Python and Scripting for Games

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2. Types and Data Structures
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3. Control Flow
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8. Structuring
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Motivation

- Maybe C/C++ are not always the best languages?
- Example: we want a program that removes the old music on the MP3 player (pretend Itunes etc does not exist) and fill it with random new music (OGG, MP3)
- Tasks:
  - Mount the MP3 player
  - Remove old music
  - While space left:
    - Pick one random song (not repeated!), copy it to the MP3 player
  - Unmount the MP3 player again
- How many lines in C/C++? Maybe 200-400?
- How many lines in bash/awk?
  - **40 lines**, no segfaults, no recompiles

Motivation, II

- Another task: convert symbols to the MIPS-board format
- Tasks:
  - Read symbols and symbol names from the ELF-file
  - Write number of symbols/string table length to the outfile
  - For each symbol:
    - Write symbol address and strtab offset
  - For each string, write the string plus NULL-termination
- Not that suitable for shell-scripts: need to keep track of symbols, binary output
- C/C++: 300-400 lines?
- Python: **26 lines** (excluding usage() and option parsing), no segfaults, no recompiles

Motivation, III

```
f = os.popen("nm %s" % (infile))
for line in f: # Read all symbols
    sym = Symbol(int( line.split()[0], 16 ), line.split()[1], line.split()[2])
    strtab_len = strtab_len + len(sym.symbol) + 1
    symbol_table.append(sym)
f.close()

f = open(outfile, "wb") # Write out to file
f.write(struct.pack(">L",len(symbol_table)))
f.write(struct.pack(">L",strtab_len))
cur_offset = 0
for sym in symbol_table: # Write the symbols
    sym.strtab_offset = cur_offset
    f.write(struct.pack(">L",sym.strtab_offset))
    f.write(struct.pack(">L",sym.address))
    cur_offset = cur_offset + len(sym.symbol) + 1
for sym in symbol_table: # Write 8 unknown bytes for each symbol
    f.write(struct.pack(">L",0))
    f.write(struct.pack(">L",0))
for sym in symbol_table: # Write the strings
    f.write(sym.symbol)
    f.write(struct.pack("b", 0))
f.close()
```


Python Introduction

- Python was invented by Guido van Rossum (Netherlands) in the early 1990s
- Interpreted, dynamically typed, object-oriented very high-level language, compiles to bytecode
- Close to pseudo code, indentation marks block structure
- Popular for application development on its own
- Used as scripting language in many applications and games
  - Gimp
  - Eve Online
  - Battlefield 2
  - ...
- Resources
  - `http://diveintopython.org` - free book
  - `http://www.thinkpython.com` - how to think like a computer scientist

Basics **00.basics/basics.py**

Description

- **Variables do not need declaring in Python**
- Strings, integers, boolean and floating point types are builtin
- **Multiple assignment is possible**
- `print` **is used to printout**

Examples

```
>>> var = 128                   # assignment, var is an int
>>> var = "var is now a string"    # assignment, var is now a string
>>> print var
var is now a string
>>> a = 64 * 48.0               # arithmetic, as expected
>>> b = 5**2.2                  # Python supports power-of directly
>>> c = "chico " + "chica"      # Arithmetic with strings
>>> a,b = 1040, 130             # multiple assignment
>>> print "Numbers are %.3f, %d" % (a,b) # printf style formatting
Numbers are 1040.000, 130
```


Basics, types **00.basics/basics.py**

Description

- `int(`*val*`[,`*base*`])` converts to an integer (of base *base*)
- `float(`*val*`)`: Corresponding to floats
- `str(`*val*`)`: Corresponding to strings (classes allow this automatically)
- `type(`*x*`)` **returns the type of a variable (also classes)**

Examples

```
>>> b = int("15") + int("0xf", 16) # to int, base 10 and base 16
>>> s = "hej is " + str(True)
>>> type(s)
<type 'str'>
if type(s) == str:
    print "s is a string!"
```


Data structures in Python

- Python also has built-in support for data structures such as lists, dictionaries, tuples and sets
  - Lists: can be used as lists, stacks and queues
  - Dictionaries: associative memories (e.g., hash tables)
  - Tuples: e.g., coordinate-pairs
  - Sets: unordered collection of unique items
- All these can store arbitrary types
- These helps tremendously when writing more complex things

