CSC148 fall 2013
names, tracing, abstraction recursion
week 12

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Outline

memory model

tracing... or not

consequences of recursion
how much detail for developers?

Enough detail to predict results and efficiency of our code — more detail than end users, less than compiler/interpreter designers. In Python:

- Every **name** contains a **value**

- Every **value** is a reference to the address of an object
searching for names

python looks, in order:

- innermost scope (function body, usually) local
- enclosing scopes nonlocal
- global (current module or __main__)
- built-in names
- see scopes and namespaces
intense example

Try running `python docs namespace example` to check your comfort level.
The first parameter, conventionally called self, is a reference to the instance:

```python
>>> class Foo:
...     def f(self):
...         return "Hi world!"
...
>>> f1 = Foo()
```

Now `Foo.f(f1)` means `f1.f()`
hunting for a method...

Start in the nearest subclass and work upwards, for example visualize method
def rec_max(L):
    """
    Return the maximum number in possibly nested list of numbers.
    """
    return max([rec_max(x) if isinstance(x, list) else x for x in L])

Recommended:

▶ trace the simplest (non-recursive) case
▶ trace the next-most complex case, **plug in known results**
▶ same as previous step...
TMI tracing

In contrast to the step-by-step, plus abstraction (previous slide), you could trace this in the visualizer
This sequence arises in applied rabbit breeding and depth of balanced BSTs. See vi hart for details.
The code is almost a direct translation of the algorithm. But, initially, there is a performance problem:

```python
def fibonacci(n: int) -> int:
    """
    nth fibonacci number, where fibonacci(0) is 0, fibonacci(1) is 1, and fibonacci(n) = fibonacci(n-1) + fibonacci(n-2) if n > 1
    """
    return n if n < 2 else fibonacci(n - 1) + fibonacci(n - 2)
```

```
>>> fibonacci(5)
5
>>> fibonacci(6)
8
```

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```

return n if n < 2 else fibonacci(n - 1) + fibonacci(n - 2)
avoiding redundant calls...

**Memoization**

If fibonacci is called on exactly the same input, the result should be the same:

```python
def fibonacci_mem(n: int) -> int:
    """memoized fibonacci""
    cached = {}
    def fib_rec(n: int) -> int:
        if not n in cached:
            if n < 2:
                cached[n] = n
            else:
                cached[n] = fib_rec(n - 1) + fib_rec(n - 2)
        return cached[n]
    return fib_rec(n)
```

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[Handwritten notes on the page:]

- """memoized fibonacci""
- `cached = {}`
- `def fib_rec(n: int) -> int:`
  - `if not n in cached:`
  - `if n < 2:`
    - `cached[n] = n`
  - `else:`
    - `cached[n] = fib_rec(n - 1) + fib_rec(n - 2)`
- "has been previously computed"
- "exactly"
Indeed, memoization can be automated:

def memoize(f: 'function') -> 'function':
    """Return memoized version of f""
    table = {}
    def g(x):
        if not x in table:
            table[x] = f(x)
        else:
            pass
        return table[x]
    return g
quicksort revisited

The efficiency of our quicksort example depended on the input list not being sorted:

```python
import random
L = list(range(1000))
random.shuffle(L)
def quick(L: list) -> list:
    """Produce list with same elements as L in ascending order""
    return (quick([x for x in L[1:] if x < L[0]]) + [L[0]] +
            quick([x for x in L[1:] if x >= L[0]])
            if len(L) > 1 else L)
```

\[
[4, 3, 2, 1, 1, 2, 3, 4, 5]
\]
You can tinker with `sys.setrecursionlimit` to overcome Python's incomplete support for recursion, or randomize the algorithm:

```python
def quick2(L: list) -> list:
    """Produce list with same elements as L in ascending order""
    if len(L) < 2:
        return L
    else:
        p = random.randint(0, len(L) - 1)
        return (quick2([x for x in L[:p] + L[p+1:] if x < L[p]]) +
                [L[p]] + quick2([x for x in L[:p] + L[p+1:] if x >= L[p]]))
```
TA roster

Tuesday: Xin, Orion, Amirali

Thursday: Sam, Aida, Edy, Anton

Friday: Zhaowei, Raymond, Patricia