```
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        "title": "PyPy on cutting edge.",
        "event_id": "PiterPy #4",
    },
    "speaker": {
        "__qname__"    : "Aleksandr Koshkin",
        "linkedin"     : "lnkfy.com/7Do",
        "github"       : "/magniff",
    }
}
```
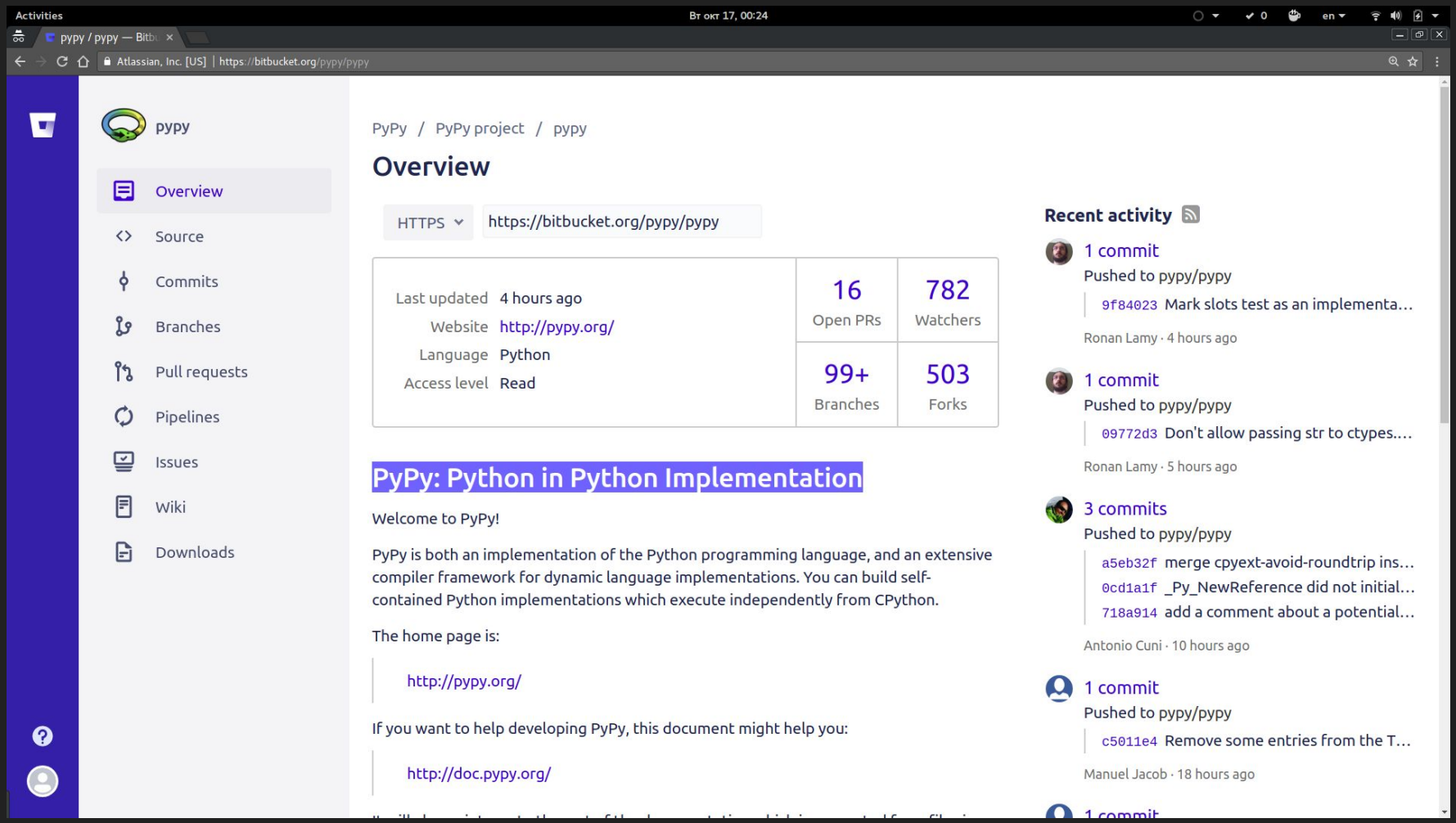

https://bitbucket.org/pypy/pypy



So, what is PyPy?

