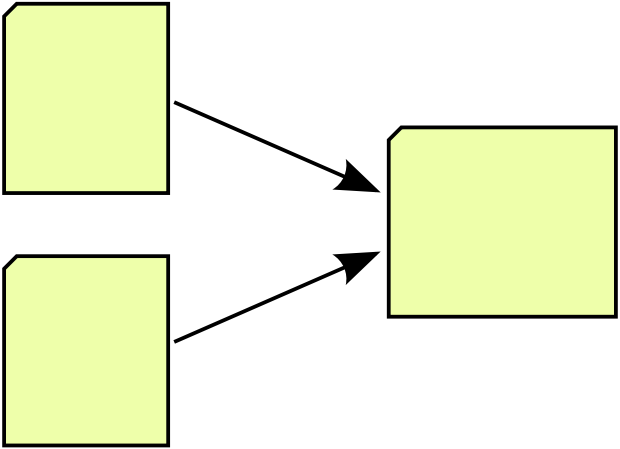
Tooling

Two levels of challenge

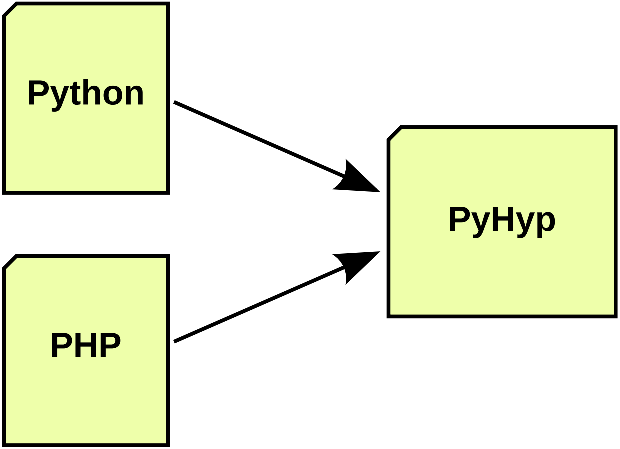
Tooling

Language friction

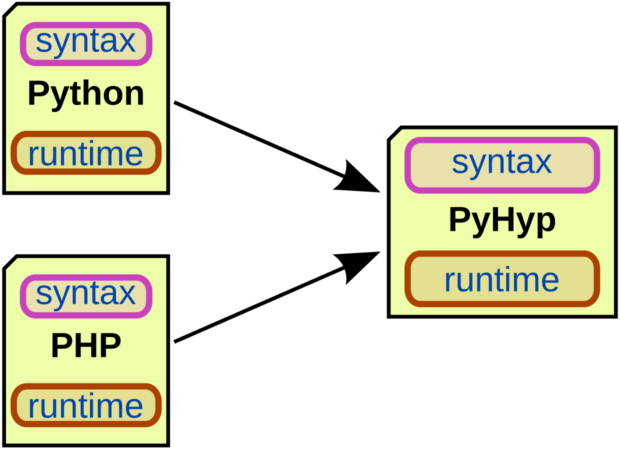
Tooling challenges

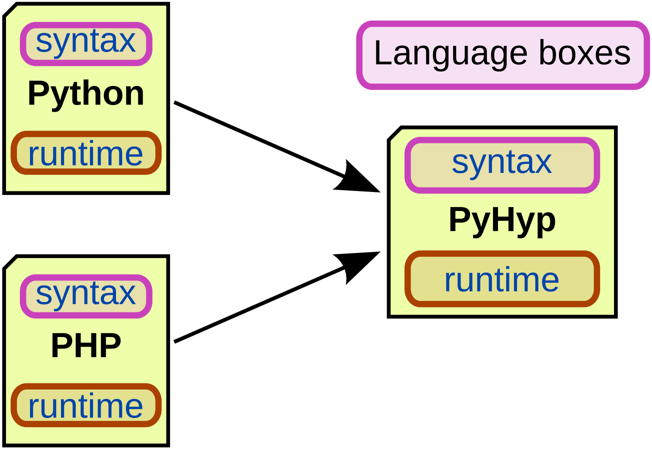


Tooling challenges

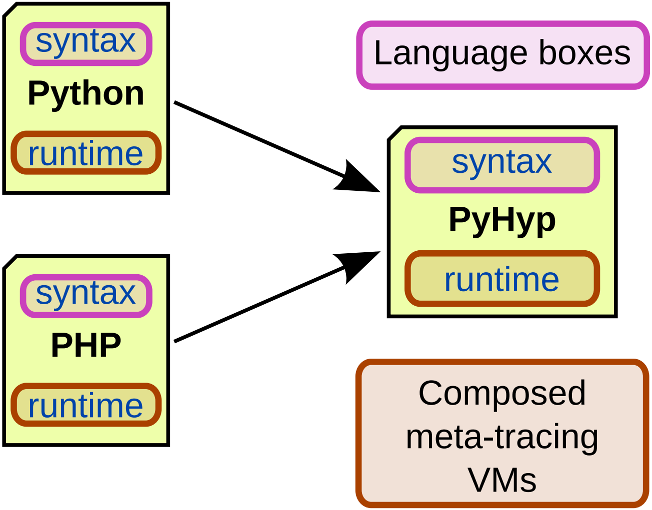


Tooling challenges




syntax
Python
runtime
syntax
PHP
runtime
Language boxes
syntax
PyHyp
runtime

Tooling challenges



Syntax composition

PL X

<grammar>

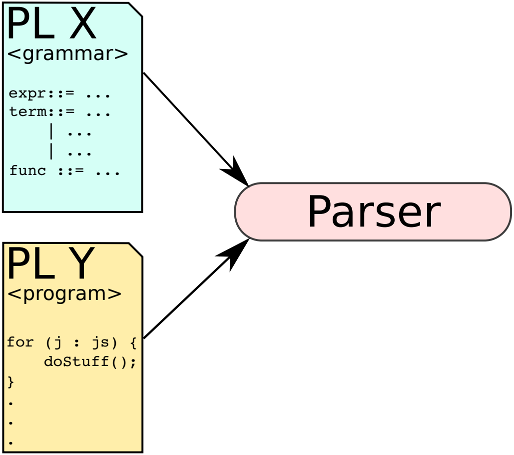
```
expr::= ...
term::= ...
    | ...
    | ...
func ::= ...
```

