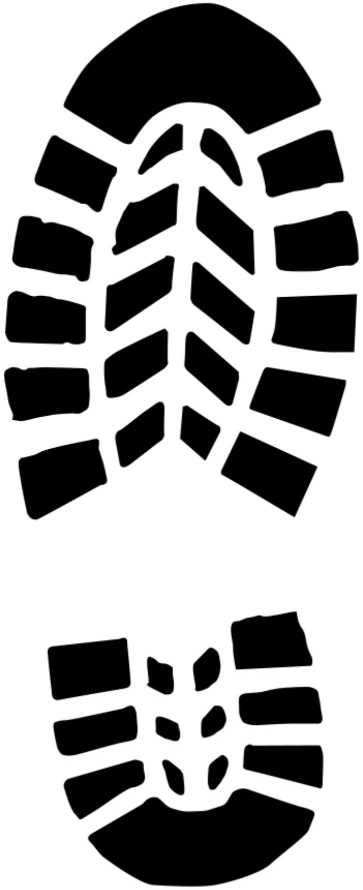


Welcome to
Python 2
Session #1

Michael Purcaro & The GSBS Bootstrappers

February 2014

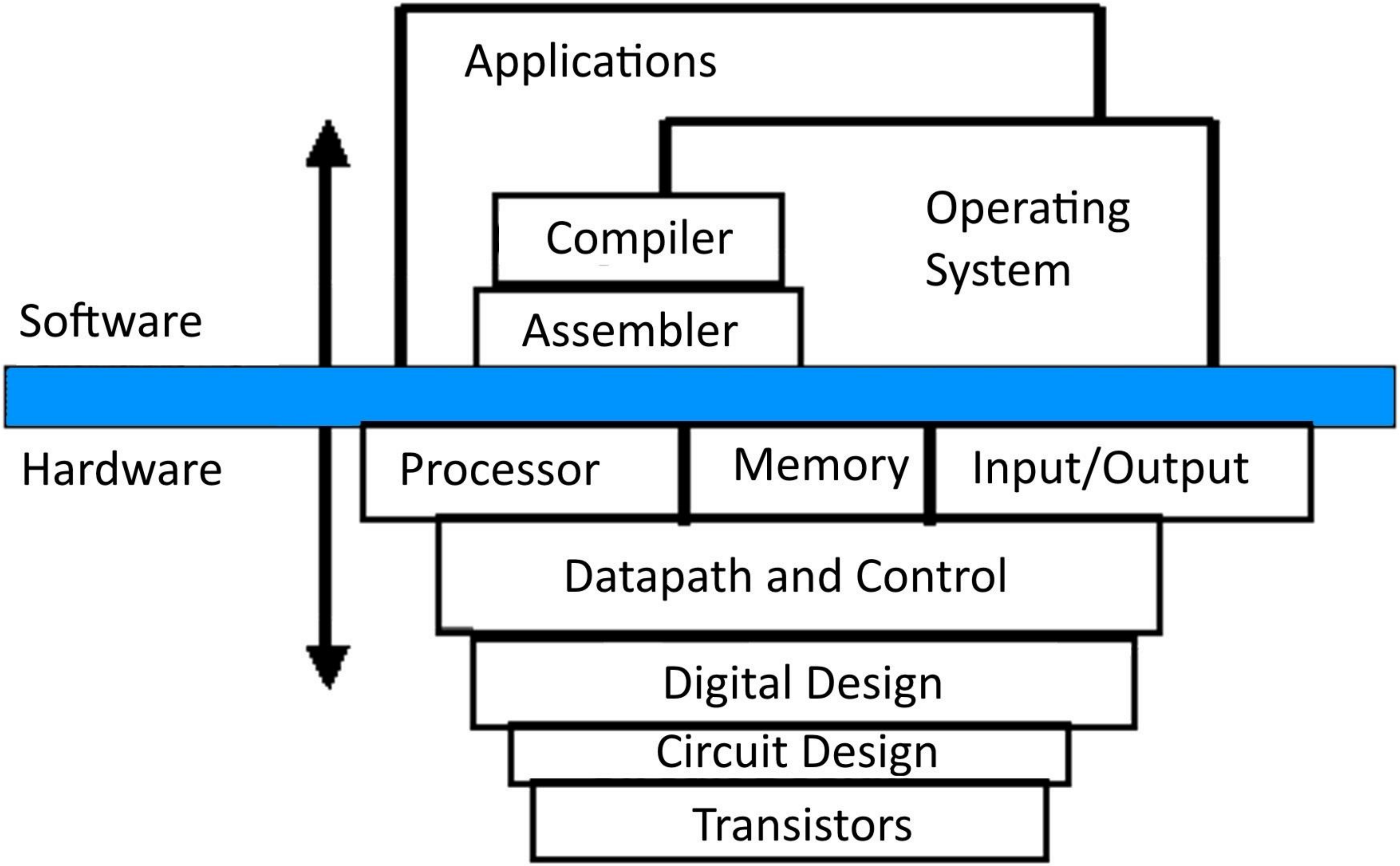
michael.purcaro@umassmed.edu

Welcome and Structure

- 6 sessions
  - Review of Python 1
