CS61A Lecture 8
Data Abstraction

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June 28, 2012
COMPUTER SCIENCE IN THE NEWS

GIZMODO AUSTRALIA

COMPUTING

Raspberry Pi Computer To Cross The Atlantic Ocean In Autonomous Boat

LUKE HOPEWELL - GIZMODO AU - YESTERDAY 6:15 AM

There's a lot you can do with a Raspberry Pi. It's a credit card-sized computer that costs next to nothing, and it's about to become the brain of a tiny boat that its developer hopes will cross the Atlantic Ocean unaided.
TODAY

• Quick orders of growth review
• Data Abstraction and making new Abstract Data Types
• Tuples
REVIEW: ORDERS OF GROWTH

What is the order of growth (using \( \Theta \) notation) for the following Python function?

```python
def foo(x):
    if x < 3:
        return x
    return foo(x % 3) + foo(x - 1)
```
**Review: Orders of Growth**

\( \Theta(n) \)

We know that the result of \( n \% 3 \) is 0, 1, or 2 (the base case), so we know that the first recursive call will always result in a base case and we can treat it as a constant time operation.

The second recursive call will take (about) \( n \) recursive calls before reaching a base case (we subtract one from \( n \) each time). So we have \( \Theta(n) \) recursive calls with constant amount of work done for each call.
DATA ABSTRACTION

We want to be able to think about data in terms of its meaning rather than in terms of the way it is represented.

Data abstraction allows us to isolate:

– How the data is represented (as parts)
– How the data is manipulated (as units)

We do this by using functions to help create a division between these two cases.
**Problem: Rational Numbers**

\[
\begin{array}{c}
\text{Numerator} \\
\hline
\text{Denominator}
\end{array}
\]

Exact representation of fractions using a pair of integers.

**Multiplication**
\[
\frac{a}{b} \times \frac{c}{d} = \frac{ac}{bd}
\]

**Addition**
\[
\frac{a}{b} + \frac{c}{d} = \frac{ad + bc}{bd}
\]

**Equality**
\[
\frac{a}{b} = \frac{c}{d} \iff ad = cb
\]
**Problem: Rational Numbers**

We’d like to be able to create and decompose rational numbers in our program:

- `make_rat(n, d) – returns the rational number \( \frac{n}{d} \)
- `numer(x) – returns the numerator of x
- `denom(x) – returns the denominator of x

These are all we need to define an Abstract Data Type (ADT).
**PROBLEM: RATIONAL NUMBERS**

```python
def mul_rats(r1, r2):
    return make_rat(numer(r1) * numer(r2), denom(r1) * denom(r2))

def add_rats(r1, r2):
    n1, d1 = numer(r1), denom(r1)
    n2, d2 = numer(r2), denom(r2)
    return make_rat(n1 * d2 + n2 * d1, d1 * d2)

def eq_rats(r1, r2):
    return numer(r1) * denom(r2) == numer(r2) * denom(r1)
```

Notice that we don’t have to know how rational numbers work in order to write any code that uses them!
PROBLEM: RATIONAL NUMBERS

Great! If we can implement `make_rat`, `numer`, and `denom`, then we can finish our wonderful rational numbers module!
PRACTICE: USING ABSTRACTIONS

How would I write a function to invert (flip) a rational number using the constructor and selectors we are using for rational numbers?
How would I write a function to invert (flip) a rational number using the constructor and selectors we are using for rational numbers?

```python
def invert_rat(r):
    return make_rat(denom(r), numer(r))
```
Tuples: Our First Data Structure

*Tuples* are a built-in datatype in Python for representing a *constant sequence* of data.

```python
>>> pair = (1, 2)
>>> pair[0]
1
>>> pair[1]
2
>>> x, y = pair
>>> x
1
>>> y
2
>>> z = pair + (6, 5, 4)
>>> z
(1, 2, 6, 5, 4)
>>> len(z)
5
>>> z[2:5]
(6, 5, 4)
>>> triplet = (1,
...            2,
...            3)
>>> triplet
(1, 2, 3)
>>> for num in triplet:
...     print(num, "potato")
... 1 potato 2 potato 3 potato
>>> (1)
1
>>> (1,)
(1,)
```
TUPLES: OUR FIRST DATA STRUCTURE

The Python data type **tuple** is an example of what we call a *data structure* in computer science.

