Implementing dynamic languages

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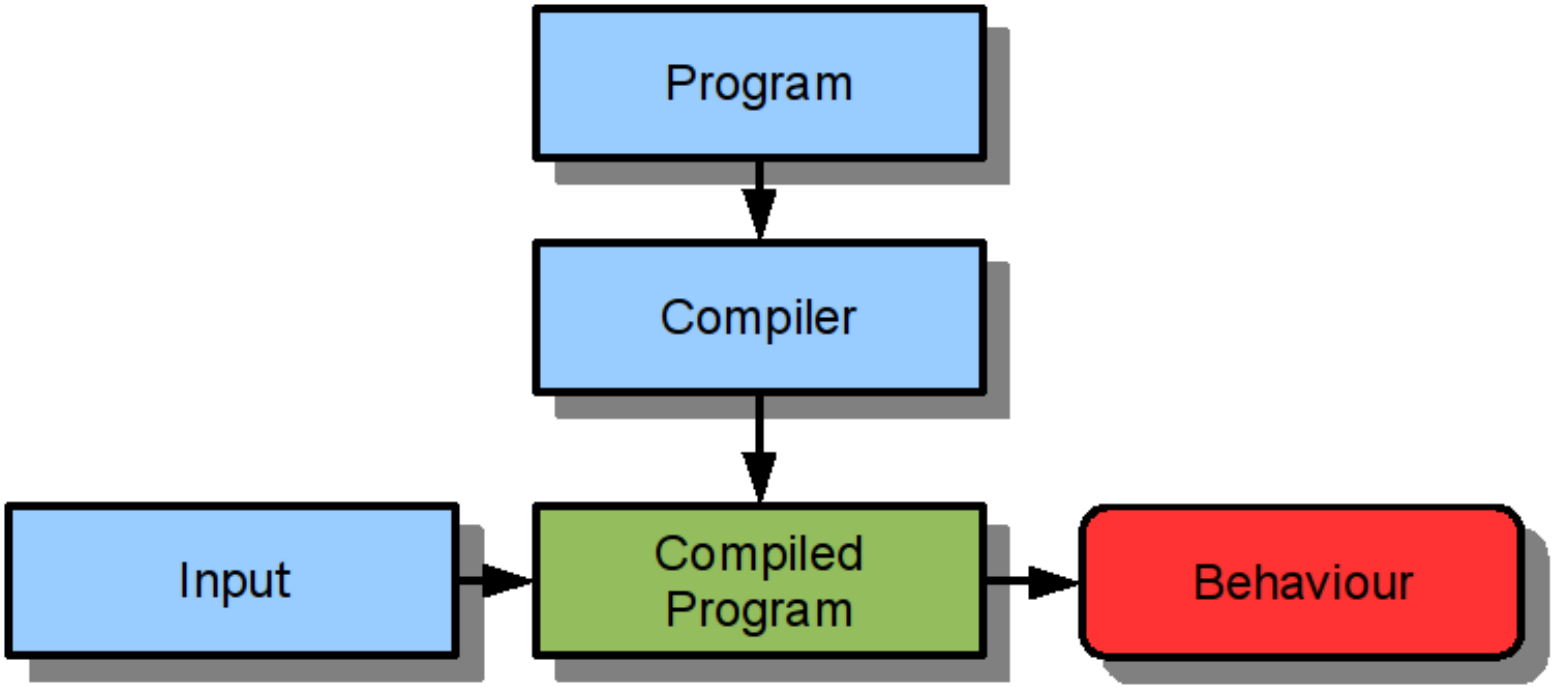
Overview

