CS61A Lecture 10
Immutable Data Structures

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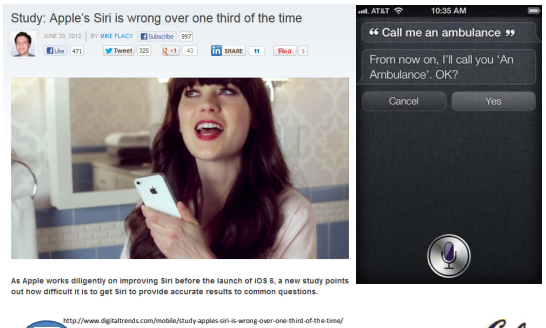
Computer Science in the News



Today

- Review: Immutable Recursive Lists.
- Map, Filter, and Reduce
- Immutable Dictionaries
- Extras: Generator Expressions

Review: Immutable Recursive Lists

An ***immutable recursive list*** (or an ***IRList***) is a *pair* such that:

- The first element of the pair is the *first* element of the list.
- The second element of the pair is the *rest* of the list – another immutable recursive list. The rest of the list could be empty.

Definition is recursive!

Immutable Recursive Lists

```
empty_irlist = ()

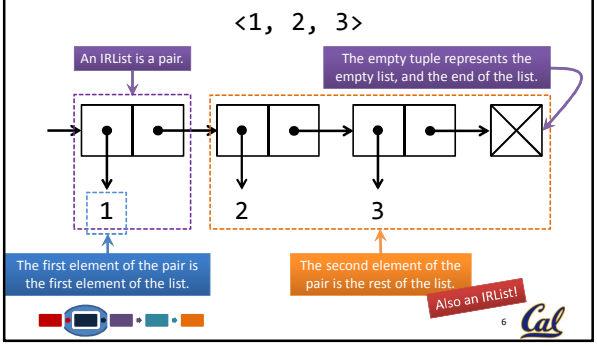
def make_irlist(first, rest=empty_irlist):
    return (first, rest)

def irlist_first(irlist):
    return irlist[0]
def irlist_rest(irlist):
    return irlist[1]
```

CONSTRUCTOR

SELECTORS

Review: Immutable Recursive Lists



Example: Appending IRLists

Let's write the function `irlist_append` which takes two IRLists and returns a new IRList with the elements of the first IRList followed by the elements of the second IRList.

```
>>> x = irlist_populate(1, 2, 3)
>>> y = irlist_populate(4, 5, 6)
>>> irlist_str(irlist_append(x, y))
"<1, 2, 3, 4, 5, 6>"
```

Example: Appending IRLists

```
>>> x = irlist_populate(1, 2, 3)
>>> y = irlist_populate(4, 5, 6)
>>> irlist_str(irlist_append(x, y))
"<1, 2, 3, 4, 5, 6>"
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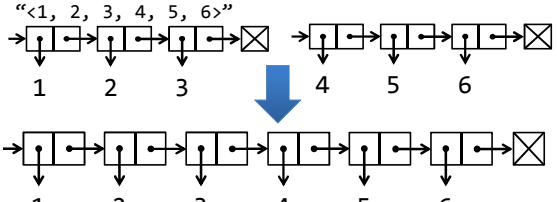
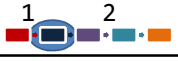




Appending IRLists

Like most IRList questions, we can solve this using recursion.

```
def irlist_append(irl1, irl2):
    if irl1 == empty_irlist:
        return irl2
    first = irlist_first(irl1)
    rest = irlist_append(irlist_rest(irli1),
                         irl2)
    return make_irlist(first, rest)
```

If the first list is empty, we return the second list.

Otherwise...

First item of the first list

followed by...

The rest of the first list appended to the second list.

Practice: Using IRLists

Write the function `sorted_insert`, which takes a number and a sorted IRList of numbers and returns a new sorted IRList with the number inserted into the *sorted* sequence *at the proper place*.

```
>>> x = irlist_populate(1, 3, 6, 9)
>>> irlist_str(sorted_insert(5, x))
"<1, 3, 5, 6, 9>"
```

Practice: Using IRLists

Write the function sorted_insert, which takes a number and a sorted IRList of numbers and returns a new sorted IRList with the number inserted into the sequence.

```
def sorted_insert(num, sorted_irl):
    if num < irlist_first(sorted_irl):
        return make_irlist(num, sorted_irl))
    first = irlist_first(sorted_irl)
    rest = sorted_insert(num,
                         irlist_rest(sorted_irl))
    return make_irlist(first, rest)
```

Announcements

- Homework 4 is due **July 3**.
- Homework 5 is due **July 6**.
- Project 2 is due **July 13**.
- No class tomorrow, July 4.
- Project 1 contest is on!
  - *How to submit*: Submit a file pig.py with your `final_strategy` to `proj1-contest`.
  - *Deadline*: Friday, **July 6** at **11:59pm**.
  - *Prize*: One of 3 copies of *Feynman* and 1 extra credit point.
  - *Metric*: We will simulate your strategy against everyone else's, and tally your win rate. Draws count as losses.

Announcements: Midterm 1

- Midterm 1 is on **July 9**.
  - *Where*? 2050 VLSB.
  - *When*? 7PM to 9PM.
  - *How much*? Material covered until July 4.
- Closed book and closed electronic devices.
- One 8.5" x 11" 'cheat sheet' allowed.
- Group portion is 15 minutes long.
- Post-midterm potluck on Wednesday, **July 11**.

Common Higher Order Functions For Sequences

There are a few very common styles of functions for interacting with sequences.

Note: The output of map is not a tuple, but instead a "map object." Python does this for efficiency reasons and it is an example of a ***stream***, which we will see towards the end of the course.

`map`