Lists **01.lists/lists.py**

Description

- Lists are enclosed in brackets
- The lists are classes, which provide methods such as `append(`*obj*`)`, `extend(`*list*`)`, `insert(`*idx*`,`*obj*`)` and *pop()*
- The `len(`*list*`)` builtin returns the number of list items
- **"Slicing"** is used to get parts of lists
- The `in` operator tests if an element is in a list

Example

```
a = [64, "hej", 130, 20] # Declare a list with some elements
a.append(48)             # Append an item
print a[1:2]             # print a sliced list with item 1-2
a.sort()                 # Sort the list
print 64 in a            # Check if 64 is a member of a
```

Dictionaries

Description
- A dictionary stores key:value pairs
- Dictionaries provide fast lookup of values

Example
```
>>> d = {"a":19}         # Create a dictionary with a:19
>>> d[1040] = "Cubase"   # Key 1040 with value "Cubase"
>>> print d.values()     # Print a list of values in the dictionary
[19, 'Cubase']
>>> print d.keys()       # Print a list of keys in the dictionary
['a', 1040]
```


Control Flow 03.control_flow/control_flow.py

Description
- Python supports the usual control flow primitives, **if**, **for** and **while**
- Block structure is marked by indentation
- **if** and **while** works the same way as in C

Definition
```
if CONDITION:
   STATEMENTS
elif CONDITION:  # to avoid excessive indentation with else, if
   STATEMETNTS
else:
   STATEMENTS

while CONDITION:
   STATEMENTS
else:
   STATEMENTS    # Run once when the condition is no longer true
```


For-loops 03.control_flow/control_flow.py

Description
- **for**-loops work differently in Python compared to C
- Instead, the loop iterates over items in a list

Definition
```
for ITEM in LIST:   # Each ITEM in LIST
    STATEMENTS      # Perform something on ITEM
else:               # Run once after the iterations, except on break
    STATEMENTS
```

Example
```
b = [48,128,130,500]
for item in b:               # Iterate over items in b
    print "Cur item:", item
for num in range(0,3):       # Range generates the list [0,1,2]
    print "Nr: ", num
```


Modules 05.modules/modules.py

Description
- Python modules are libraries
- **import** is similar to **#include** in C/C++
- `sys.path` (in the sys module) defines where to look for modules

Definition
```
import MODULE
from MODULE import ITEM, ITEM2 # Import
```

Example
```
import math                  # Import the math library
print math.pi                # Access "pi" in the math module
from math import pi, cos     # Specific functions
print pi, cos(pi)
from math import *           # Everything from math (careful!)
```


Functions 04.functions/functions.py

Description
- Python functions are defined with **def**
- Parameters can have default values
- **return** is used to return from a function

Definition
```
def NAME( LIST OF PARAMETERS ):
    "Documentation string"       # Optional
    STATEMENTS
```

Example
```
def func(x, y = 64):            # y has a default value
    return x + y, x / y         # several return values is possible

a,b = func(48)
c,d = func(48,128)
x   = func(64)                  # What will x be?
```


Classes, introduction

Definition
- Python classes support multiple inheritance, polymorphism etc.
- All member functions are virtual (in C++-terms)
- There is no data protection, members do not need to be defined
- How does Python handle structs?

Example
```
class Coord:             # Define the Coord class
      pass               # ... which is empty

p = Coord()              # New instance of the Coord class
p.x = 128                # Give the members some values
p.y = 48
```

Classes, basics — 06.classes/classes.py

Definition

- The `__init__` function is the constructor in Python
- `self` corresponds to `this` in C++
- **Derived classes** are specified after the class name
- **Note the call of the superclass constructor**

Example

```
class Entity:
    """Docstring for the class."""        # """ for multi-line strings
    def __init__(self, sprite, x=0, y=0):
        self.pos = Vector(x,y)
        ...

class MovableEntity(Entity):
    def __init__(self, sprite, vel, max_speed, x=0, y=0):
        Entity.__init__(self, sprite, x, y)
```


Classes, operators — 06.classes/operator.py

Definition

- Overriding operators is done with the `__add__`, `__mul__` (...) functions
- `__str__` is used to get the string representation of a class
- `__getitem__` is used for accesses with brackets (`[]`)