- Turbo awesome dynamic language designer framework.
- Boring tutorial that went too far.

Just a small example

```
def abs(value):
    if value >= 0:
        return value
    else:
        return -1 * value


for value in range(10**9):
    abs(value)
```

```
$ time pypy3 abs.py
real   1.082s


$ time python3 abs.py
real   2m2.030s
```

~120X faster, Karl!

Cool, lets go check it!

:3

The aim of the talk

- review the basic idea behind PyPy JIT
- be as human friendly as possible
- avoid using JIT buzzword
- (I did it again, did I?)

So what's the scoop?

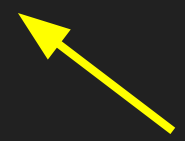
Frame evaluator

```
PyObject *
PyEval_EvalFrameEx(PyFrameObject *f, int throwflag)
{
    co = f->f_code;
    for (;;) {
        switch (opcode) {
            TARGET(LOAD_FAST)   {\* implementation of LOAD_FAST  *\}
            TARGET(LOAD_CONST)  {\* implementation of LOAD_CONST *\}
            TARGET(BINARY_ADD)  {\* implementation of BINARY_ADD *\}
            ...
    }
}
```

C API

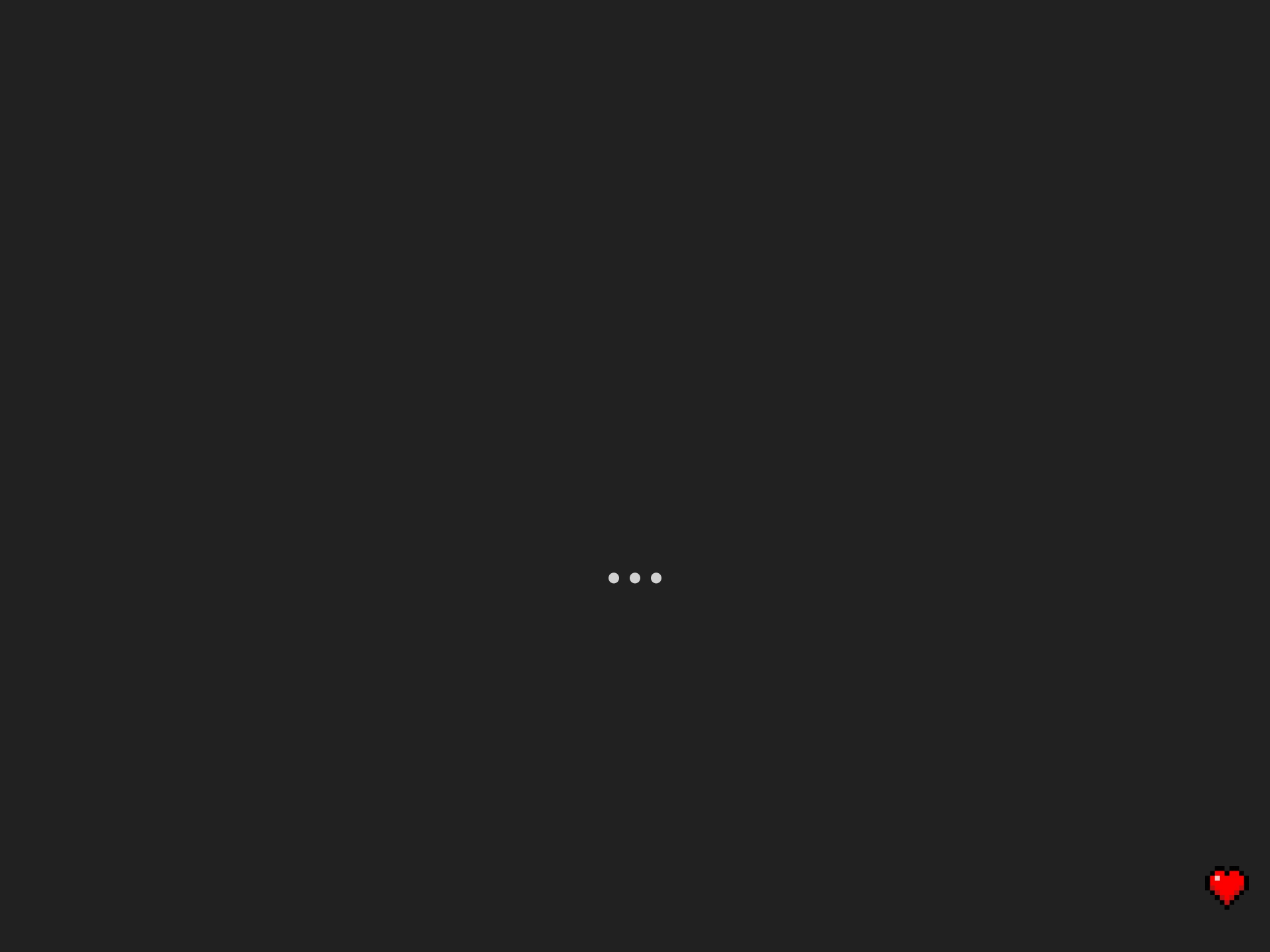
```
TARGET(BINARY_ADD) {
    PyObject *right = POP();
    PyObject *left = TOP();
    PyObject *sum;
    sum = PyNumber_Add(left, right);
    DISPATCH();
}
```

```
PyObject *
PyNumber_Add(PyObject *v, PyObject *w)
{
    PyObject *result = binary_op1(v, w, NB_SLOT(nb_add));
    ...
    return result;
}
```



```
static PyObject *
binary_op1(PyObject *v, PyObject *w, const int op_slot)
{
    PyObject *x;
    slotv = NB_BINOP(v->ob_type->tp_as_number, op_slot);
    x = slotv(v, w);
    return x;
}
```

```
PyTypeObject PyLong_Type = {
    PyVarObject_HEAD_INIT(&PyType_Type, 0)
    "int",
    offsetof(PyLongObject, ob_digit),
    sizeof(digit),
    ...
    &long_as_number,
    ...
};
```



