Exam One Review

Overview

API

- Provides basic structure for software components
  - Return values including data types
  - Name of each method or function
  - Required Parameters and associated data types for each
  - Description of what each component does
    - Not pictured here

```
class Balloon
Return:     Method:     Parameters:
            Balloon     (self, float x, float y, float maxRadius, string label,
                        int red, int green, int blue)
            draw        (self)
boolean     matches     (self, string label)
  float     lift        (self, float liftPerUnitVolume)
            inflate     (self, float increaseRadiusBy)
```

Test __main__

- The functional scout for how your program is performing
  - Ensures each component operates correctly

```
#
# Test program for Cell.
#
# To run this code and test your class, type "python Cell.py" at the
#    command prompt. Your output should be exactly like what is shown
#    on the assignment page.
#
if __name__ == "__main__":
    import Config
    # The config object stores defaults for sizes, sounds, and images
    config = Config.Config()

    # Fake a dungeon that is 3 x 3
    WIDTH = 3
    HEIGHT = 3
    StdDraw.setCanvasSize(WIDTH * config.cellPixels(), HEIGHT * config.cellPixels())
    StdDraw.setXscale(0, WIDTH * config.cellPixels())
    StdDraw.setYscale(0, HEIGHT * config.cellPixels())

    # Draw a wall at various locations
    wall = Cell(config.wallImage())
    wall.draw(config, 0, 0)
    wall.draw(config, 1, 1)

    # Wall with a different image
    wall2 = Cell(config.passageImage())
    wall2.draw(config, 2, 2)
```

Commenting Format

- Header comment
- Comment each method and function
  - Purpose/Intended Behavior
  - Input parameters
    - Name
    - Data type expected
    - Intended Behavior
  - Return values
    - Name
    - Data type expected
    - Intended Behavior
- Guide the reader through any hacks you had to use

```python
# Author Eli Hodges
#
# This section of the multiagent software package is designed to handle
#   the behavior of the non-player agents participating in the competition.
#

from game import Agent
from game import Actions
from game import Directions
import random
from util import manhattanDistance
import util
```

```python
def getFood(self):
    """
    Returns a Grid of boolean food indicator variables.

    Grids can be accessed via list notation, so to check
    if there is food at (x,y), just call

    currentFood = state.getFood()
    if currentFood[x][y] == True: ...
    """
    return self.data.food
```

Commenting Format

```python
def findPathToClosestDot(self, gameState):
    """
    Returns a path (a list of actions) to the closest dot, starting from
    gameState.
    """
    # Here are some useful elements of the startState
    startPosition = gameState.getPacmanPosition()
    food = gameState.getFood()
    walls = gameState.getWalls()
    problem = AnyFoodSearchProblem(gameState)

    fringe = util.Queue()
    travel_log = []
    directioneer = []
    ovrCost = 0
    begin = problem.getStartState()

    # Only one data type this time...
    fringe.push((begin, directioneer))

    while not (fringe.isEmpty()):
        #Create a pair of values to expand the fringe into
        node, actions = fringe.pop()

        #If we haven't logged this location yet...
        if not (node in travel_log):
            #Put it in the log...
            travel_log.append(node)
            #Check it against our treasure map...
            if problem.isGoalState(node):
                return actions
            #Mark down where we can go from here...
            children = problem.getSuccessors(node)
            #For every place in this list of places we can go...
            for child in children:

                #Break it down into usable data...
                xy, direction, cost = child
                #Make a list of where each of these places are relative to us...
                newActions = actions + [direction]

                #We're using bfs, give orders to the crew!
                if isinstance(fringe, util.Stack) or isinstance(fringe, util.Queue):
                    fringe.push((xy, newActions))
```

Dynamic Lists

Arrays

List Operations

- Insertion
  - Append() – Adds item to the end of the list
    - listName.append(item)
  - Insert() – Adds item at the **given index**
    - listName.insert(index, item)
- Removal
  - Del() – Facilitates deletion of multiple elements
    - Del listName[2 : 5]
    - Deletes elements in position 2 through 5
  - Pop() – Deletes at the given position
    - listName.pop(2)
    - Deletes the third element, index #2
- Sort
  - sort() – Sorts the list in **increasing order**
    - listName.sort()
  - Sorted() – Behaves similar to sort(), grants flexibility at higher level usage
    - ***Returns a sorted list***
    - sortedList = Sorted(listName)
- Searching
  - Index() – Finds an element, returns its index *starting at 0*
    - listName.index(element)
  - Count() – returns how many times an item occurs in a list
    - listName.count(item)

