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Berlin Python Meetup

Optimize Python code using Cython

Disclaimer

- I am not expert on Cython
- There is more than one way to use cython, I will just show a few of them
- English isn't my native language so feel free to correct me
- https://github.com/tzulberti/charlas

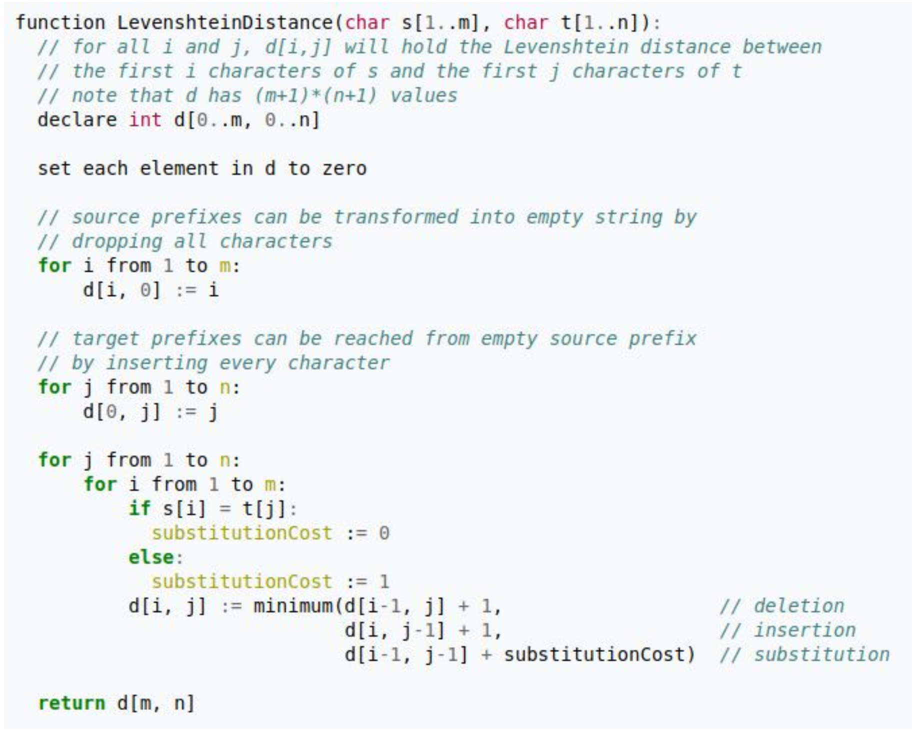
Levenshtein Distance

- The **Levenshtein distance** between two words is the minimum number of single-character edits (insertions, deletions or substitutions) required to change one word into the other.

Levenshtein Distance

- **k**itten → **s**itten (substitution of "s" for "k")
- sitt**e**n → sitt**i**n (substitution of "i" for "e")
- sittin → sittin**g** (insertion of "g" at the end).

Levenshtein Distance



```
function LevenshteinDistance(char s[1..m], char t[1..n]):
  // for all i and j, d[i,j] will hold the Levenshtein distance between
  // the first i characters of s and the first j characters of t
  // note that d has (m+1)*(n+1) values
  declare int d[0..m, 0..n]

  set each element in d to zero

  // source prefixes can be transformed into empty string by
  // dropping all characters
  for i from 1 to m:
      d[i, 0] := i

  // target prefixes can be reached from empty source prefix
  // by inserting every character
  for j from 1 to n:
      d[0, j] := j

  for j from 1 to n:
      for i from 1 to m:
          if s[i] = t[j]:
            substitutionCost := 0
          else:
            substitutionCost := 1
          d[i, j] := minimum(d[i-1, j] + 1,                   // deletion
                             d[i, j-1] + 1,                   // insertion
                             d[i-1, j-1] + substitutionCost)  // substitution

  return d[m, n]
```

C Code

```c
#define MIN3(a, b, c) ((a) < (b) ? ((a) < (c) ? (a) : (c)) : ((b) < (c) ? (b) : (c)))

// taken from https://en.wikibooks.org/wiki/Algorithm_Implementation/Strings/Levenshtein_distance#C
int levenshtein(char *s1, char *s2) {
    unsigned int x, y, s1len, s2len;
    s1len = strlen(s1);
    s2len = strlen(s2);

    unsigned int matrix[s2len+1][s1len+1];
    matrix[0][0] = 0;

    for (x = 1; x <= s2len; x++)
        matrix[x][0] = x;
    for (y = 1; y <= s1len; y++)
        matrix[0][y] = y;

    for (x = 1; x <= s2len; x++)
        for (y = 1; y <= s1len; y++)
            matrix[x][y] = MIN3(
                matrix[x-1][y] + 1,
                matrix[x][y-1] + 1,
                matrix[x-1][y-1] + (s1[y-1] == s2[x-1] ? 0 : 1)
            );

    return (matrix[s2len][s1len]);
 }
```

