Lecture 2, 8 January 2026
Classes, objects, Java

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Programming Language Concepts
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Abstract datatypes

- Abstract data types
  - Structured collection with fixed interface
  - Stack is a sequence, but only allows `push` and `pop`

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    - Can implement a priority queue using sorted or unsorted lists, or using a heap

Abstract datatypes

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  - Structured collection with fixed interface
  - Stack is a sequence, but only allows `push` and `pop`
  - Separate implementation from interface
    - Priority queue allows `insert` and `delete-max`
    - Can implement a priority queue using sorted or unsorted lists, or using a heap
  - Define ADTs without reference to implemention?

$$pop(push(s, v)) = v$$

Programming with objects

- Object are like abstract datatypes
  - Hidden data with set of public operations
  - All interaction through operations — messages, methods, member-functions, ...

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  - How public functions manipulate data

Programming with objects

- Object are like abstract datatypes
  - Hidden data with set of public operations
  - All interaction through operations — messages, methods, member-functions, ...
- Class
  - Template for a data type
  - How data is stored
  - How public functions manipulate data
- Object
  - Concrete instance of template
  - Each object maintains a separate copy of local data
  - Invoke methods on objects — send a message to the object

push (s, v)

s.push(v)

Example: 2D points, in Python

- A point has coordinates (x, y)
  - Each point object stores its own internal values `x` and `y` — instance variables
  - For a point `p`, the local values are `p.x` and `p.y`
  - `self` is a special name referring to the current object — `self.x`, `self.y`

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  - For a point `p`, the local values are `p.x` and `p.y`
  - `self` is a special name referring to the current object — `self.x`, `self.y`
- When we create an object, we need to set it up
  - Implicitly call a constructor function with a fixed name
  - In Python, constructor is called `__init__()`
  - Parameters are used to set up internal values
  - In Python, the first parameter is always `self`

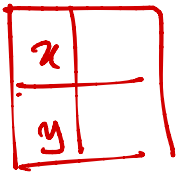
```
class Point:
  def __init__(self,a=0,b=0):
    self.x = a
    self.y = b
```

int x ;

x = 5 ;

int x = 5;

p = new Point (4, 7);




```
class Point {
    float x, y;
    -- construct
```

Lists

```
l = []        l = new List()

l.append(5)

List.append(l, 5)
```

self

Adding methods to a class

- Translation: shift a point by $(\Delta x, \Delta y)$
  - $(x, y) \mapsto (x + \Delta x, y + \Delta y)$
  - Update instance variables

```
class Point:
  def __init__(self,a=0,b=0):
    self.x = a
    self.y = b

  def translate(self,dx,dy):
    self.x += dx
    self.y += dy
```

x = a
y = b

Adding methods to a class

- Translation: shift a point by $(\Delta x, \Delta y)$
  - $(x, y) \mapsto (x + \Delta x, y + \Delta y)$
  - Update instance variables
- Distance from the origin
  - $d = \sqrt{x^2 + y^2}$
  - Does not update instance variables
  - state of object is unchanged

```
class Point:
  def __init__(self,a=0,b=0):
    self.x = a
    self.y = b

  def translate(self,dx,dy):
    self.x += dx
    self.y += dy

  def odistance(self):
    import math
    d = math.sqrt(self.x*self.x +
                  self.y*self.y)
    return(d)
```

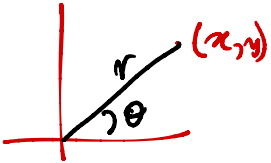
me

me, x

me y

Changing the internal implementation

- Polar coordinates: (r, θ), not (x, y)
  - $r = \sqrt{x^2 + y^2}$
  - $\theta = \tan^{-1}(y/x)$

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import math
class Point:
  def __init__(self,a=0,b=0):
    self.r = math.sqrt(a*a + b*b)
    if a == 0:
      self.theta = math.pi/2
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  def odistance(self):
    return(self.r)
```

Changing the internal implementation

- Polar coordinates: (r, θ), not (x, y)
  - $r = \sqrt{x^2 + y^2}$
  - $\theta = \tan^{-1}(y/x)$
- Distance from origin is just r
- Translation
  - Convert (r, θ) to (x, y)
  - $x = r\cos\theta$, $y = r\sin\theta$
  - Recompute r, θ from $(x + \Delta x, y + \Delta y)$