Performance

Scientific Method

- Observe
  - Find out what's relevant
- Hypothesize
  - Structure that information into a model
- Predict
  - Use that model to look into the future
- Verify
  - Do that until you're sure you're right, or you can actually see into the future
    - With like, magic or some shit
- Validate
  - If it's not working, find something that will.

- Experiments must be reproducible
  - People have to be able to follow along
- Hypotheses must be falsifiable
  - If it's not possible for you to be proven wrong, that doesn't mean you're right

Metrics

Time

- How long does your code run for?
- Tends to be integrated into your development software

```
import time

t1 = time.time()
# Put the code you want to time here
t2 = time.time()
print(t2-t1)
```

Space

- Do you have the resources for it?
  - Physical memory management always factors into development at some point.

- 8 GB = 8.6 billion places to store a byte (byte = 256 possibilities)
- Python float, 64-bits = 8 bytes
- 8 GB / 8 bytes = over 1 million floats!

Empirical Analysis

Empirical

Verifiable by observation or experience rather than theory or pure logic

Analysis

Detailed examination of the elements of something

Doubling Hypothesis

Quick and easy way to find the order of growth of your program

- Order of Growth -

Mathematically, how does your input space relate to your runtime?

Constant from ratio	Hypothesis	Order of growth
2	$T = a N$	linear, $O(N)$
4	$T = a N^2$	quadratic, $O(N^2)$
8	$T = a N^3$	cubic, $O(N^3)$
16	$T = a N^4$	$O(N^4)$

N	T(N)	ratio
400	0.16	-
800	0.63	3.94
1600	4.33	6.87
3200	33.69	7.78
6400	263.82	7.83

Prediction

Instrumental in finding bottlenecks by determining what your program ***should*** be doing

Estimating Constant, Making Predictions

N	T(N)	ratio
400	0.16	-
800	0.63	3.94
1600	4.33	6.87
3200	33.69	7.78
6400	263.82	7.83

Keith's Desktop data

$T = a N^3$

$263.82 = a (6400)^3$

$a = 1.01 \times 10^{-09}$

N	T(N)	ratio
400	11.23	-
800	94.96	8.45
1600	734.03	7.72
3200	5815.30	7.92
6400	47311.43	8.14

Keith's Laptop data

$T = a N^3$

$47311.43 = a (6400)^3$

$a=1.80 \times 10^{-07}$

Prediction:
How long for desktop to solve a 100,000 integer problem?

$1.01 \times 10^{-09} (100000)^3 = 1006393$ secs
$= 280$ hours

Prediction:
How long for laptop to solve a 100,000 integer problem?

$1.80 \times 10^{-07} (100000)^3 = 1.80 \times 10^{08}$ secs
$= 50133$ hours

Nested Loops and Growth

- Nested loops
  - A good clue to order of growth
  - But each loop must execute "on the order of" N times
  - If loop not a linear function of N, loop doesn't cause order to grow

```
for i in range(0, N):
    for j in range(0, N):
        for k in range(0, N):
            count += 1
```

N^3

N	T(N)	ratio
5000	6.85	-
10000	53.48	7.8
20000	425.97	8.0

$425.97 = a\ (20000^3)$

$a = 1.06 \times 10^{-6}$

```
for i in range(0, N):
    for j in range(0, N):
        for k in range(0, 10000):
            count += 1
```

N^2

N	T(N)	ratio
5000	13.40	-
10000	53.20	3.97
20000	212.49	3.99

$212.49 = a\ (20000^2)$

$a = 5.31 \times 10^{-7}$

Linked Lists

Sequential vs Linked

Sequential

- Fixed size
  - Allows for inefficient dynamics
- Simple
- A populated chunk of memory