A *data structure* is a type of data that exists primarily to hold other pieces of data in a specific way.
**Practice: Using Tuples and Abstractions**

Write the higher order function `map`, which takes a function, `fn`, and a tuple of values, `vals`, and returns the tuple of results of applying `fn` to each value in `vals`.

```python
>>> map(square, (1, 2, 3, 4, 5))
(1, 4, 9, 16, 25)
```
Write the higher order function map, which takes a function, \( \text{fn} \), and a tuple of values, \( \text{vals} \), and returns a the tuple of results of applying \( \text{fn} \) to each value in \( \text{vals} \).

```python
def map(fn, vals):
    results = ()
    for v in vals:
        results = results + (fn(v),)
    return results
```
ANNOUNCEMENTS

• Project 1 autograder is running now.
• Next week, we will move to 105 Stanley for the rest of the summer.
• Midterm 1 is on July 9.
  – We will have a review session closer to the date.
• If you need accommodations for the midterm, please notify DSP by the end of this week.
• HW1 grade should be available on glookup.
**Problem: Rational Numbers**

```python
def make_rat(n, d):
    return (n, d)

def numer(x):
    return x[0]

def denom(x):
    return x[1]
```
ABstraction Diagrams

rational numbers as numerators and denominators

Using the ADT
make_rat, numer, denom
Implementing the ADT

rational numbers as tuples

Using the ADT
tuple, getitem
Implementing the ADT

tuples as sequences of data

However Python implements tuples
**DATA ABSTRACTION: SO WHAT?**

It makes code more readable and intuitive.

Which version is clearer?

```python
def mul_rats(r1, r2):
    return (r1[0] * r2[0], r1[1] * r2[1])
```

```python
def mul_rats(r1, r2):
    return make_rat(numer(r1) * numer(r2), denom(r1) * denom(r2))
```

When we write code that assumes a specific implementation of our ADT, we call this a **data abstraction violation (DAV)**.
DATA ABSTRACTION: SO WHAT?

We don’t have to worry about changing all the code that uses our ADT if we decide to change the implementation!

```python
def make_rat(n, d):
    return (d, n)
def numer(x):
    return x[1]
def denom(x):
    return x[0]
```

```python
# Will still work
def mul_rats(r1, r2):
    return make_rat(numer(r1) * numer(r2),
                    denom(r1) * denom(r2))
```

```python
# Will break
def mul_rats(r1, r2):
    return (r1[0] * r2[0], r1[1] * r2[1])
```
Suppose that Louis Reasoner wrote the following function `prod_rats` that takes a tuple of rational numbers using our ADT and returns their product. Correct his code so that he does not have any data abstraction violations.

```python
def prod_rats(rats):
    total, i = (1, 1), 0
    while i < len(rats):
        total = (total[0] * rats[i][0],
                 total[1] * rats[i][1])
        i += 1
    return total
```
Suppose that Louis Reasoner wrote the following function `prod_rats` which takes a tuple of rational numbers using our ADT and returns their product. Correct his code so that he does not have any data abstraction violations.

```python
def prod_rats(rats):
    total, i = make_rat(1, 1), 0
    while i < len(rats):
        total = make_rat(numer(total) * numer(rats[i]),
                         denom(total) * denom(rats[i]))
        i += 1
    return total
```
Practice: Data Abstraction

Say I wrote the following functions to define my student ADT.

```python
def make_student(name, id):
    return (name, id)
def student_name(s):
    return s[0]
def student_id(s):
    return s[1]
```

If I changed the student ADT to also include the student’s age, what functions would I have to add or change in order to complete the abstraction?
Practice: Data Abstraction

Say I wrote the following functions to define my student ADT.

```python
def make_student(name, id):
    return (name, id)
def student_name(s):
    return s[0]
def student_id(s):
    return s[1]
```

If I changed the student ADT to also include the student’s age, what functions would I have to add or change in order to complete the abstraction?

You would have to change `make_student` to take this new parameter. If you just represent a student as the tuple `(name, id, age)`, then you only have to add a selector for the student’s age. The other two selectors would not have to be modified in this case.
CONCLUSION

• Tuples are a nice way to group data in Python.
• Learned how to design new types of data by using *data abstraction*.
• *Preview*: Useful data structures.
EXTRAS: USING FUNCTIONS TO CREATE ADTs

It turns out you don’t need to have something like tuples in a language in order to group data together. Say I wanted to make a pair abstraction, which is like a tuple of length 2. I could do this with just functions:

```python
def make_pair(first, second):
    def pair(msg):
        if msg == "first":
            return first
        elif msg == "second":
            return second
        return pair
    return pair

def first(p):
    return p("first")

def second(p):
    return p("second")
```
EXTRAS: MORE ABOUT STRINGS

Strings and tuples are both *sequences*, meaning that they are things that you can iterate over with a `for` loop. Interestingly, they can also be indexed into and sliced like tuples.

```python
>>> for letter in "abc":
...     print(letter)

a
b
c
```

```python
>>> "asdfs"[2]

d
```

```python
>>> "slaughterhouse"[1:9]

"laughter"
```