```
def translate(self,dx,dy):
  x = self.r*math.cos(self.theta)
  y = self.r*math.sin(self.theta)
  x += dx
  y += dy
  self.r = math.sqrt(x*x + y*y)
  if x == 0:
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- Distance from origin is just r
- Translation
  - Convert (r, θ) to (x, y)
  - $x = r \cos \theta$, $y = r \sin \theta$
  - Recompute r, θ from $(x + \Delta x, y + \Delta y)$
- Interface has not changed
  - User need not be aware whether representation is (x, y) or (r, θ)

```
def translate(self,dx,dy):
  x = self.r*math.cos(self.theta)
  y = self.r*math.sin(self.theta)
  x += dx
  y += dy
  self.r = math.sqrt(x*x + y*y)
  if x == 0:
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Abstraction

- User should not know whether `Point` uses `(x,y)` or `(r,theta)`
  - Interface remains identical
  - Even constructor is the same

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class Point:
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class Point:
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  - Even constructor is the same
- Python allows direct access to instance variables from outside the class

```
p = Point(5,7)
p.x = 4  # Point is now (4,7)
```

p.r
p.theta
p.x

```
class Point:
  def __init__(self,a=0,b=0):
    self.x = a
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```

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class Point:
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  - Breaks the abstraction
  - Changing the internal implementation of `Point` can have impact on other code

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class Point:
  def __init__(self,a=0,b=0):
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  - Breaks the abstraction
  - Changing the internal implementation of `Point` can have impact on other code
- Rely on programmer discipline

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class Point:
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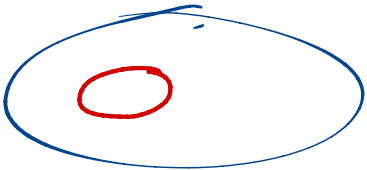
Subtyping and inheritance

- Define `Square` to be a subtype of `Rectangle`
  - Different constructor
  - Same instance variables



```
class Rectangle:
  def __init__(self,w=0,h=0):
    self.width = w
    self.height = h

  def area(self):
    return(self.width*self.height)

  def perimeter(self):
    return(2*(self.width+self.height))

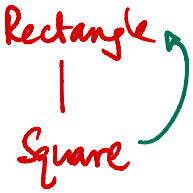
class Square(Rectangle):
  def __init__(self,s=0):
    self.width = s
    self.height = s
```

Subtyping and inheritance

- Define `Square` to be a subtype of `Rectangle`
  - Different constructor
  - Same instance variables
- The following is legal

```
s = Square(5)
a = s.area()
p = s.perimeter()
```

  - `Square` inherits definitions of `area()` and `perimeter()` from `Rectangle`

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Subtyping and inheritance . . .

- Can change the instance variable in `Square`
  - `self.side`

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class Square(Rectangle):
  def __init__(self,s=0):
    self.side = s
```

Subtyping and inheritance . . .

- Can change the instance variable in `Square`
  - `self.side`
- The following gives a run-time error

```
s = Square(5)
a = s.area()
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```

  - `Square` inherits definitions of `area()` and `perimeter()` from `Rectangle`
  - But `s.width` and `s.height` have not been defined!
  - Subtype is not forced to be an extension of the parent type

```
class Rectangle:
  def __init__(self,w=0,h=0):
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Subtyping and inheritance . . .

- Subclass and parent class are usually developed separately

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Subtyping and inheritance . . .

- Subclass and parent class are usually developed separately
- Implementor of `Rectangle` changes the instance variables

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- Implementor of `Rectangle` changes the instance variables
- The following gives a run-time error

```
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  - `Square` constructor sets `s.width` and `s.height`
  - But the instance variable names have changed!
  - Why should `Square` be affected by this?

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Subtyping and inheritance . . .