  - Object orientation
  - Modules
  - Data structures
  - Regular Expressions
  - I/O
  - Working on cluster
- Work w/ real data

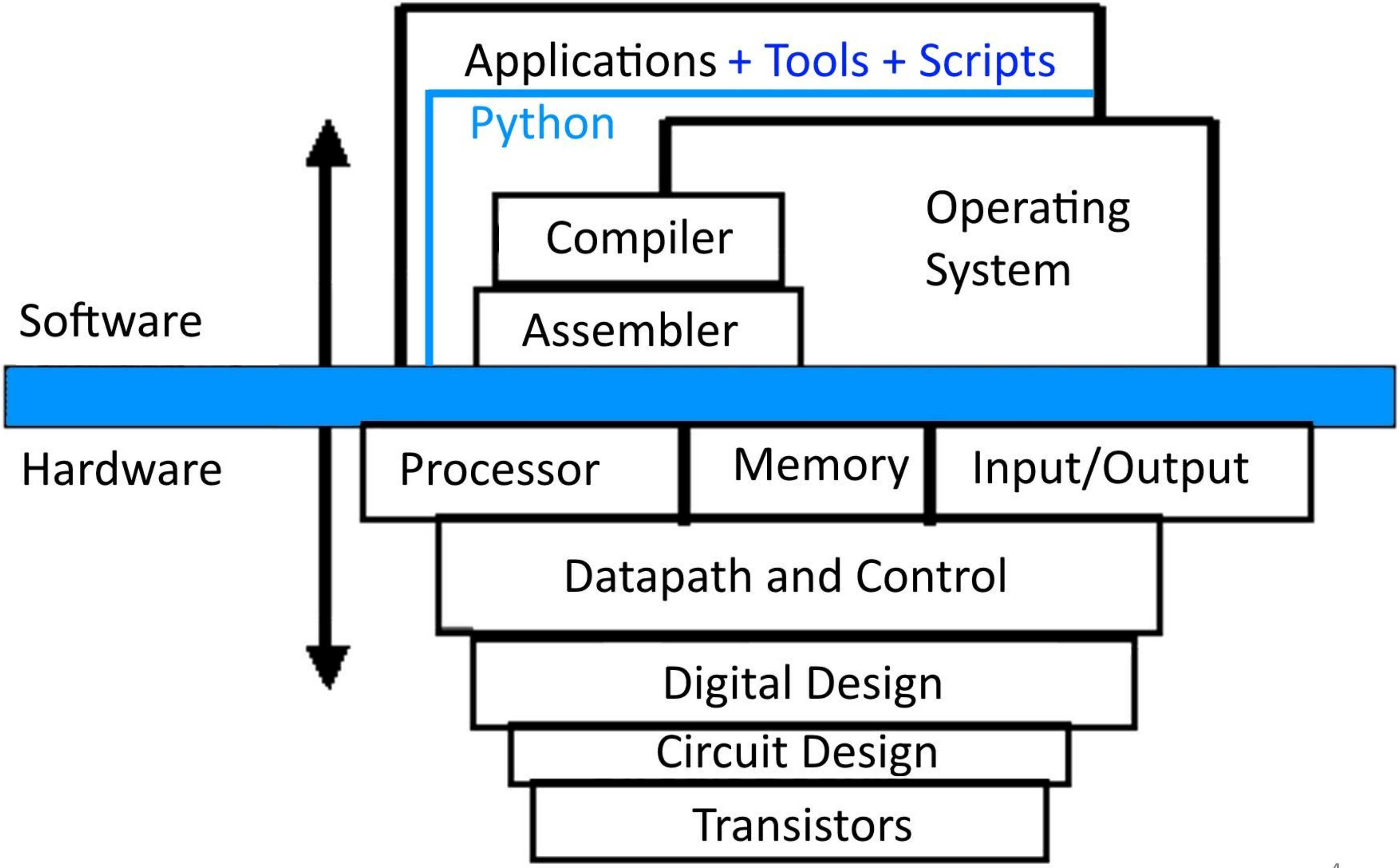
bioinfo.umassmed.edu/bootstrappers/bootstrappers-courses/python2/lecture1/

Layers of Abstraction



Based on http://www.cise.ufl.edu/~mssz/CompOrg/Figure1.1-LevelsOfAbstractn.gif

Layers of Abstraction



Computer Memory

Computer Memory: Addressing

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49
50	51	52	53	54	55	56	57	58	59
60	61	62	63	64	65	66	67	68	69
…									

Computer Memory: Addressing

0	32	64	96	128	160	192	224	256	288
320	352	384	….						

units = bits

“data structure alignment”

Computer Memory: Addressing

0	32	64	96	128	160	192	224	256	288
320	352	384	….						

Memory size limited by system, number of programs running, etc.

Processors prefer to operate in terms of these blocks of memory

Example: adding two 3 digit intgers

6

+ 7

1 3

Processors prefer to operate in terms of these blocks of memory

Base 10

	0	0	6
+	0	0	7
	0	1	3

Processors prefer to operate in terms of these blocks of memory

Base 10

	0	0	6
+	0	0	7
	0	1	3

Base 2 → 8 bit integers

0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	1
0	0	0	0	1	1	0	1

Overflow

	1	1	1	1	1	1	1	1
+	1	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0	0

Result is too large to fit in memory given!

Building Blocks: Numbers

- Numbers take up a certain amount of space in memory
- Two fundamental types in python
  - Integers (ints)
  - Decimal (float)
- `print type(1)`
- `print type(1.2)`

Building Blocks: Numbers

- Numbers take up a certain amount of space in memory
- Two fundamental types in python
  - Integers (ints)
  - Decimal (float)
- `print type(1)`
  - <type 'int'>
- `print type(1.2)`
  - <type 'float'>

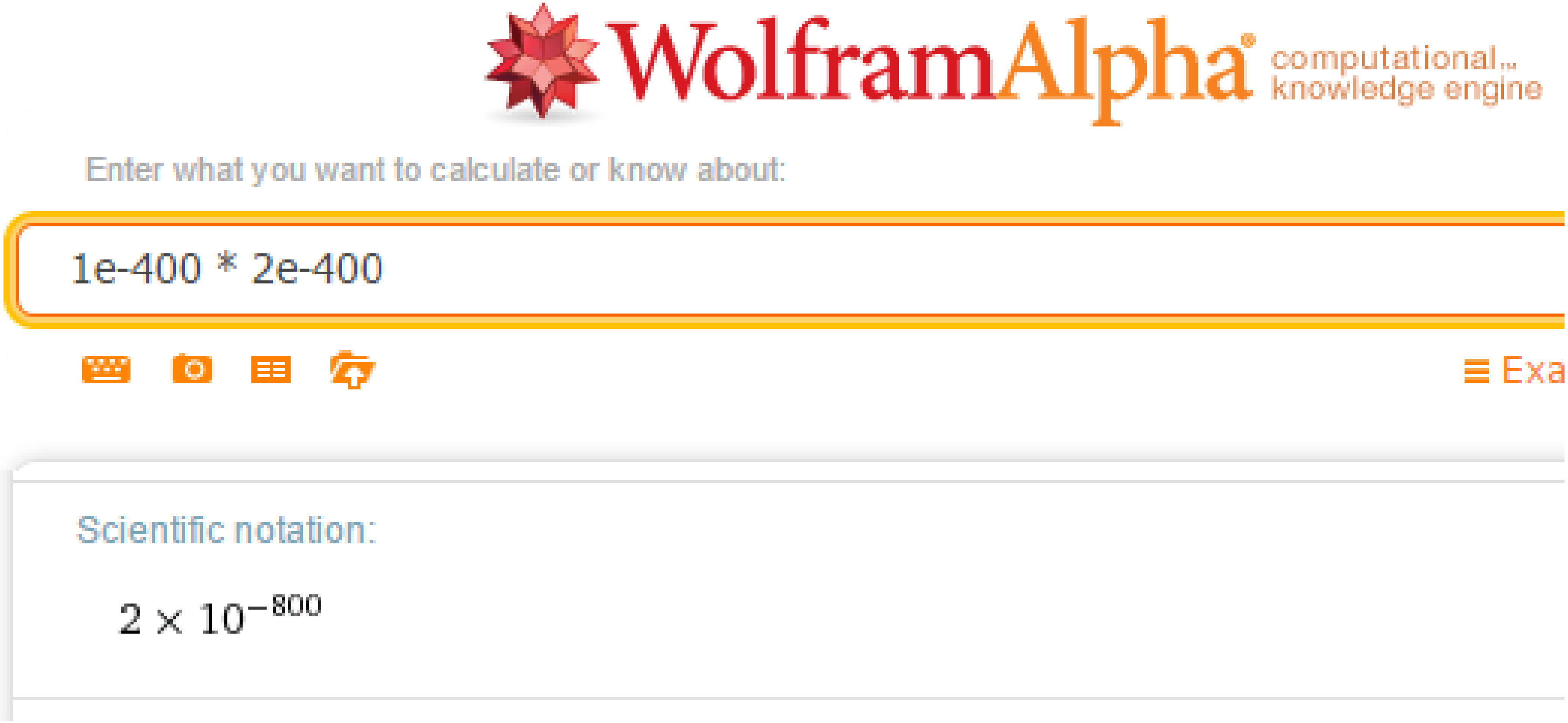
Size in memory limits precision of number types

```
print "1+2 = ", 1+2

print "1e100 + 2e100 = ", 1e100 + 2e100
print "1e400 + 2e400 = ", 1e400 + 2e400

print "1e-100 + 2e-100 = ", 1e-100 + 2e-100
print "1e-400 + 2e-400 = ", 1e-400 + 2e-400
```