Linked

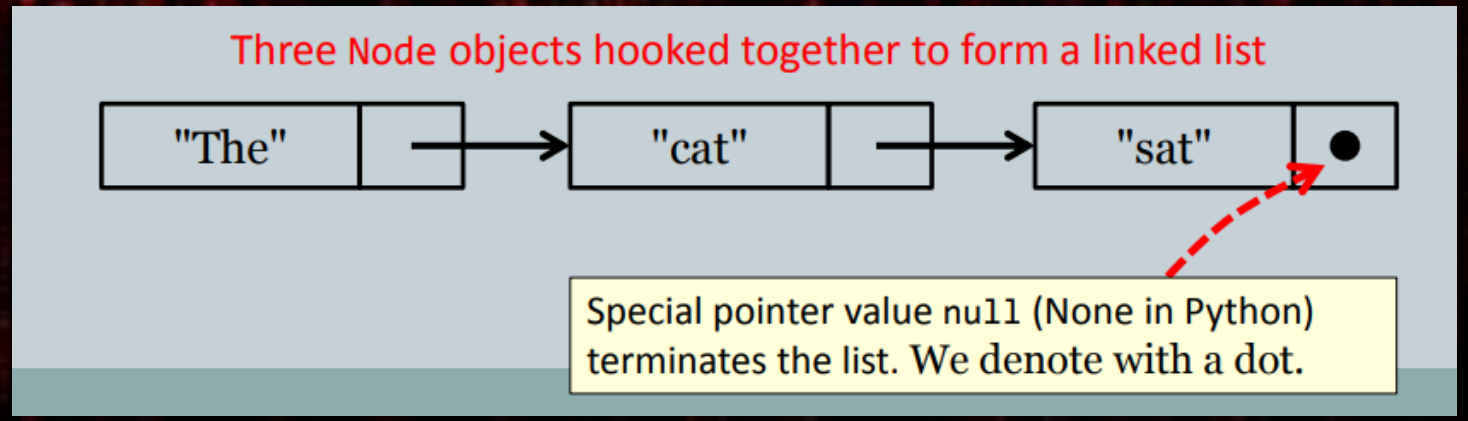
- Nodes that hold data, and point to another node
  - Does ***not*** require nodes to be neighbors in memory
- Dynamic
  - Expand by updating node relationships
- Flexible
- Comparatively challenging

Anatomy of a Linked List

- Each node contains two parts
  - An item of any kind. Literally any kind of data can be in here.
- A pointer to the next node
  - Linked lists are trains of data.

```
class Node:

def __init__(self, s):
    self.item = s
    self.next = None
```



Building a linked list

Building a linked list

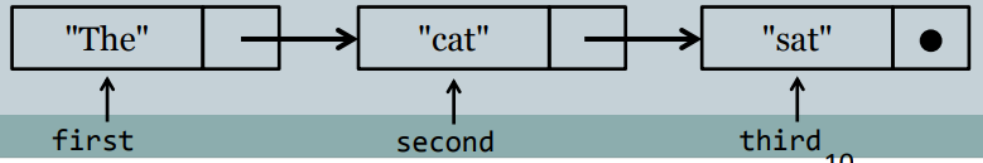
```
first  = Node()
first.item  = "The"

second = Node()
second.item = "cat"

third  = Node()
third.item  = "sat"

first.next  = second
second.next = third
```

	Memory address	Value
second →	C0	"cat"
	C1	C8
	C2	-
	C3	-
first →	C4	"The"
	C5	C0
	C6	-
	C7	-
third →	C8	"sat"
	C9	null

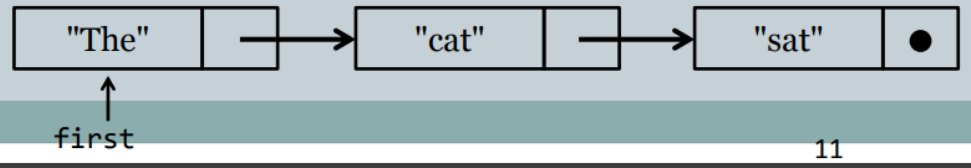


Traversing a linked list

Traversing a List

- Iterate over all elements in a linked list
  - Assume list is null terminated
  - Assume `first` instance variable points to start of list
  - Print all the strings in the list

```
current = first
while current != None:
    print(current.item)
    current = current.next
```