PL Y

<program>

```
for (j : js) {
    doStuff();
}
.
.
.
```

Syntax composition



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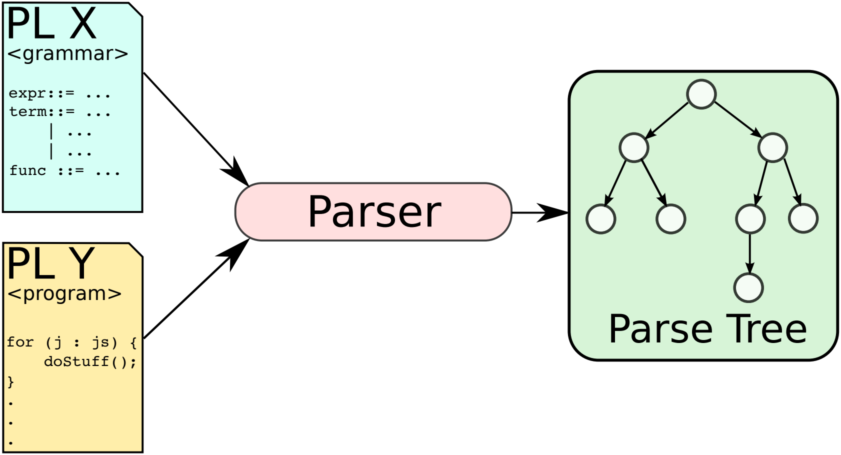

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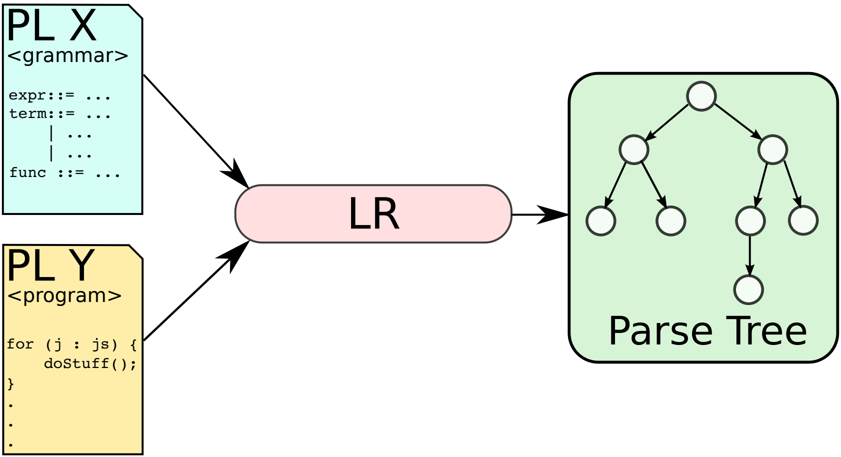

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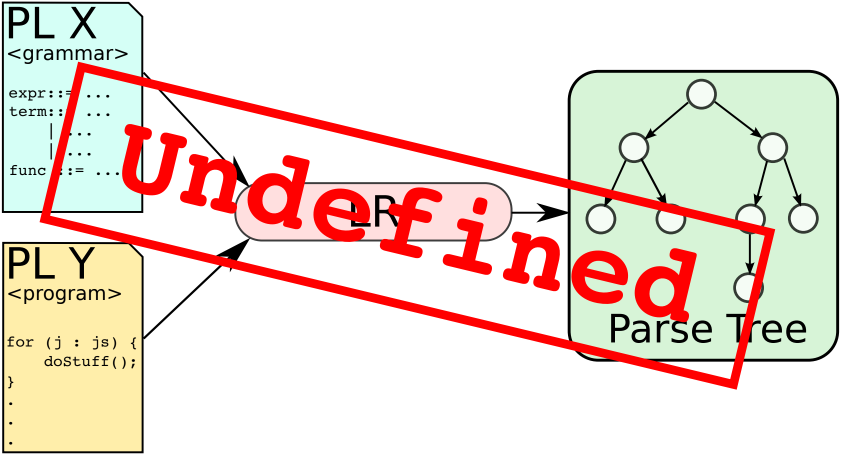