Deadly sins of dynamic programming languages

late binding: a.tp_as_number.number_add

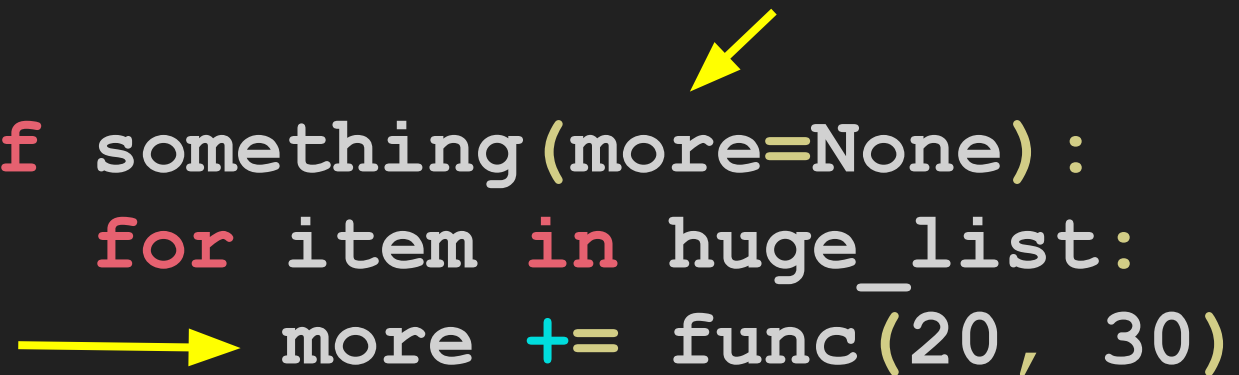
boxing: PyObject, PyType_...

vm overhead: stack, program counter

Late binding:

```
some_method = some_object.method
for value in huge_list:
    some_method(value)
```

Late binding:



```
def something(more=None):
    for item in huge_list:
        more += func(20, 30)
    return more
```

Boxing:

```
00100000000100101000111100000000
00000000000000000000000000000000
10000000000100101000111100000000
00000000000000000000000000000000
00001111000000000000000000000000
00000000000000000000000000000000
11100000111001001000100100000000
00000000000000000000000000000000
00000001000000000000000000000000
00000000000000000000000000000000
01100100000000000000000000000000
```

So, how to get rid of VM overhead?

Can we merge eval function and actual code somehow?

```
def abs(value):
    if value >= 0:
        return value
    else:
        return -1 * value
```

```
>>> dis.dis(abs)
  2           0 LOAD_FAST                0 (value)
              3 LOAD_CONST               1 (0)
              6 COMPARE_OP               5 (>=)
              9 POP_JUMP_IF_FALSE       16

  3          12 LOAD_FAST                0 (value)
             15 RETURN_VALUE

  5     >>   16 LOAD_CONST               3 (-1)
             19 LOAD_FAST                0 (value)
             22 BINARY_MULTIPLY
             23 RETURN_VALUE
```

```
def eval_frame(frame):
    stack = []
    code_counter = 0

    while code_counter < len(frame.code.co_code):
        opcode = frame.code.co_code[code_counter]
        if opcode == "LOAD_FAST":
            stack.append(frame.lookup_fast(argument))
            code_counter += 3
        elif opcode == "LOAD_CONST":
            stack.append(frame.code_object.get_const(argument))
            code_counter += 3
        elif opcode == "COMPARE_OP":
            value1 = stack.pop()
            value0 = stack.pop()
            comparator = get_comparator(argument)
            result = comparator(value0, value1)
            stack.append(result)
            code_counter += 2
        elif opcode == "BINARY_MULTIPLY"
            value1 = stack.pop()
            value0 = stack.pop()
            result = do_multiplication(value0, value1)
            stack.append(result)
            code_counter += 2
        ...
```

```
class BoxedValue:
    def __init__(self, value):
        self.low_level_value = value


class LongObject(BoxedObject):
    pass


class BoolObject(BoxedObject):
    pass
```

```
Direct manipulation is impossible:
result = LongObject(10) + LongObject(20)


Use object layer API instead:
result = add_value(
    LongObject(10), LongObject(20)
)
```

Can we merge eval function and actual code somehow?

```
def eval_frame_abs(frame):
    stack = []
    stack.append(frame.get_fast(0))
    stack.append(code.get_const(1))
    value0 = stack.pop()
    value1 = stack.pop()
    comparator = get_comparator(5)
    stack.append(comparator(value0, value1))
    if is_true(stack.pop()).low_level_value:
        stack.append(frame.get_fast(0))
        return stack.pop()
    else:
        stack.append(code.get_const(3))
        stack.append(frame.get_fast(0))
        value0 = stack.pop()
        value1 = stack.pop()
        stack.append(do_multiplication(value0, value1))
        return stack.pop()
```

```
def eval_frame_abs(frame):
    stack = []
    stack.append(frame.get_fast(0))
    stack.append(code.get_const(1))
    value0 = stack.pop()
    value1 = stack.pop()
    comparator = get_comparator(5)
    stack.append(comparator(value0, value1))
    if is_true(stack.pop()).low_level_value:
        stack.append(frame.get_fast(0))
        return stack.pop()
    else:
        stack.append(code.get_const(3))
        stack.append(frame.get_fast(0))
        value0 = stack.pop()
        value1 = stack.pop()
        stack.append(do_multiplication(value0, value1))
        return stack.pop()
```

```
def eval_frame_abs(frame):
    comparator = get_comparator(5)
    compare_result = comparator(
        frame.get_fast(0), frame.get_const(1)
    )
    if is_true(compare_result).low_level_value:
         return frame.get_fast(0)
    else:
         return do_multiplication(
                    code.get_const(3),
                    frame.get_fast(0)
                )
```

```
def eval_frame_abs(frame):
    comparator = get_comparator(5)
    compare_result = comparator(
        frame.get_fast(0), frame.get_const(1)
    )
    if is_true(compare_result).low_level_value:
         return frame.get_fast(0)
    else:
         return do_multiplication(
                    code.get_const(3),
                    frame.get_fast(0)
                )
```

```
def eval_frame_abs(frame):
    comparator = get_comparator(5)
    compare_result = comparator(
        frame.get_fast(0), frame.get_const(1)
    )
    if compare_result.low_level_value:
         return frame.get_fast(0)
    else:
         return do_multiplication(
                    code.get_const(3),
                    frame.get_fast(0)
                )
```

```
def eval_frame_abs(frame):
    comparator = get_comparator(5)
    compare_result = comparator(
        frame.get_fast(0), frame.get_const(1)
    )
    if compare_result.low_level_value:
         return frame.get_fast(0)
    else:
         return do_multiplication(
                    code.get_const(3),
                    frame.get_fast(0)
                )
```

```
def eval_frame_abs(frame):
    compare_result = gt_eq(
        frame.fast_variables[0], LongObject(0)
    )
    if compare_result.low_level_value:
         return frame.fast_variables[0]
    else:
         return do_multiplication(
                    LongObject(-1),
                    frame.fast_variables[0]
                )
```

```
def eval_frame_abs(frame):
    compare_result = gt_eq(
        frame.fast_variables[0], LongObject(0)
    )
    if compare_result.low_level_value:
        return frame.fast_variables[0]
    else:
        return do_multiplication(
                    LongObject(-1),
                    frame.fast_variables[0]
                )
```

```
def eval_frame_abs(frame):
    compare_result = gt_eq(
        frame.fast_variables[0], LongObject(0)
    )
    if compare_result.low_level_value:
        return frame.fast_variables[0]
    else:
        return do_multiplication(
                    LongObject(-1),
                    frame.fast_variables[0]
                )
```

```
def do_multiplication(value0, value1):
    if value0.type == value1.type == LongType:
        result = (
          value0.low_level_value * value1.low_level_value
        )
        return LongObject(result)
    elif ...


def gt_eq(value0, value1):
    if value0.type == value1.type == LongType:
        result = (
          value0.low_level_value >= value1.low_level_value
        )
        return BoolObject(result)
    elif ...
```

In this case types define control flow inside the object layer API functions.

```
someresult = abc(-20)
```

- Inline gt_eq and do_multiplication functions according to types.
- Unbox constant values.

this used to be boxed

```
def eval_frame_abs(frame):
    cmp_result = BoolObject(
      frame.fast_variables[0].low_level_value >= 0
    )
    if cmp_result.low_level_value:
        return frame.fast_variables[0]
    else:
        return LongObject(
                  -1*frame.fast_variables[0].low_level_value
                )
```

this used to be boxed

```
def eval_frame_abs(frame):
    cmp_result = BoolObject(
      frame.fast_variables[0].low_level_value >= 0
    )
    if cmp_result.low_level_value:
         return frame.fast_variables[0]
    else:
         return LongObject(
                  -1*frame.fast_variables[0].low_level_value
                )
```

```
def eval_frame_abs(frame):
    if frame.fast_variables[0].low_level_value >= 0:
        return frame.fast_variables[0]
    else:
        return LongObject(
                  -1*frame.fast_variables[0].low_level_value
                )
```

```
someresult = abc(-20)
```

```
def eval_frame_abs(frame):
    return LongObject(
        -1*frame.fast_variables[0].low_level_value
    )
```

How about inline caching?

```
cached_value = LongObject(20)


def eval_frame_abs(frame):
    return cached_value
```