Operations on a linked list

Add – Inserts a node at the end of the list

Insert – Inserts a node at a specific point in the list

Remove – Removes a node at a specific point in the list

Stacks and Queues

Abstract Data Types
vs
Data Structures

ADTs

ADTs don’t specify implementation details

Just provides boundaries and tools

Data Structures

- Specific Implementations of ADTs.
  - Stacks can be implemented using either an array, or a linked list

The Stack

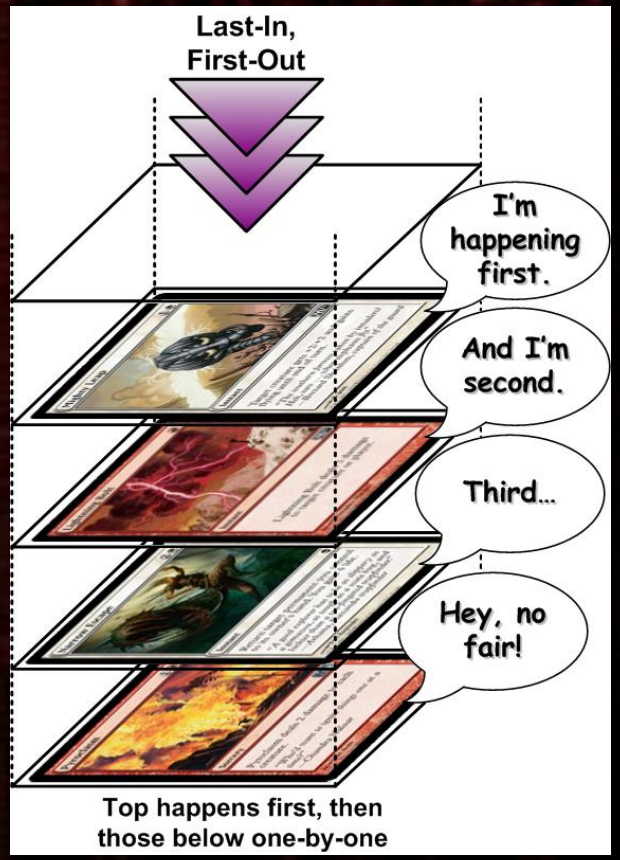
Stacks

Structure nodes as Last in, first out. (LIFO)

Operations

Push() – Inserts a node at the ***top of the stack***

Pop() – Removes the node at the ***top of the stack***



The Queue

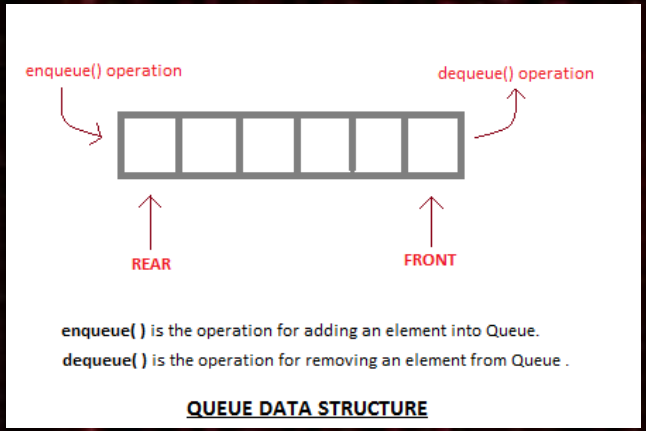
Queue

Structure nodes as First in, first out. (FIFO)

Operations

Enqueue() – Inserts a node at the ***end of the queue***

Dequeue() – Removes the node at the ***front of the queue***



LOBBY HOME PROFILE COLLECTION LOOT STORE 400 3193

BaronNashorPL
In Queue

NORMAL • BLIND

Summoner's Rift • 5v5

LOW PRIORITY QUEUE
Your team has been placed in a low priority queue because the following players have left too many matches:

BattPlayerTV

FINDING MATCH
34:02
Estimated: 0:00

FiltyFreud

BattPlayerTV
*^,^

BaronNashorPL
*^,^

GownoRex69JD

FiltyFreud: https://www.youtube.com/watch?v=SSsNaAB9wIg

FiltyFreud: https://www.youtube.com/watch?v=nGSOsEfJPO8

FiltyFreud: ahahahah

FiltyFreud: https://www.youtube.com/watch?v=-GEHyAfV4OI&index=7&list=PLoy86qeO3xK4wMi9wE1Rz4oMlw_UW2R9S