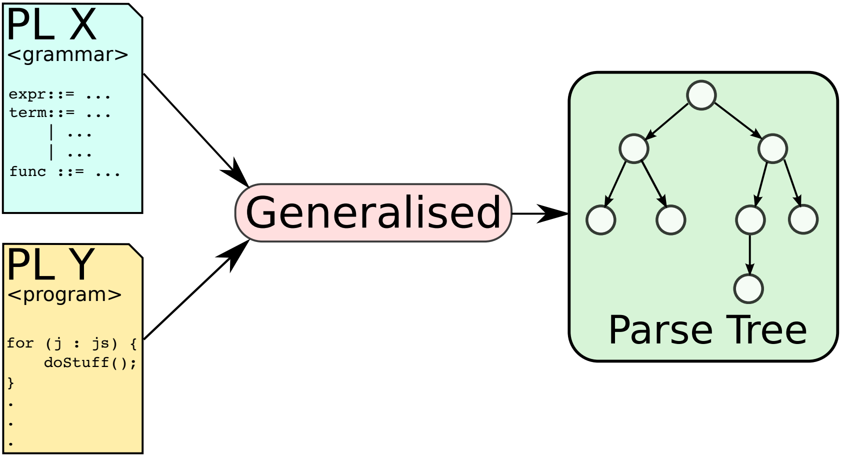
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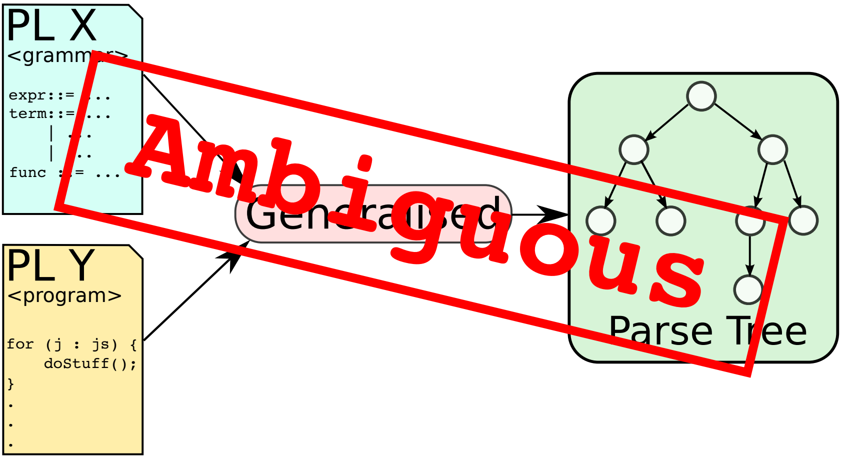
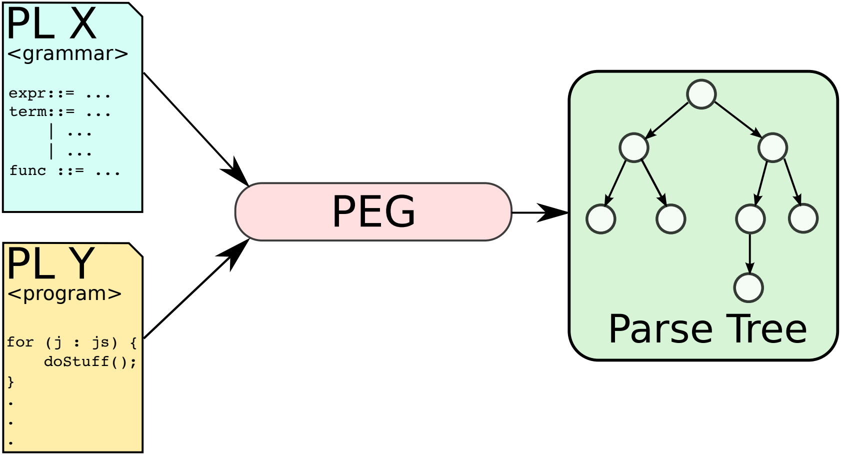
Generalised
Parse Tree

Syntax composition

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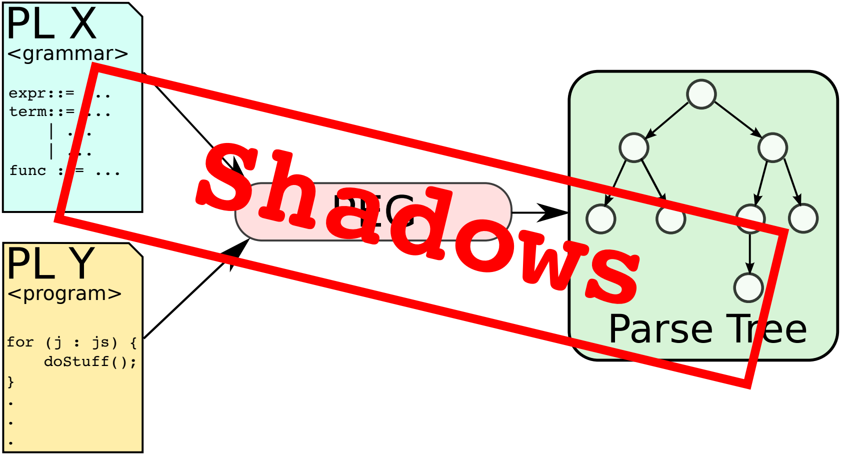
}
.
.
.
PEG
Parse Tree


PL X
<grammar>
expr::=
term::=
func
PL Y
<program>
for (j : js) {
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}
Shadows
Parse Tree

The only choice?

The only choice?

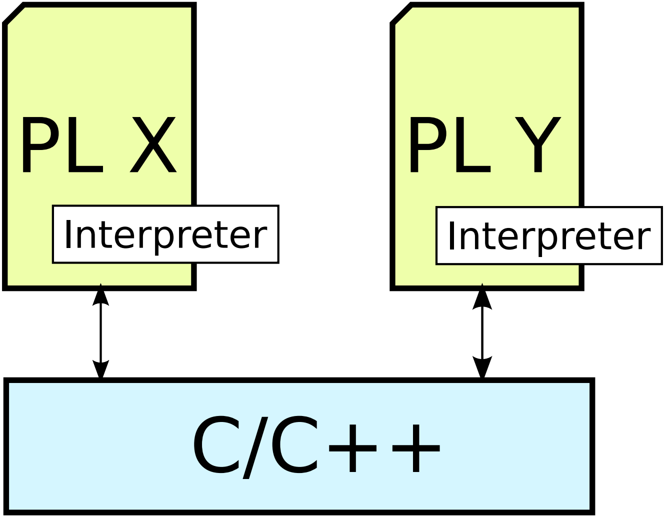
SDE

Challenge:
SDE's power $+$
a text editor feel?