Python Code

```
def levenshtein(seq1, seq2):
    size_x = len(seq1) + 1
    size_y = len(seq2) + 1
    matrix = [[0] * size_y for _ in range(size_x)]

    for x in range(size_x):
        matrix[x][0] = x
    for y in range(size_y):
        matrix[0][y] = y

    for x in range(1, size_x):
        for y in range(1, size_y):
            if seq1[x - 1] == seq2[y - 1]:
                substitution_cost= 0
            else:
                substitution_cost= 1

            matrix[x][y] = min(
                matrix[x - 1][y] + 1,   # deletion
                matrix[x][y- 1] + 1,   # insertion
                matrix[x - 1][y - 1] + substitution_cost,  # substitution
            )

     return matrix[size_x - 1][size_y - 1]
```

Other files

- There is a **main.py** file that reads the file into memory
- The levenshtein function is on a file called **difference.py**

Benchmark

- Use a list of english words
- Create different files with different set of files of tuples of that word
- Create a main function that read the file into memory and executes the Levenshtein function

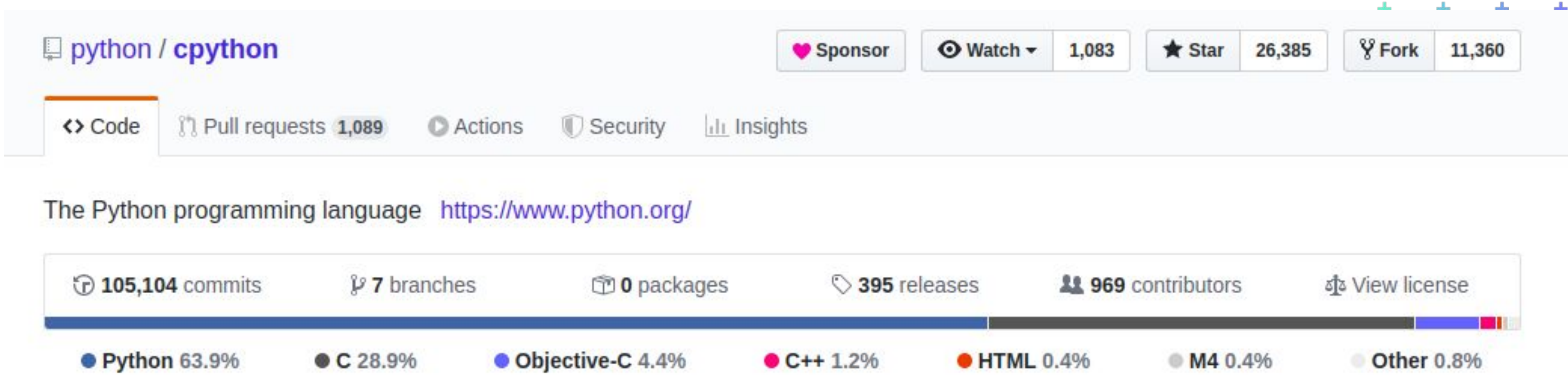
Running first Benchmark

Number of Comparisons	C	Python
29.159	0.009	1.344
58.318	0.017	2.743
116.637	0.035	5.376
233.274	0.065	8.998

Python is at least 150 times slower than C

Using C code from Python

- When we run python what we are using a Python interpreter that has some parts of the code in C



python / cpython

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Code | Pull requests 1,089 | Actions | Security | Insights

The Python programming language https://www.python.org/

105,104 commits | 7 branches | 0 packages | 395 releases | 969 contributors | View license

● Python 63.9% ● C 28.9% ● Objective-C 4.4% ● C++ 1.2% ● HTML 0.4% ● M4 0.4% ● Other 0.8%