- Pure compilation
- Pure interpretation

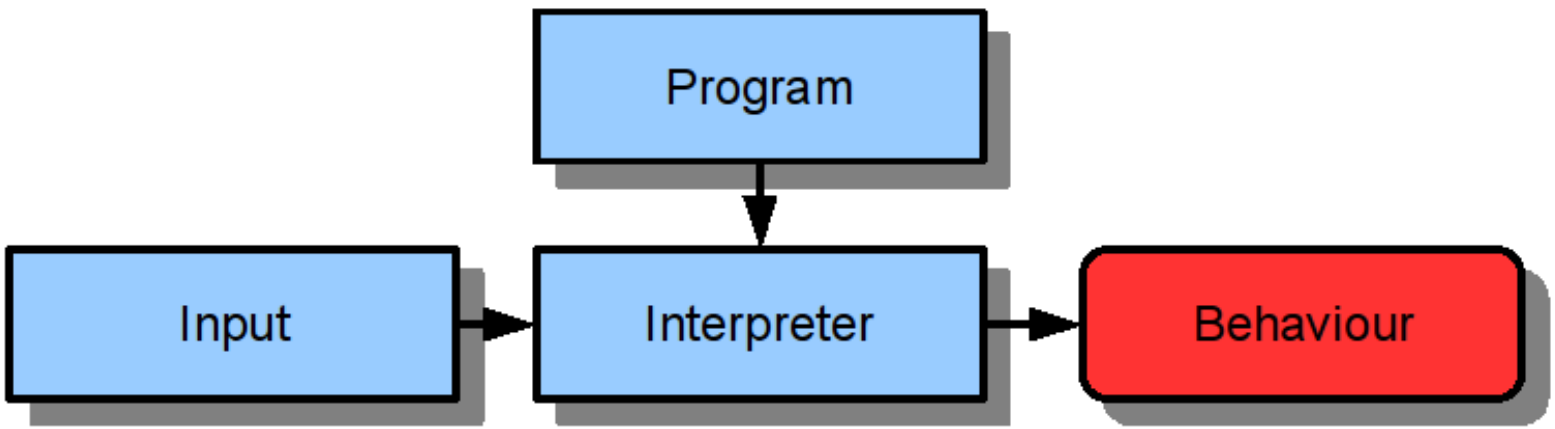
Pure compiler

Example: C, Pascal, ...



Pure interpreter

Example: some BASIC...



Hybrid approaches

It's a complete continuum. In practice:

- Interpretation typically analyze the source a bit
- Emulators interpret "compiled" code
- CPUs interpret compiled code anyway... or compile it
- JIT compilers

Dynamic languages

Dynamic languages cannot be fully compiled.

```
def sum(container, initial):
    result = initial
    for element in container:
        result = result + element
    return result
```