Eco demo

Runtime composition

Runtime composition



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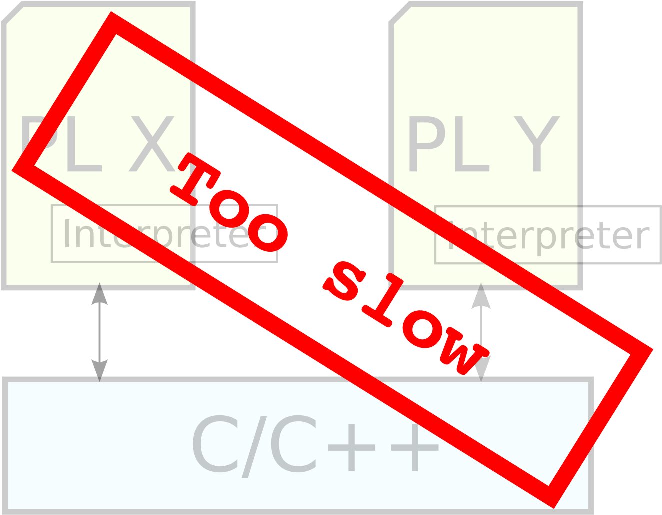

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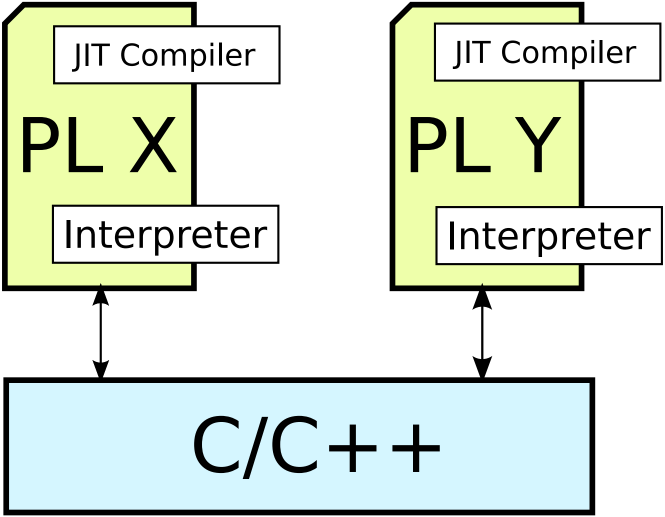

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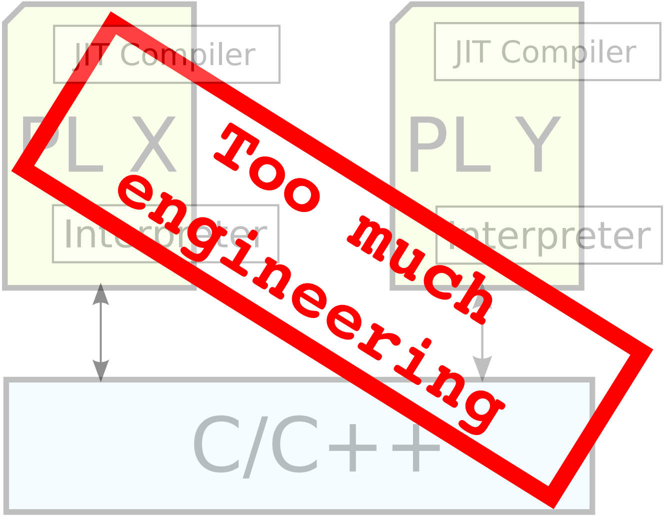

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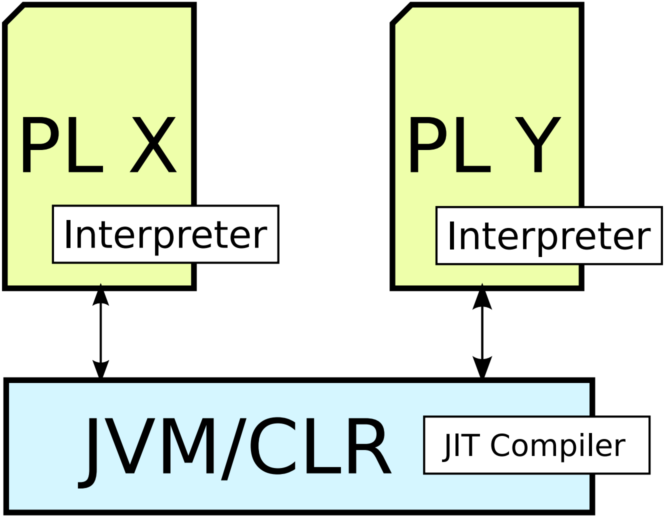