Writing C code

```c
#include <Python.h>

static PyObject *
greet_name(PyObject *self, PyObject *args)
{
    const char *name;

    if (!PyArg_ParseTuple(args, "s", &name))
    {
        return NULL;
    }

    printf("Hello %s!\n", name);

    Py_RETURN_NONE;
}

static PyMethodDef GreetMethods[] = {
    {"greet", greet_name, METH_VARARGS, "Greet an entity."},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef greet =
{
    PyModuleDef_HEAD_INIT,
    "greet",     /* name of module */
    "",          /* module documentation, may be NULL */
    -1,          /* size of per-interpreter state of the module, or -1 if the module keeps state in global variables. */
    GreetMethods
};

PyMODINIT_FUNC PyInit_greet(void)
{
    return PyModule_Create(&greet);
}
```

Introducing Cython

- It makes writing C extensions for Python as easy as Python itself.
- The C code can only be executed inside a Python interpreter
- Installation

```
pip install cython

apt-get install python-dev python3-dev build-essential
```

Cythonizing Python Code

```
$ ls -1
difference.py
main.py

$ cythonize --inplace difference.py

Compiling .../difference.py because it changed.
[1/1] Cythonizing .../difference.py
running build_ext
building 'difference' extension

… Some text ..

$ ls -1
 difference.c
 difference.cpython-36m-x86_64-linux-gnu.so
 difference.py
 main.py
```

Cythonizing Python Code

```
$ python
Type "help", "copyright", "credits" or "license" for more information.
>>> import difference
>>> difference.__file__
'/home/.../cython-first-version/difference.cpython-36m-x86_64-linux-gnu.so'
>>> difference.levenshtein('foo', 'bar')
3
```

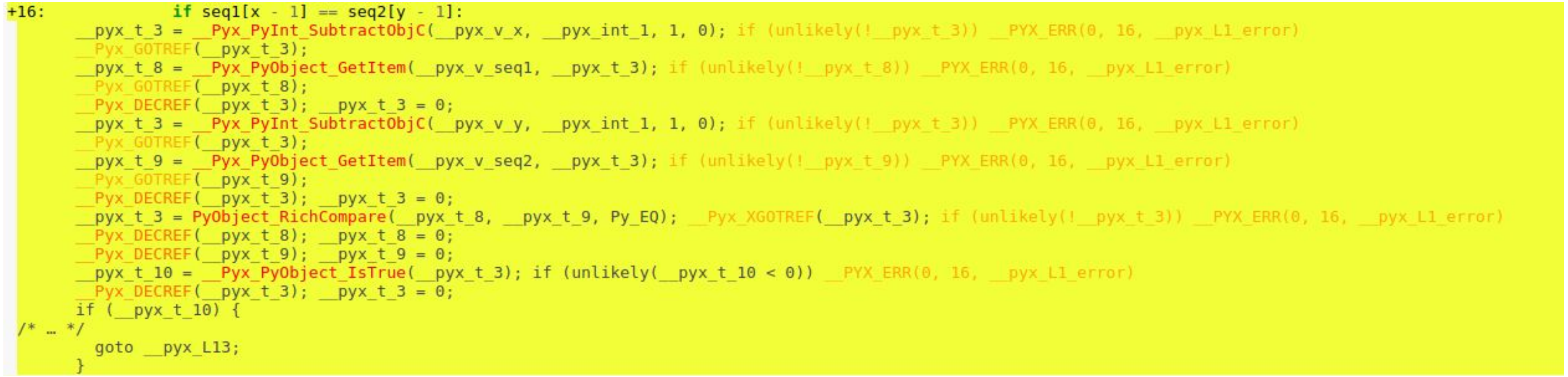
Checking Generated Code

```
$ wc -l *
  4731 difference.c
    27 difference.py
    26 main.py
  5272 total
```