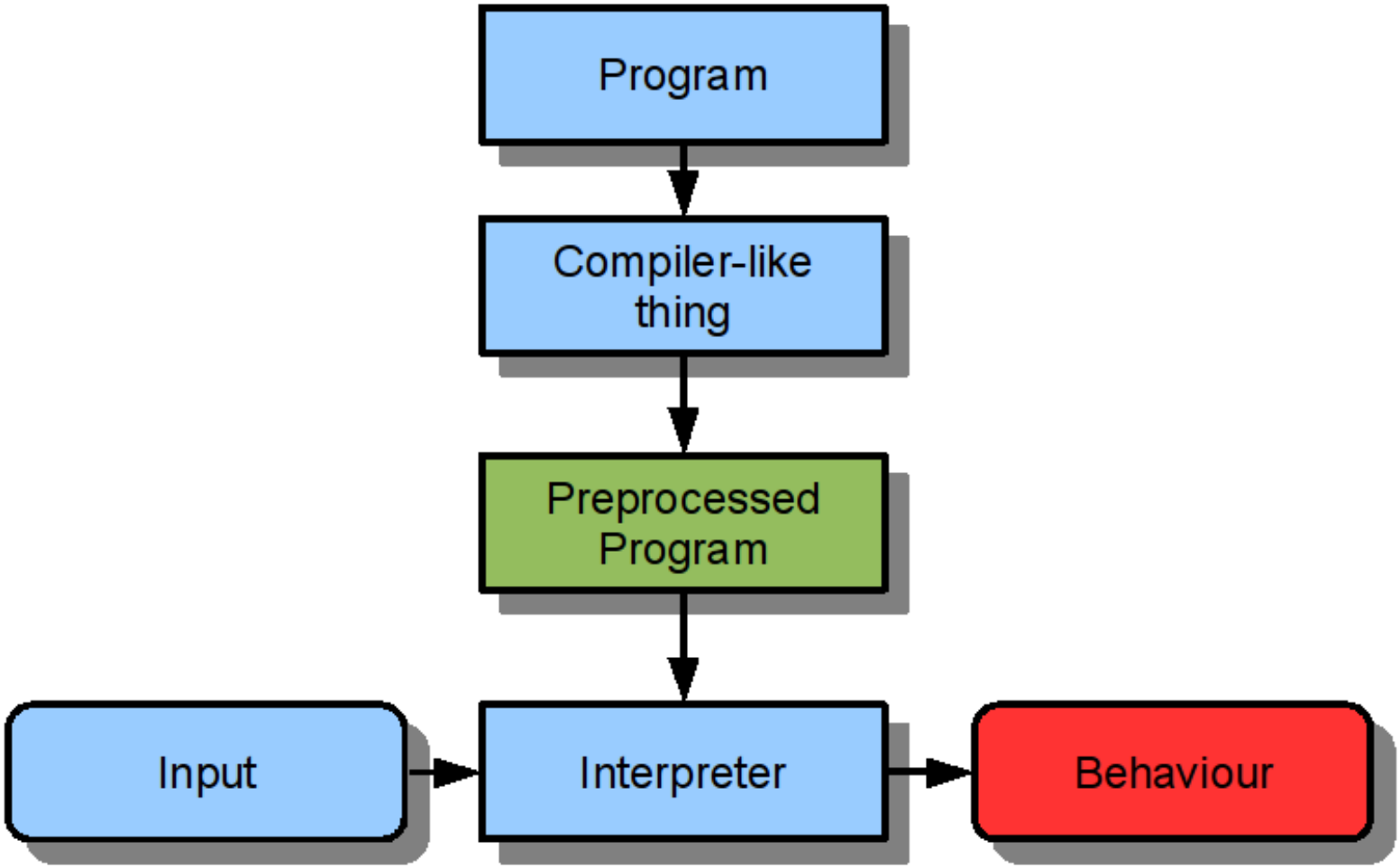
JIT compilers

Best approach for dynamic languages: we spend a lot of time in a small part of the code.

- for most of the code, interpreting is fine;
- for the rest, we compile a Just-In-Time version.

Quiz

Interpreters in practice



AST Interpreters

AST = Abstract Syntax Tree
Avoids continuous reanalysis of the source code.
See exercices :-)

AST Interpreters (2)

Upsides:

- avoids continuous reanalysis of the source code.
- simple to implement.

Downsides:

- complex data structure.
- lots of virtual calls to implement it.

Bytecode Interpreters

Turns the AST into “machine code” for a fictional processor.
Executes on top of a Virtual Machine, which plays the role of “emulator”.
“Machine code” here can be much higher level than real machine code.

Bytecode Interpreters (2)

Upsides:

- relatively fast to interpret.
- compact data structure (can be dumped to disk, etc.)

Downsides:

- a bit harder to implement.
- you need something compiler-like too.

Tiny example

```
def plus_minus(insns, x, y):
    acc = x
    pc = 0          # program counter
    while pc < len(insns):
        op = insns[pc]
        pc += 1
        if op == '+':
            acc += y
        elif op == '-':
            acc -= y
    return acc
```

Typical concepts

- Bytecodes
- Frames

In the frames:

- Program counter (pc)
- Stack
- Local variables

Python example (1)

```
def f(x):
    return x + 5
```

Python example (2)

```
def f(x):
    while x > 0:
        x = x - 10
    return x
```

Python bytecodes

- Operators: `BINARY_ADD`, `UNARY_NEGATIVE`, `LOAD_ATTR`...
- Stack handling: `POP_TOP`...
- Variables: `LOAD_FAST`, `STORE_FAST`...
- Control flow: `JUMP_ABSOLUTE`, `JUMP_IF_FALSE`...

SLF bytecodes

...

Object Models

When, What and How?

- The bytecode dispatcher is concerned with:
  - which operations to perform
  - in what order
- but how are operations performed?

The Object Model

- to actually perform operations, the *object model* is asked to do them
- clean separation of concerns:
  - *control flow*
  - *operation implementations*
- object model maps objects of the language to the implementation level

Levels

two languages involved in an interpreter:

- implemented language
- language the interpreter is written in

care is needed to not confuse those.
Terminology:

- application-level
- interpreter-level

Boxing

- Object Model strongly dependant on those two involved languages
- Very common element: *Boxing*
- boxing uses a small data structure to represent an app-level type
- commonly used for numerical types: ints, floats, bools, ...

Example: exercises

- object model: small hierarchy of classes
- boxing: `W_Integer`

How to be more efficient

- object models for prototypes need to be clever
- normally no sharing between similar objects
- can be circumvented by *maps*
- try to share bits of objects that have the same attributes

Example: PyPy

- Python implementation in Python (!)
- tries to be understandable

PyPy Architecture

clean separation between object model (called “object space”) and bytecode interpreter: