Lecture 9: Data Abstraction

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Announcements

Roadmap

- Introduction
- Functions
- Data
- Mutability
- Objects
- Interpretation
- Paradigms
- Applications

- This week (Data), the goals are:
  - To continue our journey through abstraction with *data abstraction*
  - To study useful data types we can construct with data abstraction

List Comprehensions (demo)

[<map exp> **for** <name> **in** <seq exp> **if** <filter exp>]

Short version: [<map exp> **for** <name> **in** <seq exp>]

A combined expression that evaluates to a list using this evaluation procedure:

1. Add a new frame with the current frame as its parent
2. Create an empty *result list*
3. For each element in the sequence from <seq exp>:
    1. Bind <name> to that element in the new frame
    2. If <filter exp> evaluates to a true value, then add the value of <map exp> to the result list

Data Abstraction

- Python (and other languages) implements for us some *primitive* data types, such as numbers and strings

- But most data that we care about are *compound values*, rather than just a single value like a number or string
  - A date is three numbers: year, month, and day
  - A location is two numbers: latitude and longitude

- *Data abstraction* allows us to manipulate compound values as *units*, rather than having to deal with their *parts*

Data Abstraction

- Great programmers use data abstraction to separate:
  - How compound values are *represented* (the parts)
  - How compound values are *used* (the unit)
  - This leads to programs that are more understandable, easier to maintain, and just better in general

- The separation is called the *abstraction barrier*
  - Most important thing I'll say today:

Never violate the abstraction barrier!

Example: Rational Numbers (demo)

- Rational numbers are numbers that can be expressed as

$$\frac{n}{d}$$

  where n and d are both integers

- So a rational number can be represented as two numbers, making it a compound value

- This is an exact representation of fractions
  - If we instead use floats to represent fractions, we can lose the exact representation if we perform division

Representing Rational Numbers

- To represent a compound data type, we must have:
  1. *Constructors* that allow us to construct new instances of the data type
  2. *Selectors* that allow us to access the different parts of the data type
- These are typically both functions

```
def rational(n, d):
    """Return the rational number with numerator n
    and denominator d."""
    ...
```

```
def numer(rat):
    """Return the numerator of
    the rational number rat."""
    ...
```

```
def denom(rat):
    """Return the denominator of
    the rational number rat."""
    ...
```

Using Rational Numbers (demo)

```
def rational(n, d):
    """Return the rational number with numerator n
    and denominator d."""
    ...
```

```
def numer(rat):
    """Return the numerator of
    the rational number rat."""
    ...
```

```
def denom(rat):
    """Return the denominator of
    the rational number rat."""
    ...
```

Multiplying two rational numbers: $\frac{a}{b} * \frac{c}{d} = \frac{ac}{bd}$

```
def mul_rational(rat1, rat2):
    """Multiply rat1 and rat2 and return a new rational number."""
    return rational(numer(rat1) * numer(rat2),
                    denom(rat1) * denom(rat2))
```

Implementing Rational Numbers (demo)

- There are many different ways we could choose to implement rational numbers
- One of the simplest is to use lists

```
from fractions import gcd  # Greatest common divisor
def rational(n, d):
    """Return the rational number with numerator n
    and denominator d."""
    divisor = gcd(n, d)  # Reduce to lowest terms
    return [n//divisor, d//divisor]
```

```
def numer(rat):
    """Return the numerator of
    the rational number rat."""
    return rat[0]
```

```
def denom(rat):
    """Return the denominator of
    the rational number rat."""
    return rat[1]
```

The Abstraction Barrier

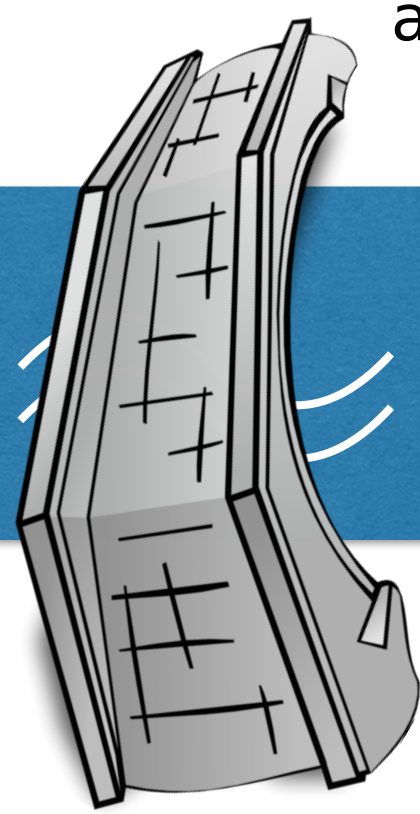
The almighty abstraction barrier!

The Abstraction Barrier

Data Type
Usage

Rational numbers as
a unit and its parts

```
mul_rational
add_rational
print_rational
```



Abstraction
Barrier

Constructors and Selectors

```
rational, numer, denom
```

Data Type
Implementation

Rational numbers as
two-element lists

```
[n, d]
rat[0]
rat[1]
```

Abstraction Barrier Violations

- Constructors and selectors provide us with *abstraction*, allowing us to use the data type without having to know its implementation
- An *abstraction barrier violation* is when we assume knowledge about the data type implementation, rather than using constructors and selectors
- Remember the most important thing I'll say today:

Never violate the abstraction barrier!

- Why is this such a bad thing?

Abstraction Barrier Violations

```
from fractions import gcd
def rational(n, d):
    divisor = gcd(n, d)
    return [n//divisor,
            d//divisor]

def numer(rat):
    return rat[0]

def denom(rat):
    return rat[1]
```

```
def mul_rational(rat1, rat2):
    return [rat1[0]*rat2[0],
            rat1[1]*rat2[1]]
```

No selectors!

No constructor either!

```
# You write many more lines of code
# with abstraction barrier violations...
```

Abstraction Barrier Violations

```
from fractions import gcd
def rational(n, d):
    divisor = gcd(n, d)
    return {'n': n//divisor,
            'd': d//divisor}

def numer(rat):
    return rat['n']

def denom(rat):
    return rat['d']
```

```
def mul_rational(rat1, rat2):
    return [rat1[0]*rat2[0],
            rat1[1]*rat2[1]]
```

No selectors!

No constructor either!

```
# You write many more lines of code
# with abstraction barrier violations...
```

- Switching data type implementations breaks `mul_rational`! Along with the rest of your code...
- If we don't violate abstraction, everything will always work if we keep our constructors and selectors consistent

A Dictionary Abstract Data Type

(demo)

Summary

- *Data abstraction* provides us with a powerful set of ideas for working with compound values
  - Using abstraction allows us to think about data types in terms of units and parts, rather than worrying about the implementation
  - This leads to programs that are easier to maintain and easier to understand

- An abstraction barrier violation is when we assume knowledge about the underlying data type implementation
  - One more time for emphasis:

Never violate the abstraction barrier!