Example

```
class Vector:
    def __init__(self, x,y):
        self.x = x
        self.y = y
    def __add__(self, other):
        return Vector(self.x + other.x, self.y + other.y)
    def __str__(self):
        return str(self.x) + " " + str(self.y)
    def __getitem__(self, obj):
        if type(obj) != int:
            return None                                  # Should raise an exception
        if obj == 0:
            return self.x
        elif obj == 1:
            return self.y
        return None                                      # Should raise an exception
```


Exceptions — 07.exceptions/exceptions.py

Description

- Exceptions are catched with the `try`/`except` pair in Python
- Exceptions are classes and can be inherited from just like other classes
- `raise` raises an exception

Example

```
try:
    16 / 0
except ZeroDivisionError, detail:
    print "Ouch! Got an exception:", detail
class CorrectNumberException(Exception):
    def __str__(self):
        return "The supplied number is not one of the allowed numbers"

def testNum(num):
    if num not in [16,20,48,64,128,130,500,520,1000,1040,2000]:
        raise CorrectNumberException
```


Iterators, generators

Description

- **for** calls the `iter` function on a class to get an iterator object and then `next` to get the next item
- The `StopIteration` exception is raised when the items are up
- `__iter__` returns an iterator

Example

```
class Reverse:
    "Iterator for looping over a sequence backwards"
    def __init__(self, data):
        self.data = data
        self.index = len(data)
    def __iter__(self):
        return self
    def next(self):
        if self.index == 0:
            raise StopIteration
        self.index = self.index - 1
        return self.data[self.index]
```


Complete example — 06.classes/classes.py

Example

```
class Entity:
    obj_id=0                                     # Class-global variable (static member in C++)
    def __init__(self, x=0, y=0):
        self.pos = Vector(x,y)
        self.obj_id = Entity.obj_id
        Entity.obj_id = Entity.obj_id + 1
    def draw(self):
        pass

class MovableEntity(Entity):
    def __init__(self, vel, max_speed, x=0, y=0):
        Entity.__init__(self, x, y)              # Call the constructor of the base class
        self.vel = vel
        self.max_speed = max_speed
        self.mass = 10                           # How heavy this object is
    def seek(self):
        if self.aim_for_target == self.pos:
            return Vector(0,0)
        desired_vel = (self.aim_for_target - self.pos).norm() * self.max_speed
        return desired_vel - self.vel
    def update(self, frame_time):                # Time in fractions of a second
        accel = (self.seek() / self.mass) * frame_time
        self.vel = self.vel + accel * frame_time
        self.pos = self.pos + self.vel * frame_time

while True:                                      # The would-be game loop
    for e in entity_list:
        e.update(frame_time)
        e.draw()
```


File reading — 08.files/files.py

Description

- **Opening and closing files are similar to C**
- There are more convenience functionsfor reading and writing
- **Pickling allows saving and loading objects and classes automatically**
  - Loading and saving objects becomes *much* easier!

Example

```
f = open("files.py", "r")
for line in f.readlines():
    print line
f.close()

f = open("pickle", "w")
e = Entity("meboo", 16, 0)
pickle.dump(e, f)
f.close()
...
e = pickle.load(f)
```

Interfacing Python with C

- There are two ways of interfacing Python with C/C++: **manually** or through an **interface-generator**
- Manual implementation gives you more control, but is much more tedious
  - Handling of reference counting etc., is manual
- There are many interface generators for Python: SWIG, boost, CXX etc.
- Boost: C++-only, Python only, easier to call Python from C++
  - Used by Civilization IV
- SWIG: Supports C and C++, bindings for many languages (Python, Lua, ...). Calling Python from C/C++ is slightly harder.
  - Used by, e.g., the Ogre 3D engine

SWIG introduction

09.swig/first/

Description

- `%module NAME` defines a new module (namespace)
- `%{` and `%}` contains things included verbatim in the wrapper file
- The rest of the file **defines the interface to export**
- Running **swig -python** on this file generates a `testing_wrap.c` and a `testing.py` file
- SWIG maps basic types (ints, strings, floats) to corresponding types in Pyhon - everything else is handled through pointers (references)