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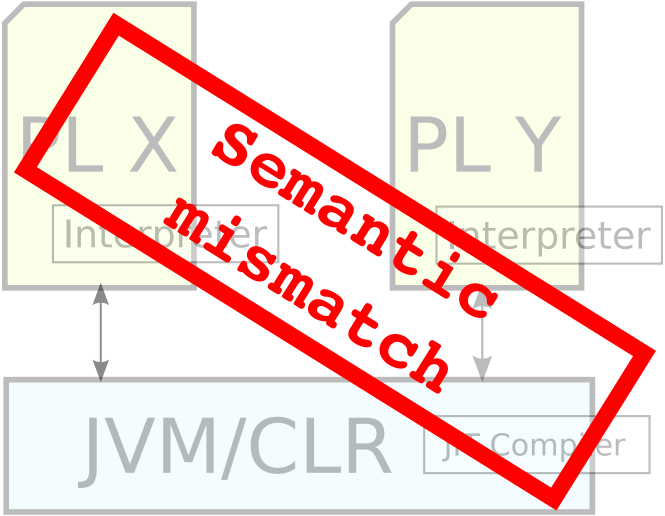

Runtime composition

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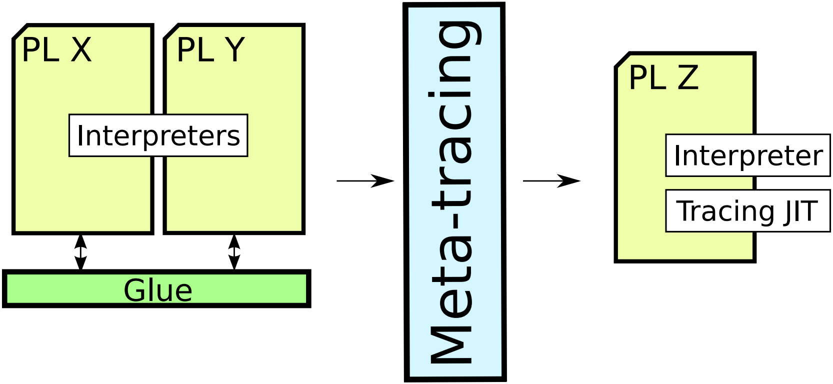
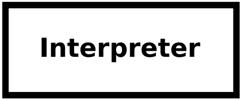


Meta-tracing translation with RPython



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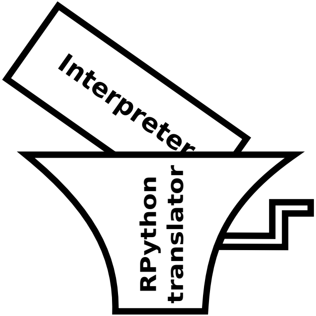

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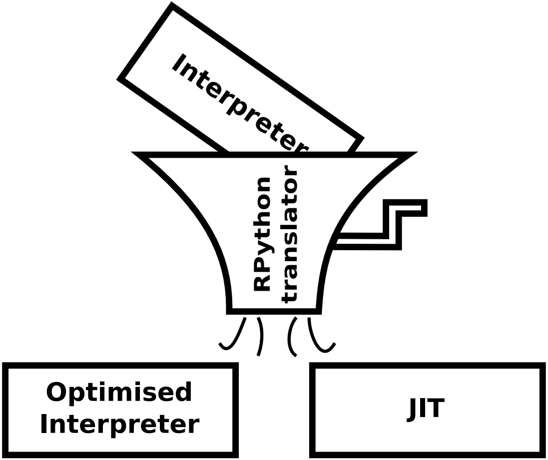

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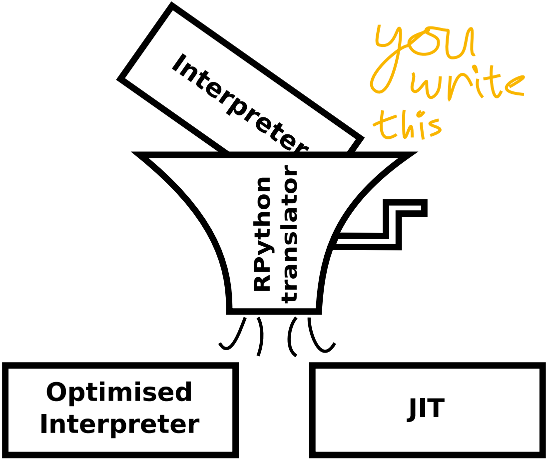

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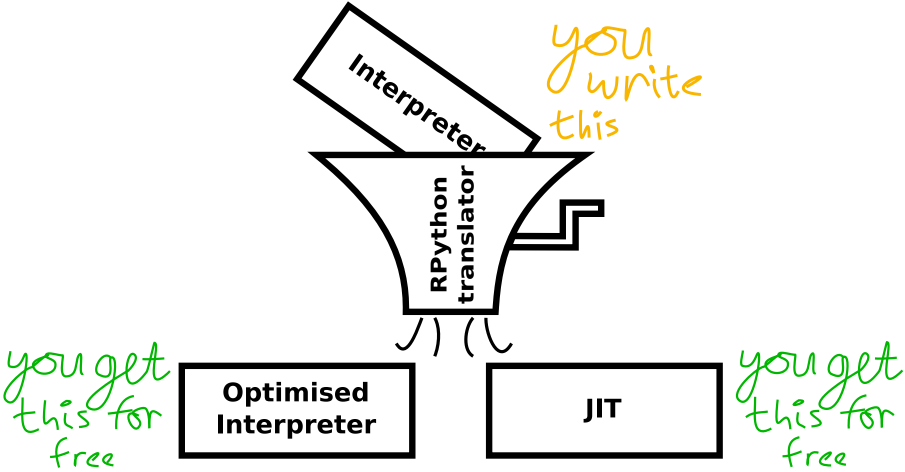


Adding a JIT to an RPython interpreter

```
...
pc := 0
while 1:

    instr := load_next_instruction(pc)
    if instr == POP:
        stack.pop()
        pc += 1
    elif instr == BRANCH:
        off = load_branch_jump(pc)

        pc += off
    elif ...:
        ...
```

Observation: interpreters are big loops.