CANCEL IN QUEUE

SOCIAL

*^,^ We are all Weebs
6 online

NCFU nyan cat fans
4 online

BattPlayerTV
In Queue

devilpichu
In Game

FiltyFreud
In Queue

GownoRex69JD
In Queue

Alfa omega1234
Mobile

AllyStev
Mobile

browniemanboy
Mobile

coldscars997
Mobile

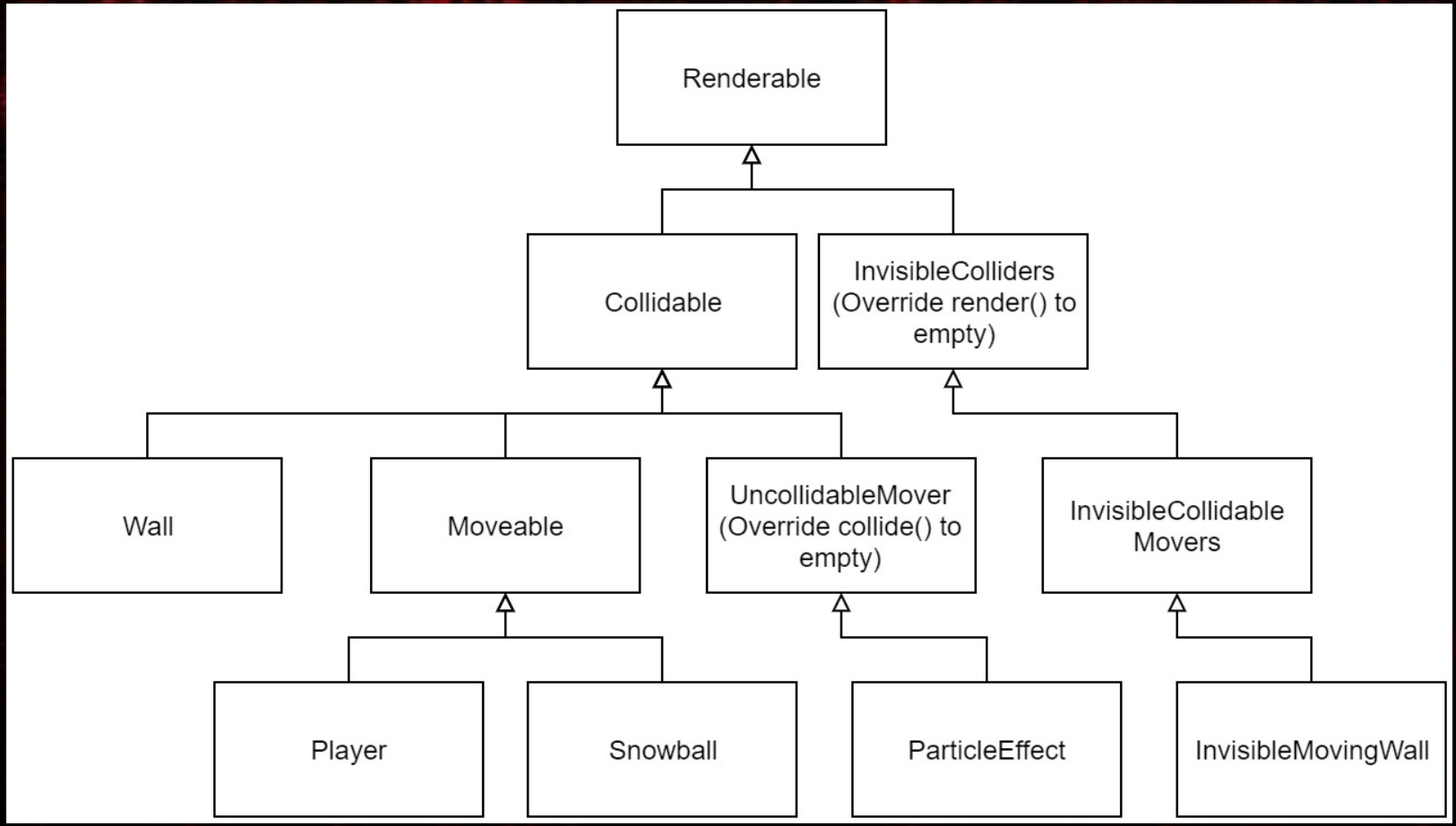
V7.1-3644497.3656864

Inheritance

What’s the point?