Size in memory limits precision of number types

```
print "1+2 = ", 1+2
1+2 =  3

print "1e100 + 2e100 = ", 1e100 + 2e100
1e100 + 2e100 =  3e+100

print "1e400 + 2e400 = ", 1e400 + 2e400
1e400 + 2e400 =  inf      wrong!

print "1e-100 + 2e-100 = ", 1e-100 + 2e-100
1e-100 + 2e-100 =  3e-100

print "1e-400 + 2e-400 = ", 1e-400 + 2e-400
1e-400 + 2e-400 =  0.0    wrong!
```

Arbitrary precision numbers possible!



Enter what you want to calculate or know about:

1e-400 * 2e-400

Scientific notation:

2×10^{-800}

Arbitrary precision numbers in Python

```
import gmpy
from gmpy import mpf

print "mpf('1e100') + mpf('2e100') = ", mpf('1e100') + mpf('2e100')

print "mpf('1e400') + mpf('2e400') = ", mpf('1e400') + mpf('2e400')

print "mpf('1e-100') + mpf('2e-100') = ", mpf('1e-100') + mpf('2e-100')

print "mpf('1e-400') + mpf('2e-400') = ", mpf('1e-400') + mpf('2e-400')
```

Arbitrary precision numbers in Python

```
import gmpy
from gmpy import mpf
```

```
print "mpf('1e100') + mpf('2e100') = ", mpf('1e100') + mpf('2e100')
mpf('1e100') + mpf('2e100') =  3.e100

print "mpf('1e400') + mpf('2e400') = ", mpf('1e400') + mpf('2e400')
mpf('1e400') + mpf('2e400') =  3.e400

print "mpf('1e-100') + mpf('2e-100') = ", mpf('1e-100') + mpf('2e-100')
mpf('1e-100') + mpf('2e-100') =  3.e-100

print "mpf('1e-400') + mpf('2e-400') = ", mpf('1e-400') + mpf('2e-400')
mpf('1e-400') + mpf('2e-400') =  3.e-400
```

