61A Lecture 30

Monday, April 13

Announcements

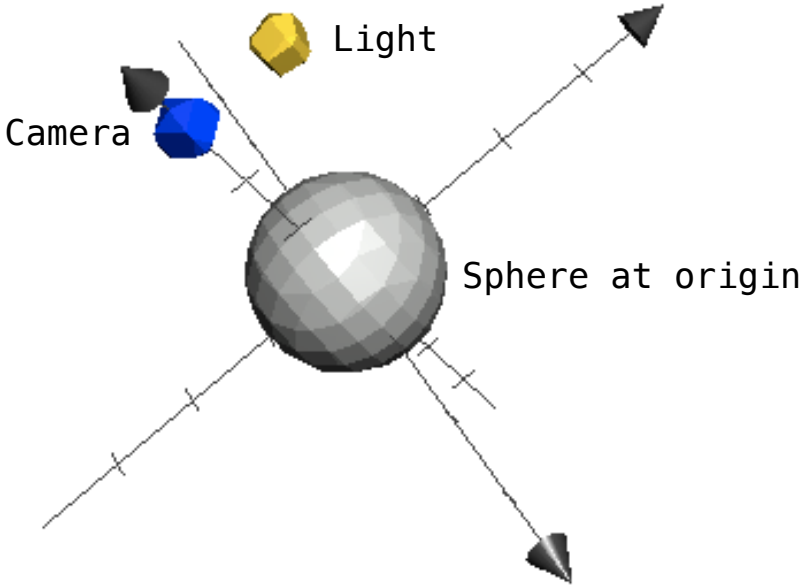
- Homework 8 due Wednesday 4/15 @ 11:59pm (small)
- Project 4 due Thursday 4/23 @ 11:59pm (BIG!)
  - Project/Homework party Tuesday 4/14 5pm–6:30pm in 2050 VLSB
  - Early point #1: Questions 1–12 submitted (correctly) by Friday 4/17 @ 11:59pm
  - Early point #2: All questions (including Extra Credit) by Wednesday 4/22 @ 11:59pm
- If you want the first early submission point, you need to:
  - Pass the tests for the designated questions
  - Run **`python3 ok --submit`**
  - Log on to http://ok.cs61a.org and create a group with your partner

Ray Tracing

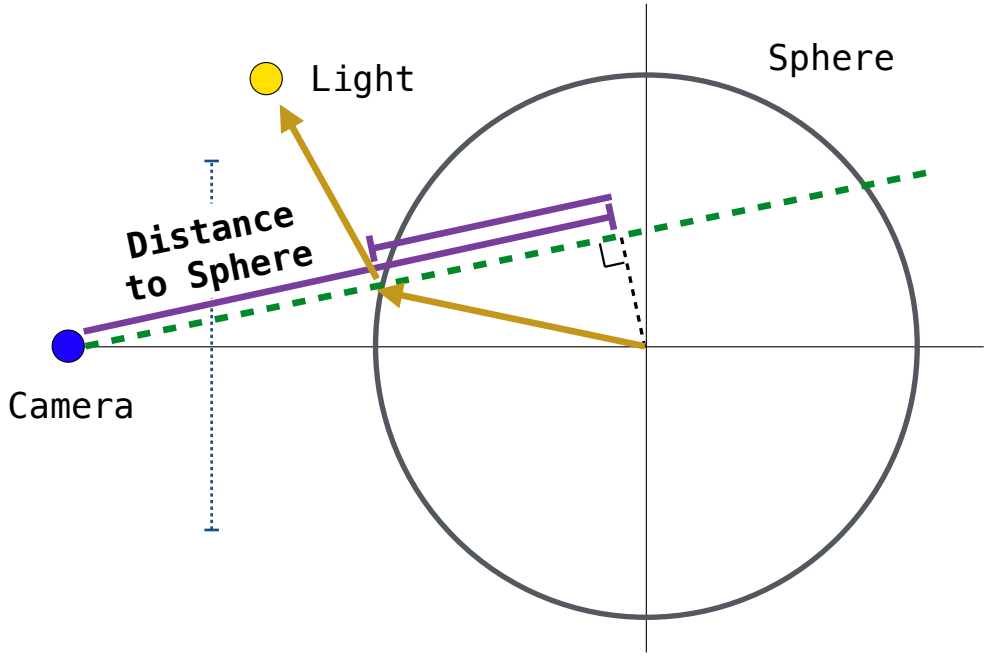
A technique for displaying a 3D scene on a 2D screen by tracing a path through every pixel

The Scene:

(Demo)



Dramatization:



(Demo)

Information Hiding

Attributes for Internal Use

An attribute name that starts with one underscore is not meant to be referenced externally.

```
class FibIter:
    """An iterator over Fibonacci numbers."""
    def __init__(self):
        self._next = 0
        self._addend = 1

    def __next__(self):
        result = self._next
        self._addend, self._next = self._next, self._addend + self._next
        return result
```

"Please don't reference these directly. They may change."

```
>>> fibs = FibIter()
>>> [next(fibs) for _ in range(10)]
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34]
```

This naming convention is not enforced, but is typically respected

A programmer who designs and maintains a public module may change internal-use names

Starting a name with *two underscores* enforces restricted access from outside the class

Names in Local Scope

A name bound in a local frame is not accessible to other environments, except those that extend the frame

```
def fib_generator():
    """A generator function for Fibonacci numbers.

    >>> fibs = fib_generator()
    >>> [next(fibs) for _ in range(10)]
    [0, 1, 1, 2, 3, 5, 8, 13, 21, 34]
    """
    yield 0
    previous, current = 0, 1
    while True:
        yield current
        previous, current = current, previous + current
```