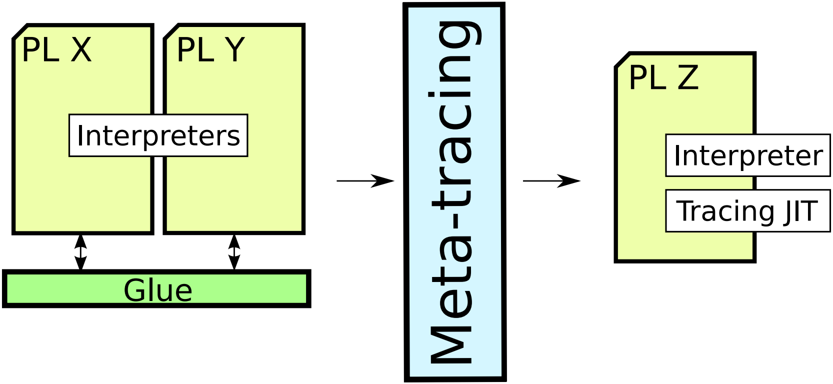
Adding a JIT to an RPython interpreter

```
...
pc := 0
while 1:
    jit_merge_point(pc)
    instr := load_next_instruction(pc)
    if instr == POP:
        stack.pop()
        pc += 1
    elif instr == BRANCH:
        off = load_branch_jump(pc)
        if off < 0: can_enter_jit(pc)
        pc += off
    elif ...:
        ...
```

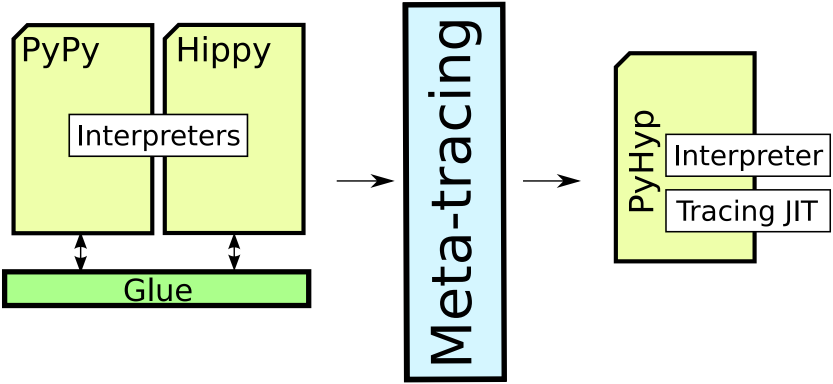
Observation: interpreters are big loops.

Runtime composition recap

Runtime composition recap



Runtime composition recap



Composed Richards vs. other VMs

Type	VM	
Mono	CPython 2.7.7	9.475 $\pm$ 0.0127
	HHVM 3.4.0	4.264 $\pm$ 0.0386
	HippyVM	0.250 $\pm$ 0.0008
	PyPy 2.4.0	0.178 $\pm$ 0.0006
	Zend 5.5.13	9.070 $\pm$ 0.0361

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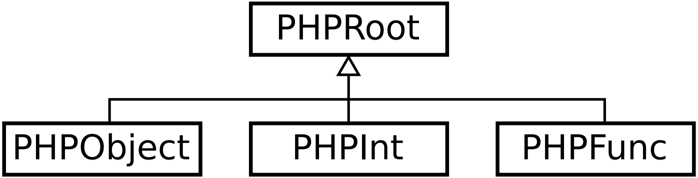
Composed	PyHyp	0.335 $\pm$ 0.0012

Datatype conversion



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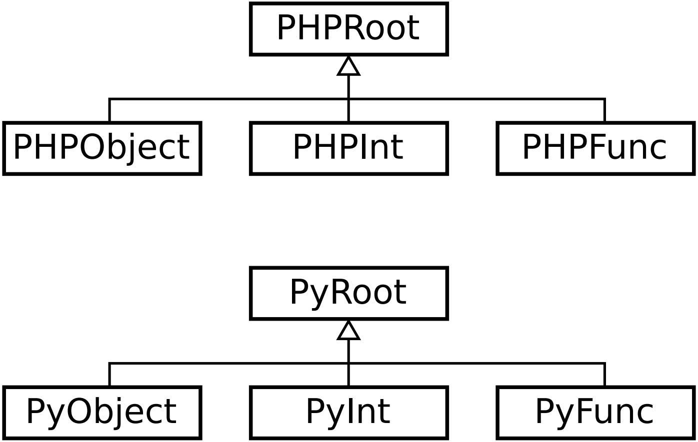


Datatype conversion: primitive types

PHP	Python

Datatype conversion: primitive types

PHP	Python
$\boxed{\text{2 : PHPInt}}$	

Datatype conversion: primitive types

PHP	Python
2 : PHPInt	2 : PyInt

Datatype conversion: user types

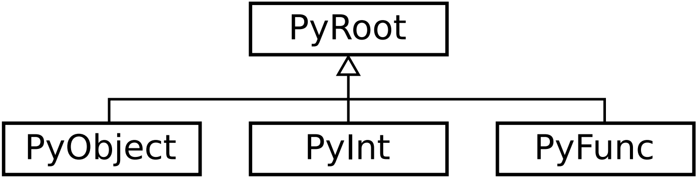
PHP	Python

PHP

Python

o : PHPObject

Datatype conversion: user types



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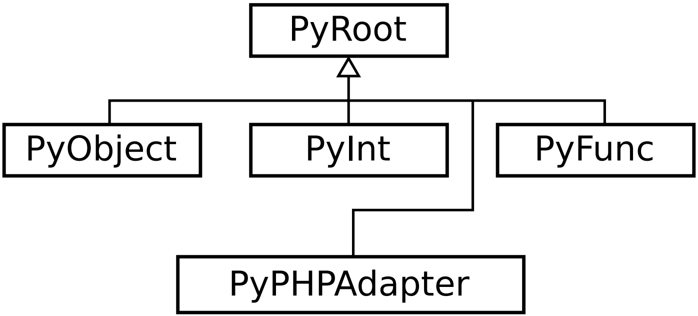