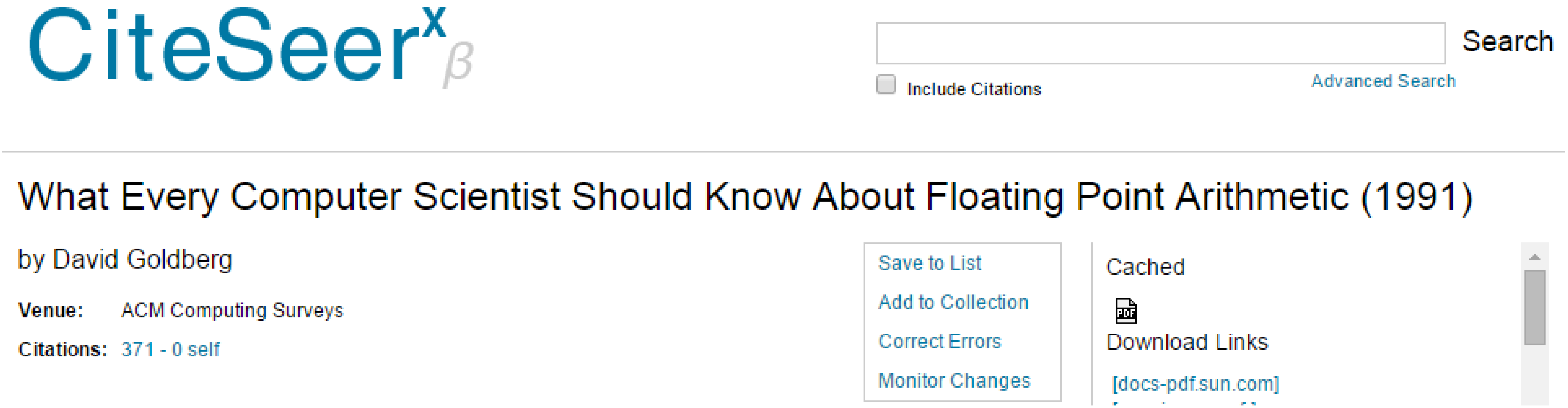
More examples in Lecture1/nums.py

Why aren’t all numbers arbitrary precision?

- Performance
- Size in memory
- Many complex and subtle floating point issues

Why aren’t all numbers arbitrary precision?

- Performance
- Size in memory
- Many complex and subtle floating point issues



What Every Computer Scientist Should Know About Floating Point Arithmetic (1991)

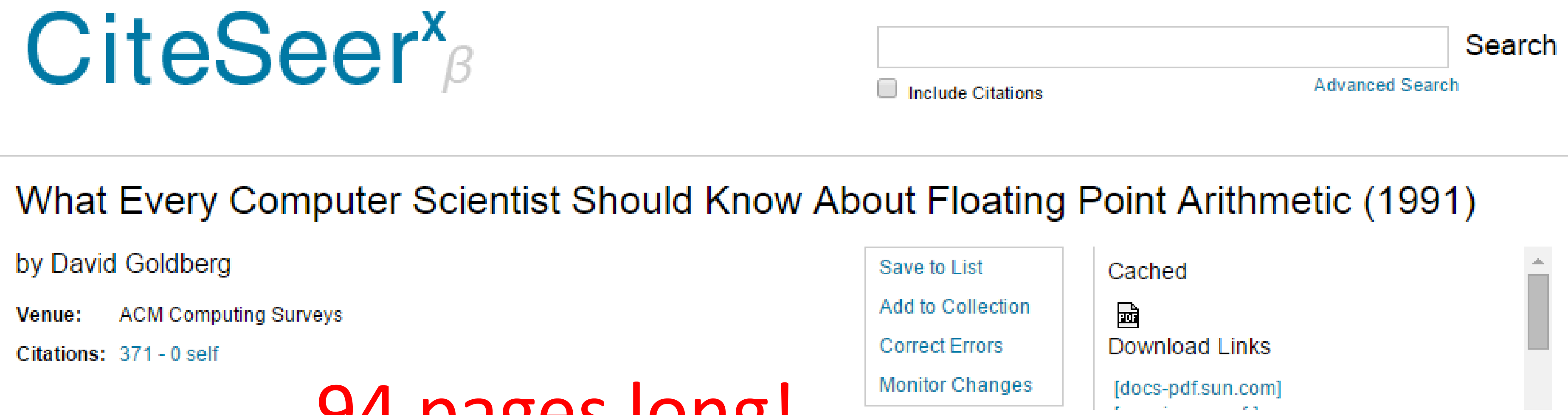
by David Goldberg

Venue: ACM Computing Surveys

Citations: 371 - 0 self

Why aren’t all numbers arbitrary precision?

- Performance
- Size in memory
- Many complex and subtle floating point issues



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94 pages long!