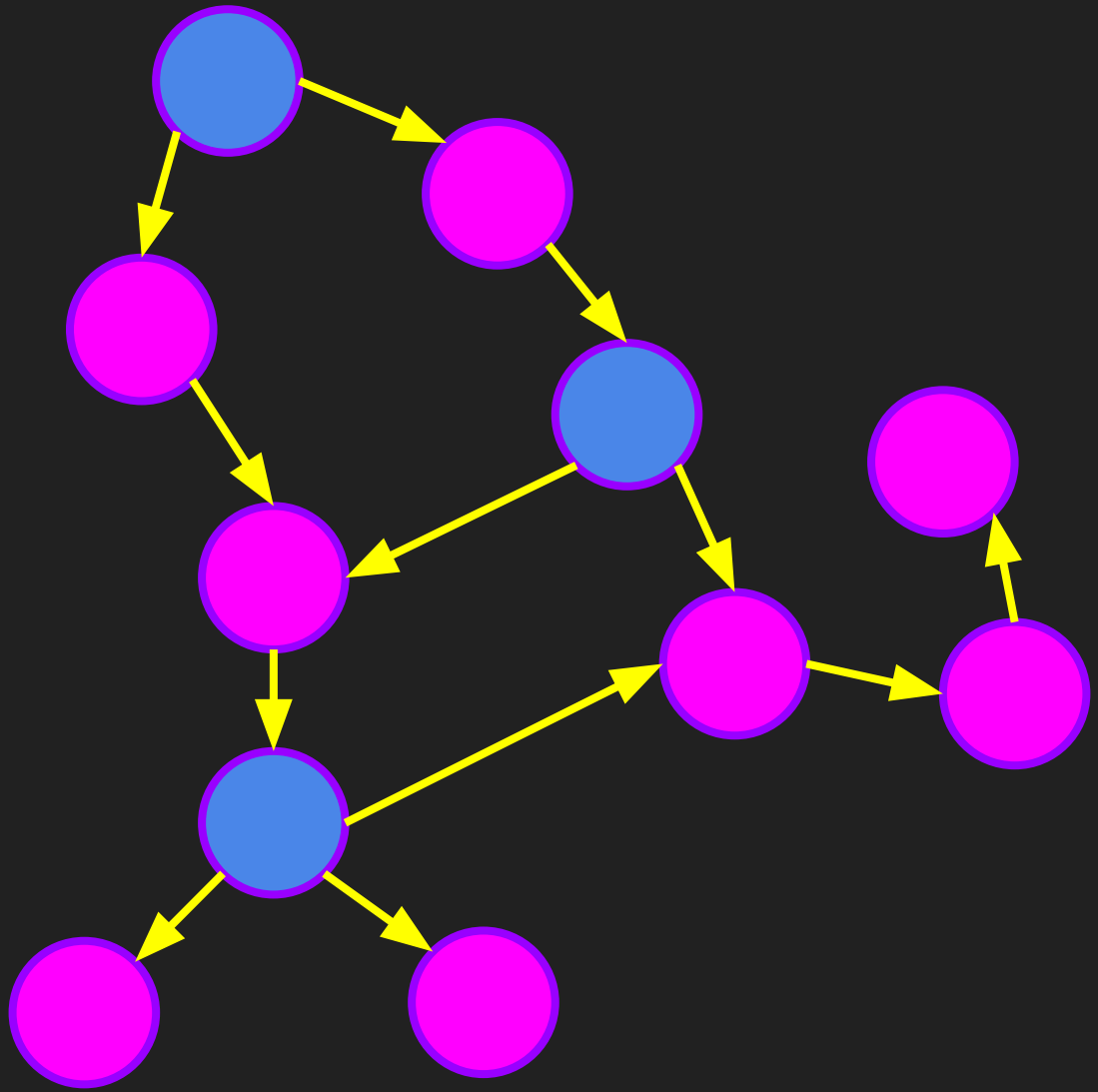
How about throwing code away?