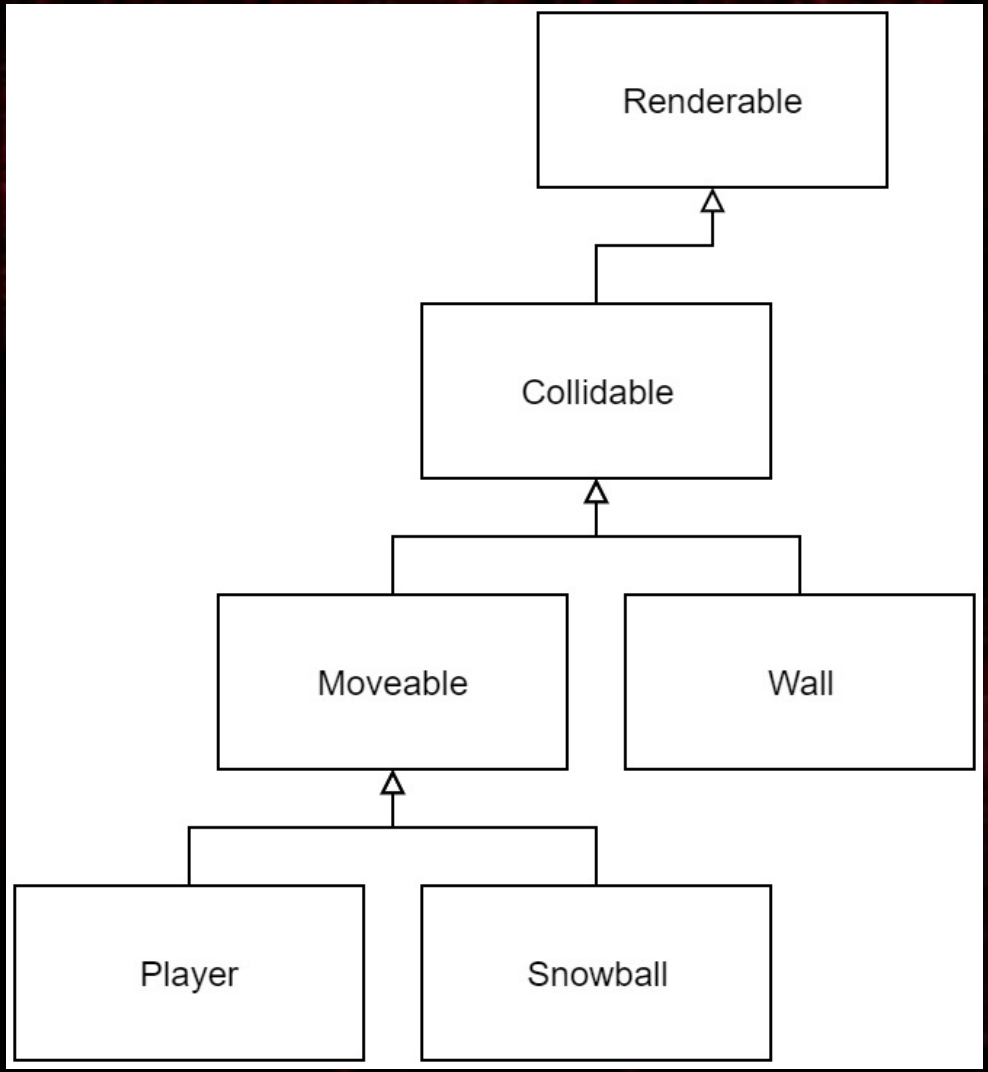
The main purpose of inheritance is to make it easier for us to understand our code by structuring it in a way that reduces duplication.