Building Blocks: Lists

- Contiguous set of blocks in memory

```
v = []
for i in range(10):
    v.append(i)
print v
```

Building Blocks: Lists

- Contiguous set of blocks in memory

```
v = []
for i in range(10):
    v.append(i)
print v
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

Building Blocks: Lists

- Contiguous set of blocks in memory

```
v = []
for i in range(10):
    v.insert(0, i)
print v
```

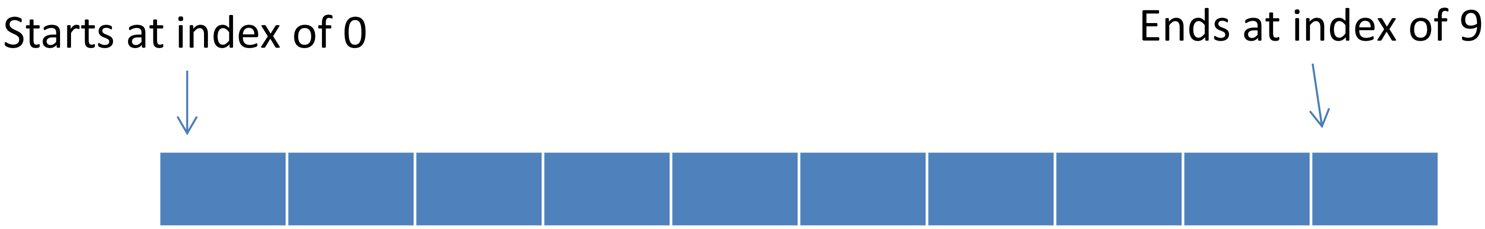
Building Blocks: Lists

- Contiguous set of blocks in memory

```
v = []
for i in range(10):
    v.insert(0, i)
print v
[9, 8, 7, 6, 5, 4, 3, 2, 1, 0]
```

Building Blocks: Lists

- 0-based indexing (list of length 10)

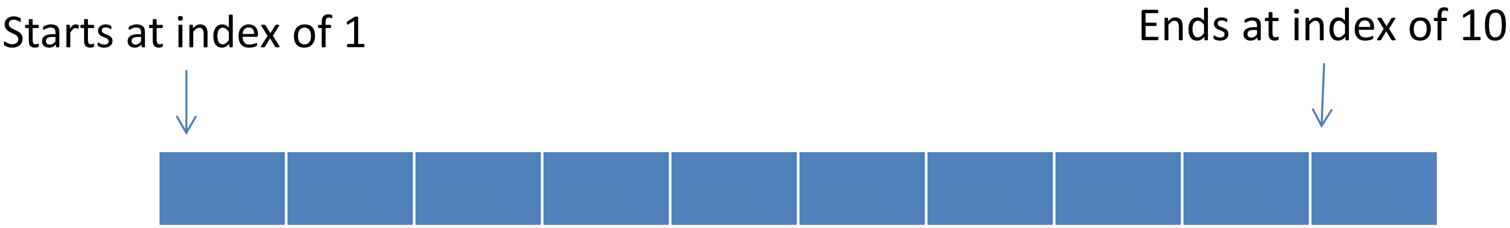


Starts at index of 0

Ends at index of 9

  - Python, C, C++, Java, Javascript

- 1-based indexing (list of length 10)



Starts at index of 1

Ends at index of 10

  - R, MATLAB

Building Blocks: Lists

```
v = [1, 1, 2, 3, 5, 8, 13, 21]
print v.count(1)
print v[0]
print v[-1]
print v[-2]
print v[1:2]
print v[::-1]
print v.index(21)
```

See https://docs.python.org/2/tutorial/datastructures.html for document on lists

Building Blocks: Lists

```
v = [1, 1, 2, 3, 5, 8, 13, 21]
print v.count(1)
2
print v[0]
1
print v[-1]
21
print v[-2]
13
```

Building Blocks: Lists

```
v = [1, 1, 2, 3, 5, 8, 13, 21]
print v[1:2]
[1]
```

[inclusive, exclusive)

```
print v[::-1]
```

or v.reverse()

```
[21, 13, 8, 5, 3, 2, 1, 1]
```

```
print v.index(21)
7
```

Building Blocks: Lists

```
v = [1, 1, 2, 3, 5, 8, 13, 21]
v = v[3:5]
print v
v[0] = 100
print v
v[1] = [1,1,2]
print v
```

Building Blocks: Lists