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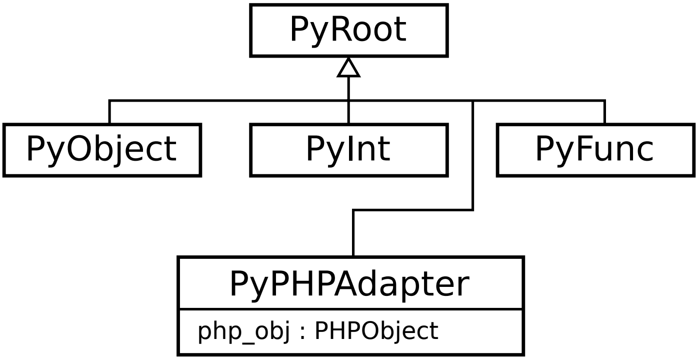
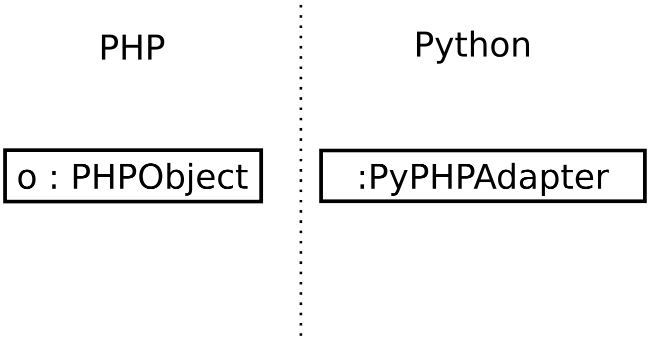


Datatype conversion: user types

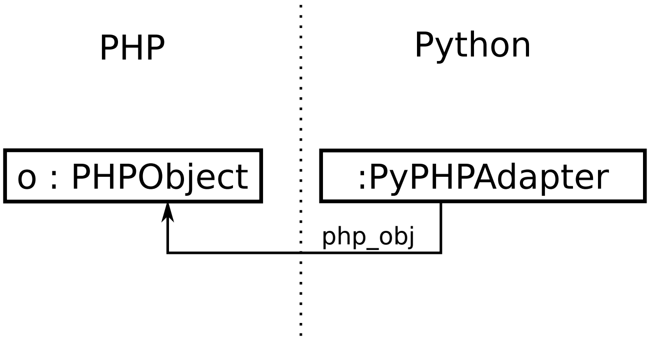
PHP

Python

o : PHPObject


PHP
Python
o : PHPObject
:PyPHPAdapter

Datatype conversion: user types



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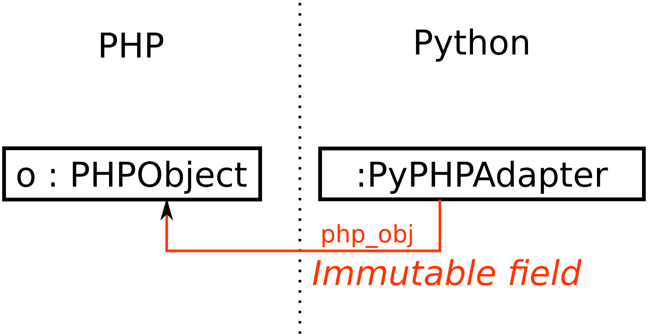

Friction

A good composition needs to reduce *friction*.

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- Lexical scoping (or lack thereof) in PHP and Python (semantic friction)

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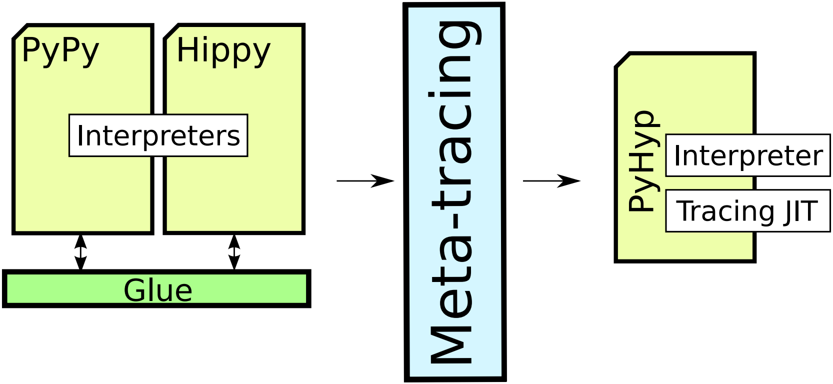
Friction