Inheritance



Abstract Classes

- Abstract classes are **unimplementable ideas**
  - Very useful to use as the foundation for classes lower in the hierarchy



Generic Data Types

A *generic type* is a generic class or interface that is parameterized over types

If your class or method can work with more than one data type…

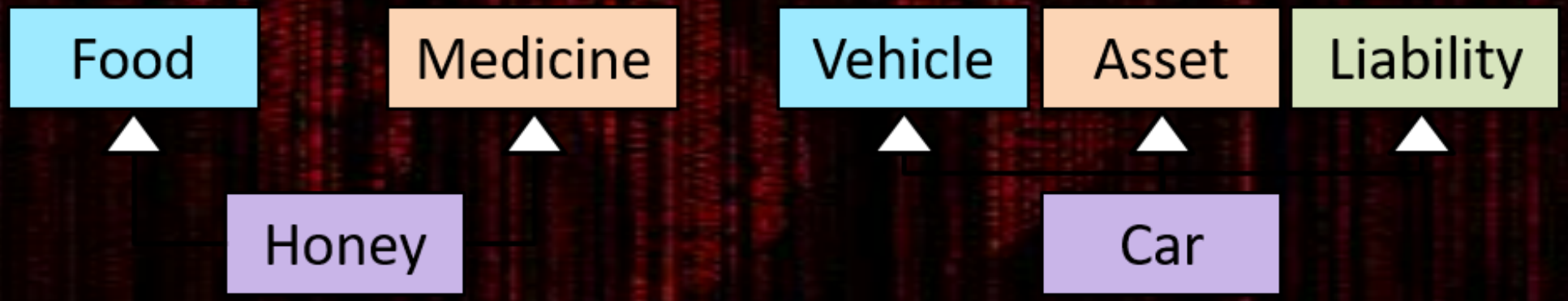
(Strings, Ints, nodes, structures you've made yourself, a tuple named doink that you haven't renamed yet…)

It's a generic.

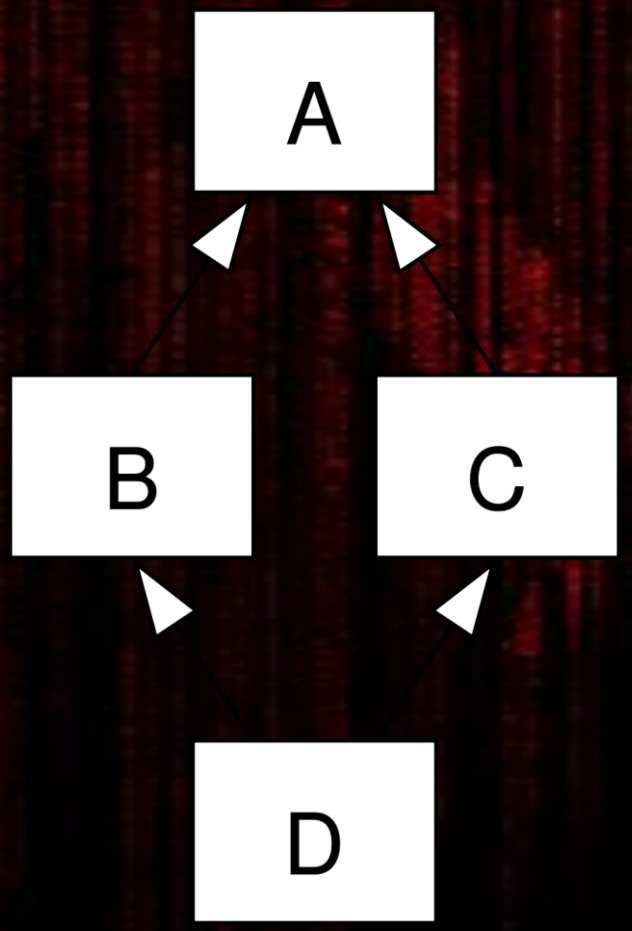
If it ***technically won't break*** when you run a second data type through it, it's a generic. The goal is to re-use your code when you can