```
v = [1, 1, 2, 3, 5, 8, 13, 21]
v = v[3:5]
print v
[3, 5]
v[0] = 100
print v
[100, 5]
v[1] = [1,1,2]
print v
[100, [1, 1, 2]]
```

Building Blocks: Strings

- Essentially (if not exactly) a list of characters

```
s = "Hello World!"
print s
s = "Hello World!\n"
print s
print s[0:5]
s[0:5] = "HELLO!"
print s
```

Building Blocks: Strings

- Essentially (if not exactly) a list of characters

```
s = "Hello World!"
print s
Hello World!
s = "Hello World!\n"
print s
Hello World!

print s[0:5]
Hello
```

Building Blocks: Strings

- Essentially (*if not exactly*) a list of characters

```
s = "Hello World!\n"
s[0:5] = "HELLO!"
print s
```

```
Traceback (most recent call last):
  File "./strings.py", line 9, in <module>
    s[0:4] = "HELLO!"
TypeError: 'str' object does not support item assignment
```

Building Blocks: Strings

- Essentially (*if not exactly*) a list of characters

```
s = "Hello World!\n"
s = "HELLO!" + s[5:-1]
print s
```

Building Blocks: Strings

- Essentially (*if not exactly*) a list of characters

```
s = "Hello World!\n"
s = "HELLO!" + s[5:-1]
print s
```

```
HELLO! World!
```

Building Blocks: Strings

```
s = "Hello World!"
print s.startswith("He")
print s.split()
print s.split("o")
```

Building Blocks: Strings

```
s = "Hello World!"
print s.startswith("He")
True
print s.split()
['Hello', 'World!']
print s.split("o")
['Hell', ' W', 'rld!']
```

Building Blocks: Strings

```
s = "2015"
print s == 2015
print int(s) == 2015
print s == str(2015)
```

Building Blocks: Strings

```
s = "2015"
print s == 2015
False
print int(s) == 2015
True
print s == str(2015)
True
```

Dealing with files and folders

- docs.python.org/2/library/os.path.html
- `import os`
  - (os is a Python module: code that can be imported and used w/ your own programs)
- Get home folder:

```
homeFolder = os.path.expanduser("~")
```

- Get absolute path

```
homeFolder = os.path.abspath(homeFolder)
```

- Append a folder (or file) name to path

```
python2folder = os.path.join(homeFolder, "python_2")
```

Dealing with files and folders

- Make directories if needed:

```
import os, errno
def mkdir_p(path):
    # from http://stackoverflow.com/a/600612
    try:
        os.makedirs(path)
    except OSError as exc: # Python >2.5
        if exc.errno == errno.EEXIST and os.path.isdir(path):
            pass
        else: raise
```

Example: make a folder for today’s lecture

```
import os, errno

def mkdir_p(path):
    # from http://stackoverflow.com/a/600612
    try:
        os.makedirs(path)
    except OSError as exc: # Python >2.5
        if exc.errno == errno.EEXIST and os.path.isdir(path):
            pass
        else: raise

homeFolder = os.path.abspath(os.path.expanduser("~"))
desktopFolder = os.path.join(homeFolder, "Desktop")
python2folder = os.path.join(desktopFolder, "python_2")
lecture1folder = os.path.join(python2folder, "lecture_1")
print "today's lecture folder location will be:", lecture1folder
mkdir_p(lecture1folder)
```

Downloading a file

```
url = “http://someaddress.com/fileName.txt”

fileName = os.path.basename(url)
fnp = os.path.join(lecture1folder, fileName)
print "going to download", fileName, "from", url

import urllib
urllib.URLopener().retrieve(url, fnp)
```

Reading a large file line-by-line

```
with open(fileNameAndPath) as f:
    for line in f:
        print line
```

Extended Exercise 1

Goal: count how many signal peaks are present in processed ENCODE ChIP-seq data on chromosome 7

url:
http://bib3.umassmed.edu/~purcarom/Python2/Lecture1/ENCFF002COQ.narrowPeak

File format:
genome.ucsc.edu/FAQ/FAQformat.html#format12

Answer hint: between 2000 and 3000

Extended Exercise 2

Modify code from Extended Exercise 1 to count what percentage of chromosome 7 (assume hg19) is covered by peaks.

Length of chr7 in hg19: 159138663

(Length of HG19 chromosomes in hg19.chrom.sizes in bioinfo.umassmed.edu/bootstrappers/bootstrappers-courses/python2/lecture1/)

Answer hint: <5%