Checking Generated Code

```
$ cython --annotate difference.py

$ chromium-browser difference.html
```



```
+16:             if seq1[x - 1] == seq2[y - 1]:
      __pyx_t_3 = __Pyx_PyInt_SubtractObjC(__pyx_v_x, __pyx_int_1, 1, 0); if (unlikely(!__pyx_t_3)) __PYX_ERR(0, 16, __pyx_L1_error)
      __Pyx_GOTREF(__pyx_t_3);
      __pyx_t_8 = __Pyx_PyObject_GetItem(__pyx_v_seq1, __pyx_t_3); if (unlikely(!__pyx_t_8)) __PYX_ERR(0, 16, __pyx_L1_error)
      __Pyx_GOTREF(__pyx_t_8);
      __Pyx_DECREF(__pyx_t_3); __pyx_t_3 = 0;
      __pyx_t_3 = __Pyx_PyInt_SubtractObjC(__pyx_v_y, __pyx_int_1, 1, 0); if (unlikely(!__pyx_t_3)) __PYX_ERR(0, 16, __pyx_L1_error)
      __Pyx_GOTREF(__pyx_t_3);
      __pyx_t_9 = __Pyx_PyObject_GetItem(__pyx_v_seq2, __pyx_t_3); if (unlikely(!__pyx_t_9)) __PYX_ERR(0, 16, __pyx_L1_error)
      __Pyx_GOTREF(__pyx_t_9);
      __Pyx_DECREF(__pyx_t_3); __pyx_t_3 = 0;
      __pyx_t_3 = PyObject_RichCompare(__pyx_t_8, __pyx_t_9, Py_EQ); __Pyx_XGOTREF(__pyx_t_3); if (unlikely(!__pyx_t_3)) __PYX_ERR(0, 16, __pyx_L1_error)
      __Pyx_DECREF(__pyx_t_8); __pyx_t_8 = 0;
      __Pyx_DECREF(__pyx_t_9); __pyx_t_9 = 0;
      __pyx_t_10 = __Pyx_PyObject_IsTrue(__pyx_t_3); if (unlikely(__pyx_t_10 < 0)) __PYX_ERR(0, 16, __pyx_L1_error)
      __Pyx_DECREF(__pyx_t_3); __pyx_t_3 = 0;
      if (__pyx_t_10) {
/* … */
        goto __pyx_L13;
      }
```

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Benchmark Cython Code

Number of Comparisons	C	Cython First Version
29.159	0.009	0.575
58.318	0.017	0.997
116.637	0.035	2.311
233.274	0.065	3.958

Cythonized code is at least 65 times slower than C, but we got 2x performance against pure Python

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Helping Cython

- We could tell the types of the variables on Cython
- We could tell that all the indexes are in bound of the arrays

Helping Cython

Variable types

```
import cython

@cython.locals(
    seq1=str,
    seq2=str,
    matrix=list,
    size_x=cython.int,
    size_y=cython.int,
    x=cython.int,
    y=cython.int,
)
def levenshtein(seq1, seq2):
    size_x = len(seq1) + 1
    size_y = len(seq2) + 1
     matrix = [[0] * size_y for _ in range(size_x)]
```

Helping Cython

Variable types

```
Type "help", "copyright", "credits" or "license" for more
information.
>>> import difference
>>> difference.levenshtein('asd', 'foobar')
6
>>> difference.levenshtein(u'asd', 123)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Argument 'seq2' has incorrect type (expected str,
got int)
```

Benchmark Cython Types

Number of Comparisons	C	Cython with types
29.159	0.009	0.246
58.318	0.017	0.566
116.637	0.035	0.984
233.274	0.065	2.283

Cythonized code is at least 33 times slower than C, but we got 4.5x performance against pure Python

Helping Cython

Array Bounds

- Cython will raise an IndexError if getting a value out of bounds
- This will be checked every time you access a position
- You can disable that, but will raise a **segfault** instead than an exception

Helping Cython

Array Bounds

```
def example(values, index):
    return values[index]
```

Helping Cython

Array Bounds

```
>>> import len_example
>>> len_example.__file__
'/home/.../len_example.cpython-36m-x86_64-linux-gnu.so'
>>> len_example.example([1,2,3], 1000)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "len_example.py", line 2, in len_example.example
    return values[index]
IndexError: list index out of range
```

Helping Cython

Array Bounds

```
import cython


@cython.boundscheck(False)
@cython.locals(
    seq1=str,
    seq2=str,
    ...
    y=cython.int,
)
def levenshtein(seq1, seq2):
    size_x = len(seq1) + 1
```