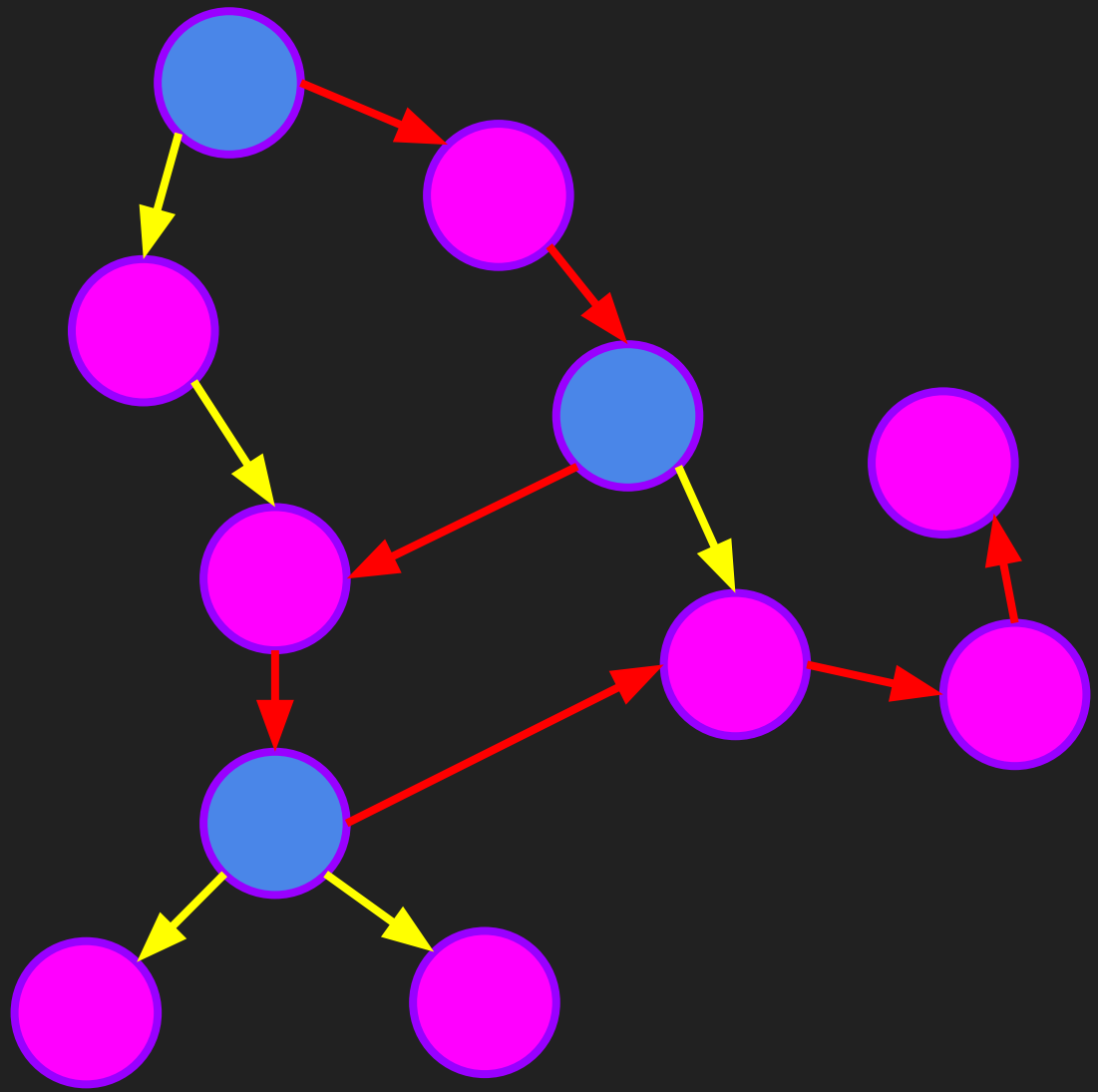
```
def eval_frame_abs(frame):
    pass
```