Example (example.i)

```
%module example
%{
#include "game.h"                    /* This is included in the generated wrapper */
%}
int testing(int a, int b);
```


SWIG, C++

09.swig/cpp

Description

- C++ classes can be wrapped by SWIG
- Most functionaly "just works" with the wrapped class
- **You can derive Python classes from C++ classes**
- **Overriding member functions** is also possible

Example (C)

```
class Entity
{
public:
  Entity(char *sprite, int x, int y);
  ~Entity();

  void draw(void);
  void update(double seconds);

  double x,y;
};
```

Example (Python)

```
class PythonEntity(Entity):
    def draw(self):
        print "draw: Python: ", self.x, self.y

e = Entity("bruce", 0, 0)
b = PythonEntity("monty", 64, 64)  # Uses the C++ __init__

e.update(0.3)                      # Will call C++
e.draw()
b.update(0.3)                      # Will call C++
b.draw()                           # Will call Python
```


SWIG, Internals

Description

- SWIG generates two files on compilation of an interface
  - C/C++ wrapper file - proxy class
  - Python wrapper file - Python to C/C++

Example (example_wrap.cc)

```
static PyObject *_wrap_Entity_draw(PyObject *, PyObject *args) {
    PyObject *resultobj;
    Entity *arg1 = (Entity *) 0 ;
    PyObject * obj0 = 0 ;

    if(!PyArg_ParseTuple(args,(char *)"O:Entity_draw",&obj0)) goto fail;
    SWIG_Python_ConvertPtr(obj0, (void **)&arg1, SWIGTYPE_p_Entity, SWIG_POINTER_EXCEPTION | 0);
    if (SWIG_arg_fail(1)) SWIG_fail;
    (arg1)->draw();

    Py_INCREF(Py_None); resultobj = Py_None;
    return resultobj;
    fail:
    return NULL;
}
```


Interacing, Overview

Description

- Including `Python.h` and linking with Python libraries is necessary
- You might need to set the include path
- Almost all functions in the Python/C API deals with `PyObject` pointers
- Reference counting must be handled from C manually

Example

```
Py_Initialize();
PyRun_SimpleString("import sys");
PyRun_SimpleString("sys.path.append('')");
...
Py_Finalize();
```


Interfacing, C-Python

10.c-api/python-from-c

Python Code

```
def adder(a,b):
    return a + b
```

Calling through wrapper

```
/* Open the module */
p_module = PyImport_ImportModule("script");

if (!(p_dict = PyModule_GetDict(p_module)))
  python_error("Dictionary");

/* Call the Python function */
p_res = call_adder(p_dict, 5, 6);
if (p_res) {
  printf("res: %ld\n", PyInt_AsLong(p_res));
  Py_DECREF(p_res);
}
Py_DECREF(p_dict);
Py_DECREF(p_module);
```

C implementation

```
PyObject *call_adder(PyObject *p_dict, int a, int b) {
  PyObject *p_func = PyDict_GetItemString(p_dict, "adder");
  /* Borrowed reference */

  if (p_func && PyCallable_Check(p_func)) {
      PyObject *p_args;
      PyObject *p_value;

      /* Construct objects from the format string below */
      p_args = Py_BuildValue("ii", a, b);
      if ( !p_args )
          python_error("Cannot convert argument");

      p_value = PyObject_CallObject(p_func, p_args);
      Py_DECREF(p_args); /* We are done with Args */

      return p_value;
    }

  return NULL;
}
```

Interfacing, Python-C — 10.c-api/c-from-python

C, function

```
static int subber(int a, int b) {
  return a - b;
}
```

Python Code

```
import seemodule

print seemodule.subber(20,16)
```

C, setup

```
static PyMethodDef module_methods[] = {
  { "subber", HAPI_subber, METH_VARARGS, "..." },
  { NULL, NULL, 0, NULL }
};

/* This function MUST be named like this */
PyMODINIT_FUNC initseemodule(void) {
  Py_InitModule("seemodule", module_methods);
}
```

C wrapper

```
PyObject *HAPI_subber(PyObject *self, PyObject *args) {
  int ret, a, b;

  /* Parse the tuple we got */
  if ( !PyArg_ParseTuple(args, "ii", &a, &b) )
    return NULL;
  ret = subber(a, b);

  return Py_BuildValue("i", ret);
}
```