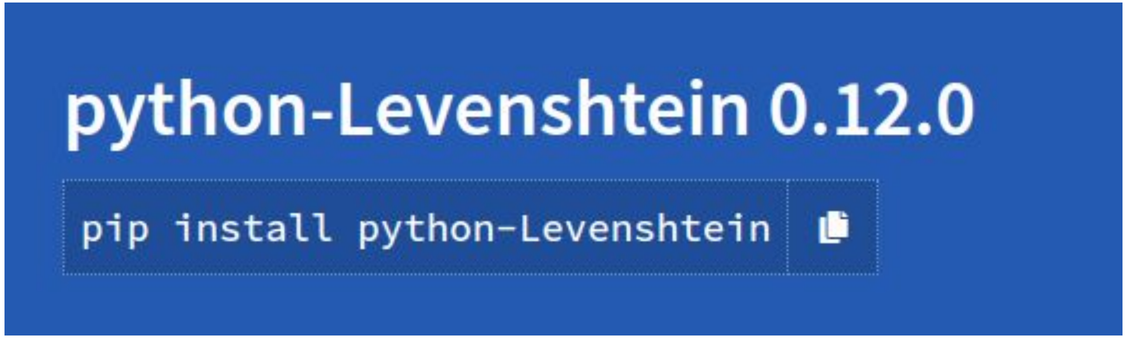
Benchmark Array Bounds

Number of Comparisons	C	Cython without bounds
29.159	0.009	0.254
58.318	0.017	0.435
116.637	0.035	1.566
233.274	0.065	2.095

Cythonized code is at least 30 times slower than C, but we got 5x performance against pure Python

Using Python Package Index

- What if we checked PyPi for a module that already does this?
- python-levenshtein



python-Levenshtein 0.12.0

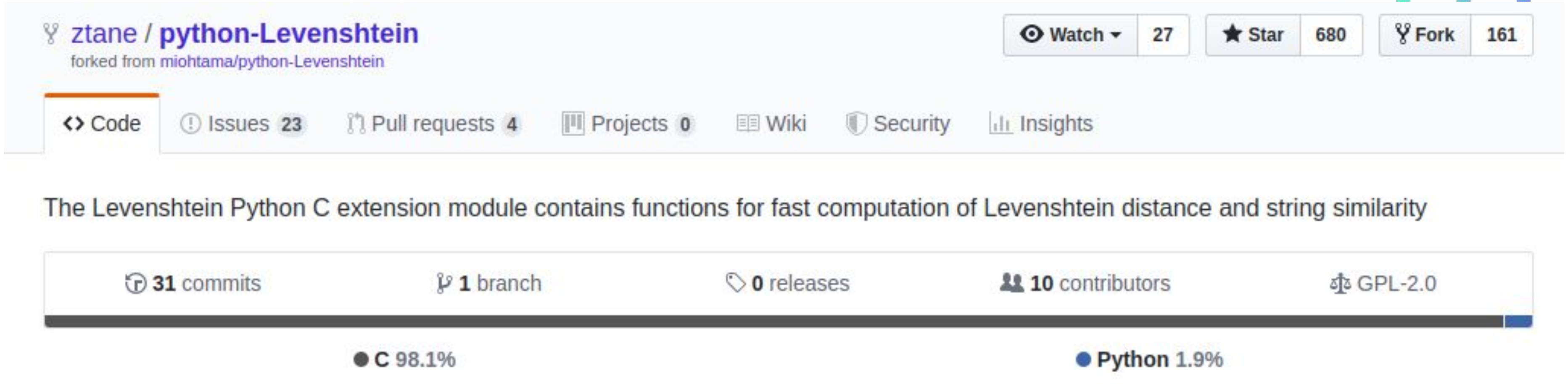
```
pip install python-Levenshtein
```

Benchmark Using Library

Number of Comparisons	C	Library
29.159	0.009	0.029
58.318	0.017	0.058
116.637	0.035	0.099
233.274	0.065	0.213

The library is 4 times slower that C code, and 38 times faster than our Python code

Python-Levenshtein



ztane / python-Levenshtein
forked from miohtama/python-Levenshtein

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Code | Issues 23 | Pull requests 4 | Projects 0 | Wiki | Security | Insights

The Levenshtein Python C extension module contains functions for fast computation of Levenshtein distance and string similarity

31 commits | 1 branch | 0 releases | 10 contributors | GPL-2.0

● C 98.1% ● Python 1.9%

https://github.com/ztane/python-Levenshtein

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Conclusion

- Check if there is a library on pypi.org that optimize the code
- Data science libraries are already optimized
- Only optimize what you need. There is no need to optimize everything
- https://github.com/tzulberti/charlas

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- We use Cython on a Web application that process 2,000,000,000 per day
- We are opening an Office in Berlin
- https://jampp.com/careers.html