Multiple Inheritance

Multiple Inheritance



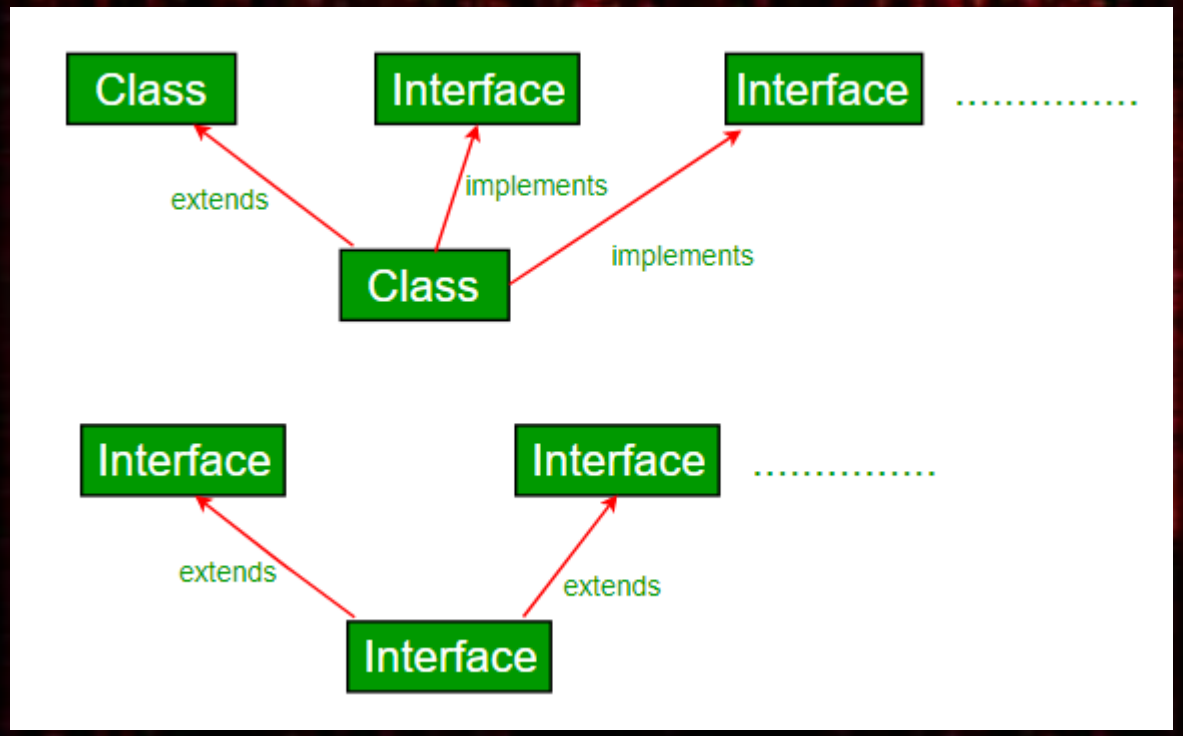
When does it break?



With python, it doesn’t really

Each language handles things differently

Interfaces



If your language doesn’t have multiple inheritance, just use an interface to pretend it does

Recursion

Recursion

A method that calls itself is
recursive

Solves problems by collapsing in on itself

Must define a stopping point

Recursion

A method that calls itself is **recursive**

Solves problems by collapsing in on itself

Recursion

RECURSION

Hello Recursion

- Goal: Compute factorial N! = 1 * 2 * 3 … * N
  - Base case: 0! = 1
  - Induction step:
    - Assume we know (N – 1)!
    - Use (N – 1)! to find N!

```
4! = 4 * 3 * 2 * 1 = 24

4! = 4 * 3!
3! = 3 * 2!
2! = 2 * 1!
1! = 1 * 0!
0! = 1
```

```
import sys

def fact(N):
    if N == 0:
        return 1
    return fact(N - 1) * N

if __name__ == "__main__":
    N = int(sys.argv[1])
    print(str(N) + "! = " + str(fact(N)))
```

base case

induction step

When to use

- If it is more intuitive to observe, use it.
- If it’s easier to debug, use it.
- If you will spend more resources doing things recursively, don’t.
- If you’re a time traveler with a craptop, don’t.

System Call Stack

Stack Overflow occurs when you use more memory than your stack can manage.

Processes resolve following stack behavior.

Base case is resolved, and returned to the recursive call above.

Examples

Slide collection 07-08
on Moodle