C, main

```
int main(int argc, char *argv[]) {
  Py_Initialize();

  initseemodule();

  PyRun_SimpleString("import sys");
  PyRun_SimpleString("sys.path.append('')");
  PyRun_SimpleString("import main");

  Py_Finalize();
}
```

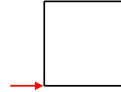

Python Bytecode

Description

- Python bytecode is stack-based, references pushed on the stack

Python function

```
def func3(x, y = 64, z = 128):
    return x + y, z + x
```



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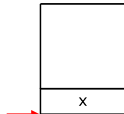

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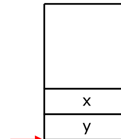

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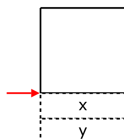

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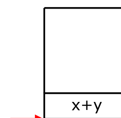

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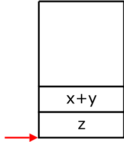

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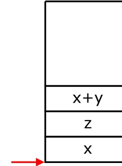

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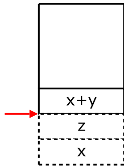

Python Bytecode

Description

- Python bytecode is stack-based, references pushed on the stack

Python function

```
def func3(x, y = 64, z = 128):
    return x + y, z + x
```

Bytecode

```
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 6 BINARY_ADD
 7 LOAD_FAST            2 (z)
10 LOAD_FAST            0 (x)
13 BINARY_ADD
14 BUILD_TUPLE          2
17 RETURN_VALUE
18 LOAD_CONST           0 (None)
21 RETURN_VALUE
```


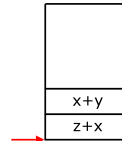

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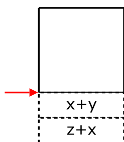

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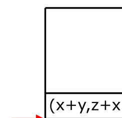

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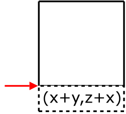

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Garbage collection and reference counting

- Python uses reference counting
  - A count is increased for each new reference to an object, decreased when it is released
  - However, with cycles, reference counting is not enough
- Garbage collection is used for cylces in references
- Garbage collection is known to be a problem for real-time performance
  - Python therefore provides a means to control the garbage collection in the gc module

Why Game Scripting?

- Martin Bronlow, "Game Programming Golden Rules": Non-programmers should be able to add content to a game
- Scripting allows the game engine to become more extensible
- ... but performance can be a problem with interpreted languages

Desired Features from a Scripting System

Martin Bronlow, "Game Programming Golden Rules":

- Easy to understand and create
- Dynamically loaded
- Safe, not crash the game
- Multitasking
- Debuggable
- Expandable
- Not be able to break the game engine

Structuring

- A game implemented with scripting can be implemented in different ways
- One way is to use the scripting system as an add-on to the game engine
  - The game is still centered around the (probably) C++ implementation
  - Scripting defines behavioral patterns etc.
- Another way is to center the implementation around the scripting implementation
  - The C++ implementation is then a "library"
  - Only performance-critical parts are implemented in C++

Micro-threading

Description

- Harry Kalogirou, Sylphis3D Game Engine (uses *Stackless Python*)
  - http://harkal.sylphis3d.com/2005/08/10/multithreaded-game-scripting-with-stackless-python/
- "The game engine is the operating system of the game"
- Actions / events

Example

```
def close(self):
    try:
        self.setVelocity(self.mMoveVelocity)
        self.sleep(self.mCloseMoveTime)
    except CCollition, col:
        print "Oups.. sorry", col.name
    self.setVelocity(CVector3.ZERO)
```

Humongous Entertainment (now Atari)

- Bruce Dawson (GDC 2002)
- Humongous used SCUMM before
  - Well-suited to adventure games
  - Not very general
- Humongous uses Python for the main game engine, using C++ for perforamce-critical tasks
- They use a custom interface generator, similar to SWIG and also wrote an in-house debugger
- Garbage collection is done at the end of each level and they use a custom memory allocator for Python
- Humongous found that Python increased productivity with no noticable performance loss

Quiz!

Quiz: Can you find the hidden code in the Python examples?

Questions?