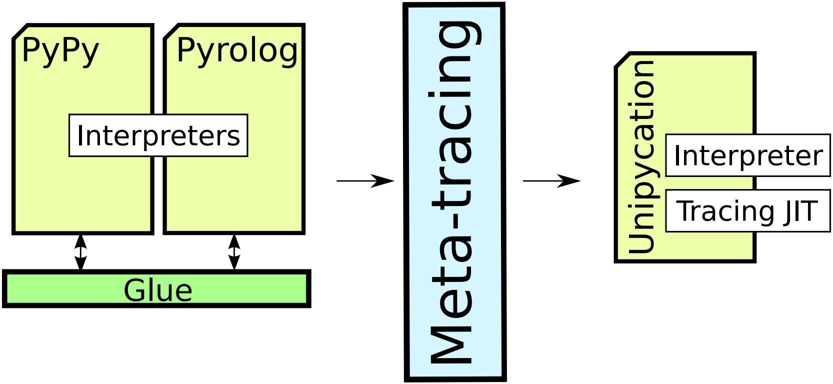
A good composition needs to reduce *friction*. Some examples:

- Lexical scoping (or lack thereof) in PHP and Python (semantic friction)
- PHP datatypes are immutable except for references and objects; Python's are largely mutable (semantic and performance friction)
- PHP has only dictionaries; Python has lists and dictionaries (semantic friction)

Unipycation



Unipycation



Unipycation demo

Absolute timing comparison

VM	Benchmark	*Python*		*Prolog*		*Python → Prolog*	
CPython-SWI	SmallFunc	0.125s	±0.007	0.257s	±0.002	28.893s	±0.227
	L1A0R	2.924s	±0.284	7.352s	±0.048	9.310s	±0.084
	L1A1R	4.184s	±0.038	18.890s	±0.111	20.865s	±0.067
	NdL1A1R	7.531s	±0.080	18.643s	±0.197	667.682s	±6.895
	TCons	264.415s	±2.250	48.819s	±0.252	2185.150s	±18.225
	Lists	9.374s	±0.059	25.148s	±0.221	2207.304s	±16.073
Unipycation	SmallFunc	0.001s	±0.000	0.006s	±0.001	0.001s	±0.000
	L1A0R	0.085s	±0.000	0.086s	±0.000	0.087s	±0.000
	L1A1R	0.112s	±0.000	0.114s	±0.000	0.115s	±0.000
	NdL1A1R	0.500s	±0.003	0.548s	±0.085	2.674s	±0.012
	TCons	6.053s	±0.288	2.444s	±0.003	36.069s	±0.225
	Lists	0.845s	±0.002	1.416s	±0.003	5.056s	±0.035
Jython-tuProlog	SmallFunc	0.088s	±0.003	3.050s	±0.053	52.294s	±0.475
	L1A0R	1.078s	±0.009	206.590s	±3.846	199.963s	±2.476
	L1A1R	2.145s	±0.232	293.311s	±5.691	294.781s	±6.193
	NdL1A1R	7.939s	±0.457	1857.687s	±5.169	1990.985s	±15.071
	TCons	543.347s	±3.289	8014.477s	±17.710	8202.362s	±24.904
	Lists	5.661s	±0.046	6981.873s	±18.795	5577.322s	±15.754

Relative timing comparison

VM	Benchmark	$\frac{\textit{Python}\rightarrow\textit{Prolog}}{\textit{Python}}$		$\frac{\textit{Python}\rightarrow\textit{Prolog}}{\textit{Prolog}}$		$\frac{\textit{Python}\rightarrow\textit{Prolog}}{\text{Unipycation}}$	
CPython-SWI	SmallFunc	231.770×	±13.136	112.567×	±1.242	27821.079×	±2331.665
	L1A0R	3.184×	±0.300	1.266×	±0.014	107.591×	±0.995
	L1A1R	4.987×	±0.049	1.105×	±0.007	181.899×	±0.590
	NdL1A1R	88.654×	±1.368	35.814×	±0.554	249.737×	±2.922
	TCons	8.264×	±0.101	44.760×	±0.453	60.583×	±0.637
	Lists	235.459×	±2.314	87.772×	±1.017	436.609×	±4.415
Unipycation	SmallFunc	1.295×	±0.105	0.182×	±0.054	1.000×	
	L1A0R	1.020×	±0.002	1.012×	±0.002	1.000×	
	L1A1R	1.025×	±0.002	1.002×	±0.003	1.000×	
	NdL1A1R	5.349×	±0.045	4.879×	±0.924	1.000×	
	TCons	5.959×	±0.282	14.756×	±0.092	1.000×	
	Lists	5.982×	±0.045	3.569×	±0.026	1.000×	
Jython-tuProlog	SmallFunc	592.904×	±19.517	17.143×	±0.338	50354.204×	±4341.413
	L1A0R	185.460×	±2.818	0.968×	±0.021	2310.844×	±28.093
	L1A1R	137.427×	±14.537	1.005×	±0.028	2569.873×	±52.847
	NdL1A1R	250.776×	±14.666	1.072×	±0.009	744.699×	±6.726
	TCons	15.096×	±0.106	1.023×	±0.004	227.409×	±1.592
	Lists	985.149×	±8.674	0.799×	±0.003	1103.206×	±8.338

What can we use this for?

What can we use this for?

First-class languages

What can we use this for?

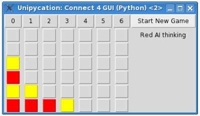
First-class languages

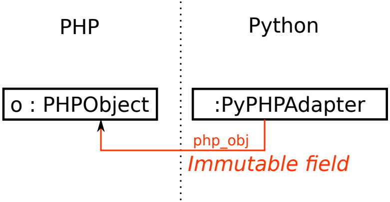
Language migration

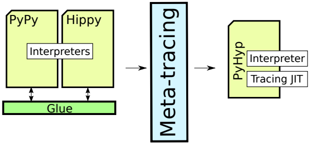
Thanks to our funders

- EPSRC: *COOLER* and *Lecture*.
- Oracle: various.

Thanks for listening







http://soft-dev.org/