```
>>> nums = (1, 2, 3, 4, 5)
>>> tuple(map(lambda x: x * x, nums))
(1, 4, 9, 16, 25)
>>> tuple(map(lambda x: x + 1, nums))
(2, 3, 4, 5, 6)
```

Common Higher Order Functions For Sequences

There are a few very common styles of functions for interacting with sequences.

Note: Like map, the output of filter is not a tuple, but instead a "filter object." Python does this for efficiency reasons and it is an example of a ***stream***, which we will see towards the end of the course.

`filter`

```
>>> nums = (1, 2, 3, 4, 5)
>>> tuple(filter(lambda x: x % 2 == 0, nums))
(2, 4)
>>> tuple(filter(lambda x: x <= 3, nums))
(1, 2, 3)
```

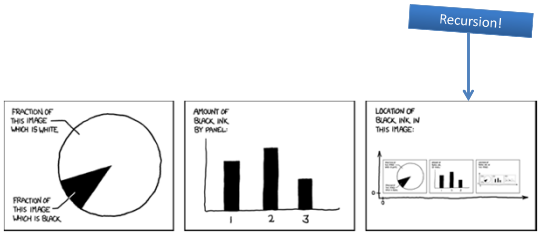
Common Higher Order Functions For Sequences

There are a few very common styles of functions for interacting with sequences.

`reduce`

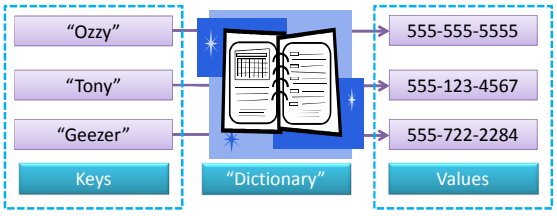
```
>>> from functools import reduce
>>> nums = (1, 2, 3, 4, 5)
>>> reduce(lambda x, y: x * y, nums, 1)
120
>>> reduce(lambda x, y: x + y, nums, 0)
15
```

Break



Making Associations Between Data

Often we want to associate pieces of data with other pieces of data.



Immutable Dictionaries

```
>>> phone_bk = make_idict((“Ozzy”, “555-5555”),
...                       (“Tony”, “123-4567”),
...                       (“Geezer”, “722-2284”))
>>> idict_select(phone_bk, “Ozzy”)
“555-5555”
>>> idict_select(phone_bk, “Geezer”)
“722-2284”
>>> idict_keys(phone_bk)
(“Ozzy”, “Tony”, “Geezer”)
```

Immutable Dictionaries

```
def make_idict(*mappings):
    return mappings

def idict_select(idict, key):
    for mapping in idict:
        if key == mapping[0]:
            return mapping[1]

def idict_keys(idict):
    return tuple(map(lambda mapping: mapping[0],
                     idict))
```

Constructor

Selectors

Returns None if the key is not in the dictionary!

Example: Immutable Dictionaries

Say I wanted to remove an entry from my dictionary. Let’s write the function `idict_remove`, which takes an IDict and a key and returns a new IDict with that key removed.

```
>>> d = make_idict((“A”, 1),
...                (“B”, 2),
...                (“C”, 3))
>>> idict_select(d, “B”)
2
>>> d = idict_remove(d, “B”)
>>> idict_select(d, “B”) # Returns None
```

Example: Immutable Dictionaries

We can solve this by focusing on what ***is*** going in the new IDict, rather than thinking about removing an item from the group.

```
def idict_remove(id, rm_key):
    kv_pairs = ()
    for key in idict_keys(id):
        val = idict_select(id, key)
        if key != rm_key:
            kv_pairs += ((key, val),)
    return make_idict(*kv_pairs)
```

Practice: Immutable Dictionaries

Say instead I wanted to have a function to add a new item to the dictionary. Write `idict_insert`, which takes an IDict, a key, and a value and returns a new IDict with this update.

```
>>> d = make_idict((“A”, 1), (“B”, 2), (“C”, 3))
>>> idict_select(d, “Z”) # Returns None
>>> d = idict_insert(d, “Z”, 55)
>>> idict_select(d, “Z”)
55
>>> d = idict_insert(d, “B”, 42)
>>> idict_select(d, “B”)
42
```

Practice: Immutable Dictionaries

Say instead I wanted to have a function to add a new item to the dictionary. Write `idict_insert`, which takes an IDict, a key, and a value and returns a new IDict with this update.

```
def idict_insert(id, new_key, new_val):
    kv_pairs = ()
    for key in idict_keys(id):
        val = idict_select(id, key)
        if key != new_key:
            kv_pairs += ((key, val),)
    kv_pairs += ((new_key, new_val),)
    return make_idict(*kv_pairs)
```

Conclusion

- Map, Filter, and Reduce are very common higher order functions for working with sequences.
- Dictionaries are a useful way of mapping one set of data to another.
- ***Preview***: Hierarchical Data!

Extras: Generator Expressions

As you might imagine, the idea of mapping and filtering through a sequence to produce a new sequence is ***extremely*** useful.

Python's got ~~an app~~ a syntax for that!

```
<expr> for <var> in <sequence> [if <boolean expr>]
```

Extras: Generator Expressions

```
>>> (x for x in (1, 2, 3))
<generator object <genexpr
>>> tuple(x for x in (1, 2, 3))
(1, 2, 3)
>>> tuple(x * x for x in range(10))
(0, 1, 4, 9, 16, 25, 36, 49, 64, 81)
>>> tuple(x for x in range(10) if x % 2 == 0)
(0, 2, 4, 6, 8)
>>> tuple(x * x for x in range(10) if x % 2 == 0)
(0, 4, 16, 36, 64)
```

Like map and filter, generator expressions don't generate a tuple! So you take the result and pass it to the tuple constructor.