There is no way to access values bound to "previous" and "current" externally

Singleton Objects

A singleton class is a class that only ever has one instance

NoneType, the class of None, is a singleton class; None is its only instance

For user-defined singletons, some programmers re-bind the class name to the instance

```
class empty_iterator:
    """An iterator over no values."""
    def __next__(self):
        raise StopIteration
empty_iterator = empty_iterator()
```

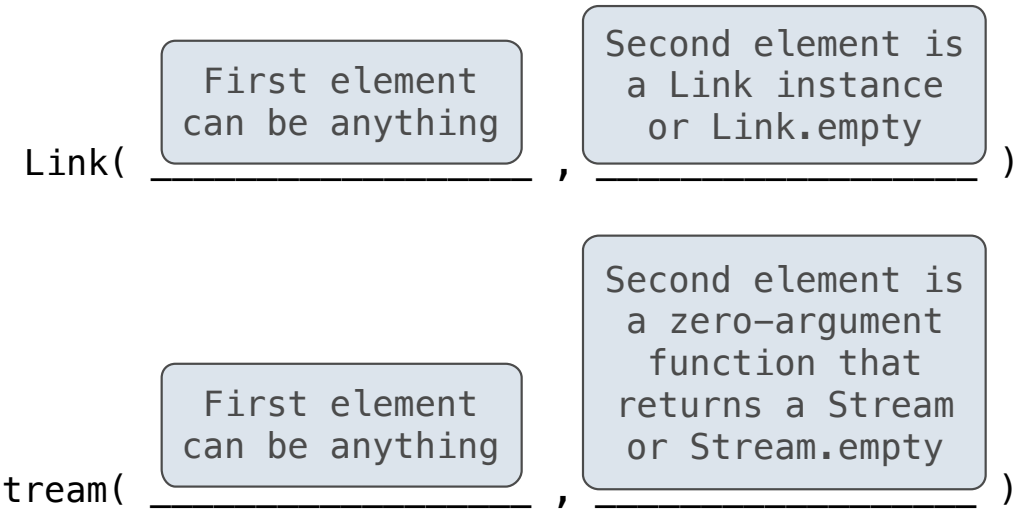
The instance

The class

Streams

Streams are Lazy Linked Lists

A stream is a linked list, but the rest of the list is computed on demand



Once created, Streams and Links can be used interchangeably using `first` and `rest` methods

(Demo)

Integer Stream

An integer stream is a stream of consecutive integers

An integer stream starting at first is constructed from first and a function compute_rest that returns the integer stream starting at first+1

```
def integer_stream(first=1):
    """Return a stream of consecutive integers, starting with first.

    >>> s = integer_stream(3)
    >>> s.first
    3
    >>> s.rest.first
    4
    """
    def compute_rest():
        return integer_stream(first+1)
    return Stream(first, compute_rest)
```

(Demo)

Cross the Stream

Which definition will produce which row of elements after executing `s = f()`?

```
def f(x=1):
    return Stream([x], lambda: f([x]))

def f(x=[1]):
    return Stream(x,   lambda: f(x+[1]))

def f(x=1):
    s =    Stream([x], lambda: s)
    return s

def f(x=[]):
    x.append(1)
    return Stream(x,   lambda: f(x))
```

s.first	s.rest.first
[1]	[1, 1]
[1, 1]	[1, 1]
[1]	[1]
[1]	[[1]]

Stream Processing

(Demo)

Stream Implementation

Stream Implementation

A stream is a linked list with an *explicit* first element and a rest-of-the-list that is computed lazily

```
class Stream:
    """A lazily computed linked list."""
    class empty:
        def __repr__(self):
            return 'Stream.empty'
    empty = empty()

    def __init__(self, first, compute_rest=lambda: Stream.empty):
        assert callable(compute_rest), 'compute_rest must be callable.'
        self.first = first
        self._compute_rest = compute_rest

    @property
    def rest(self):
        """Return the rest of the stream, computing it if necessary."""
        if self._compute_rest is not None:
            self._rest = self._compute_rest()
            self._compute_rest = None
        return self._rest
```

Higher-Order Functions on Streams

Mapping a Function over a Stream

Mapping a function over a stream applies a function only to the first element right away; the rest is computed lazily

```
def map_stream(fn, s):
    """Map a function fn over the elements of a stream s."""
    if s is Stream.empty:
        return s
    def compute_rest():
        return map_stream(fn, s.rest)
    return Stream(fn(s.first), compute_rest)
```

This body is not executed until compute_rest is called

Not called yet

```
>>> s = integer_stream(3)
>>> s
Stream(3, <...>)
>>> m = map_stream(lambda x: x*x, s)
>>> first_k(m, 5)
[9, 16, 25, 36, 49]
```

Filtering a Stream

When filtering a stream, processing continues until an element is kept in the output

```
def filter_stream(fn, s):
    """Filter stream s with predicate function fn."""
    if s is Stream.empty:
        return s
    def compute_rest():
        return filter_stream(fn, s.rest)
    if fn(s.first):
        return Stream(s.first, compute_rest)
    else:
        return compute_rest()
```

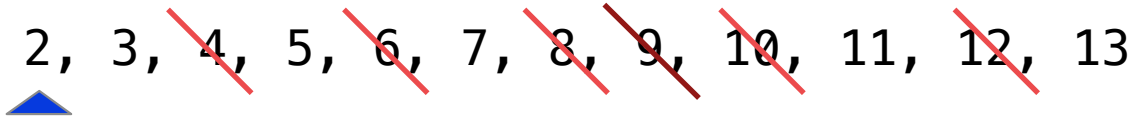
Actually compute the rest

A Stream of Primes

The stream of integers not divisible by any k <= n is:

- The stream of integers not divisible by any k < n
- Filtered to remove any element divisible by n

This recurrence is called the Sieve of Eratosthenes



(Demo)