- Need a mechanism to hide private implementation details
  - Declare component private or public

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- Working within privacy constraints
  - Instance variables `wd` and `ht` of `Rectangle` are private
  - How can the constructor for `Square` set these private variables?
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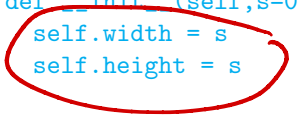

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- Need to have elaborate declarations
  - Type and visibility of variables
- Static type checking catches errors early

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Getting started with Java

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The only way to learn a new programming language is by writing programs in it. The first program is the same for all languages.

Print the words

```
hello, world
```

This is a big hurdle; to leap over it you have to create the program text somewhere, compile it successfully, load it, run it, and find out where your output went. With these mechanical details mastered, everything else is comparatively easy

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```

- . . . and Java

```
public class helloworld{
  public static void main(String[] args)
  {
    System.out.println("hello, world");
  }
}
```

Why so complicated?

- Let's unpack the syntax

```
public class helloworld{
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Why so complicated?

- Let's unpack the syntax
- All code in Java lives within a class
  - No free floating functions, unlike Python and other languages
  - Modifier `public` specifies visibility

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Why so complicated?

- Let's unpack the syntax
- All code in Java lives within a class
  - No free floating functions, unlike Python and other languages
  - Modifier `public` specifies visibility
- How does the program start?
  - Fix a function name that will be called by default
  - From C, the convention is to call this function `main()`

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public class helloworld{
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Why so complicated . . .

- Need to specify input and output types for `main()`
  - The signature of `main()`
  - Input parameter is an array of strings; command line arguments
  - No output, so return type is `void`

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  - The signature of `main()`
  - Input parameter is an array of strings; command line arguments
  - No output, so return type is `void`
- Visibility
  - Function has be available to run from outside the class
  - Modifier `public`

```
public class helloworld{
  public static void main(String[] args)
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}
```

Why so complicated . . .

- Availability
  - Functions defined inside classes are attached to objects
  - How can we create an object before starting?
  - Modifier `static` — function that exists independent of dynamic creation of objects

```
public class helloworld{
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Why so complicated . . .

- The actual operation
  - `System` is a public class

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  - `out` is a stream object defined in `System`
    - Like a file handle
    - Note that `out` must also be `static`

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  - `println()` is a method associated with streams
    - Prints argument with a newline, like Python `print()`

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```

- Punctuation {, }, ; to delimit blocks, statements
  - Unlike layout and indentation in Python

Compiling and running Java code

- A Java program is a collection of classes

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Compiling and running Java code

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- Each class is defined in a separate file with the same name, with extension `java`
  - Class `helloworld` in `helloworld.java`

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- Java programs are usually interpreted on Java Virtual Machine (JVM)
  - JVM provides a uniform execution environment across operating systems
  - Semantics of Java is defined in terms of JVM, OS-independent
  - "Write once, run anywhere"

Compiling and running Java code

- `javac` compiles into JVM bytecode
  - `javac helloworld.java` creates bytecode file `helloworld.class`

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public class helloworld{
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- Note:
  - `javac` requires file extension `.java`
  - `java` should not be provided file extension `.class`
  - `javac` automatically follows dependencies and compiles all classes required
    - Sufficient to trigger compilation for class containing `main()`

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- 2-byte `char` for Unicode

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- Boolean constants are `true`, `false`

```
boolean b1, b2;

b1 = false;
b2 = true;
```

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- Modifier `final` indicates a constant

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final float pi = 3.1415927f;

pi = 22/7;  // Flagged as error;
```

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- Shortcut for updating a variable

```
int a = 0, b = 10;
a += 7;    // Same as a = a+7
b *= 12;   // Same as b = b*12
```

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- Instead, invoke method `substring` in class `String`
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- If we change a `String`, we get a new object
  - After the update, `s` points to a new `String`
  - Java does automatic garbage collection

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- For example

```
int[] a;
int n;

n = 10;
a = new int[n];

n = 20;
a = new int[n];

a = {2, 3, 5, 7, 11};
```