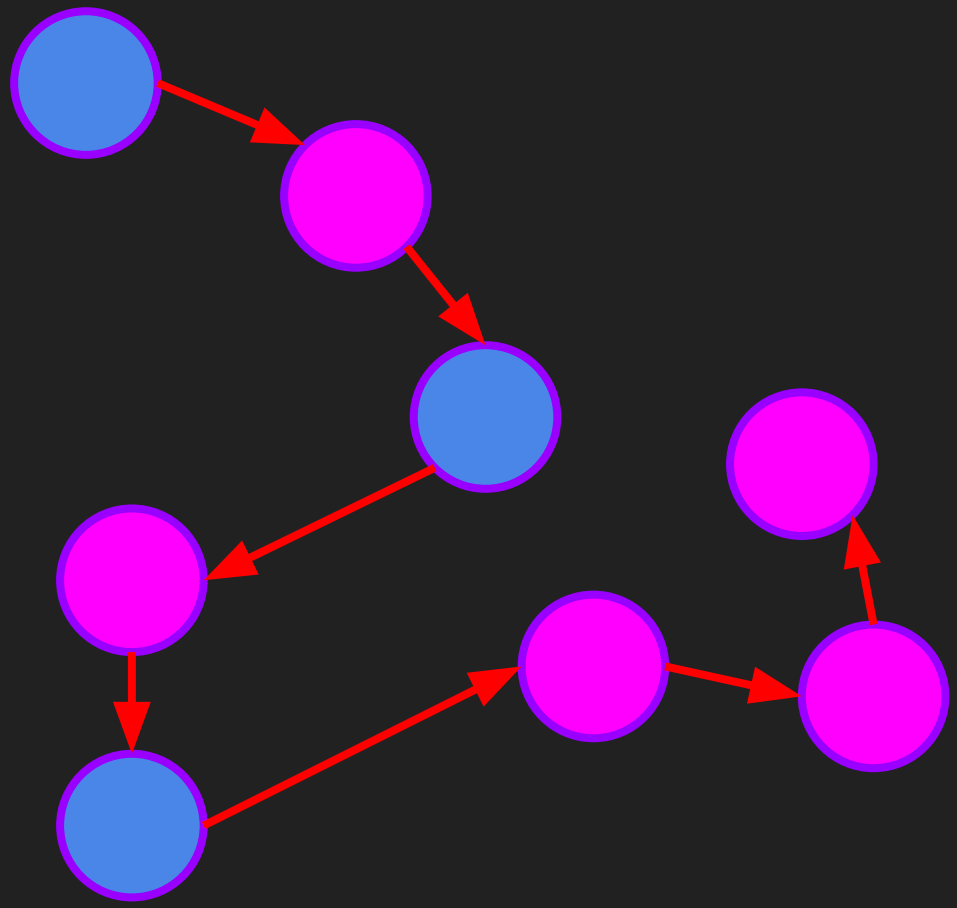
Sometime this happens, you never know...

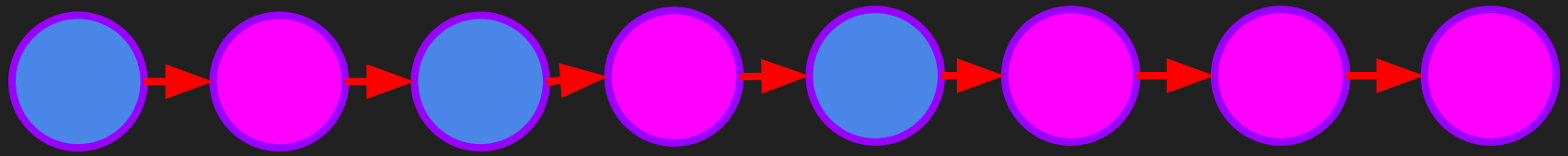
```
def abs(value):
    if value >= 0:
        return value
    else:
        return -1 * value


for value in range(10**9):
    abs(value)
```

So, in general









Conclusions

- Dynamic languages are slow intrinsically.
- Performance comes with specialization.
- Availability of runtime feedback in crucial.

:3