Java: class hierarchy, polymorphism

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Programming Language Concepts

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A Java class

- An `Employee` class

```
public class Employee{
  private String name;
  private double salary;

  // Some Constructors ...

  // "mutator" methods
  public boolean setName(String s){ ... }
  public boolean setSalary(double x){ ... }

  // "accessor" methods
  public String getName(){ ... }
  public double getSalary(){ ... }

  // other methods
  public double bonus(float percent){
     return (percent/100.0)*salary;
  }
}
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- Some constructors to set up the object
- Accessor and mutator methods to set instance variables
- A public method to compute bonus

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Subclasses

- Managers are special types of employees with extra features

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public class Manager extends Employee{
     private String secretary;
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     public String getSecretary(){ ... }
}
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  - Every `Manager` has a `name`, `salary` and methods to access and manipulate these.
- `Manager` is a subclass of `Employee`
  - Think of subset

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- Some constructors for Employee

```
public class Employee{
  ...
  public Employee(String n, double s){
     name = n; salary = s;
  }
  public Employee(String n){
     this(n,500.00);
  }
}
```

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- Some constructors for Employee
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- Some constructors for Employee
- Use parent class's constructor using super
- A constructor for Manager

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public class Employee{
  ...
  public Employee(String n, double s){
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  }
  public Employee(String n){
     this(n,500.00);
  }
}


public class Manager extends Employee{
  ..
  public Manager(String n, double s, String sn){
     super(n,s);   /* super calls
                      Employee constructor */
     secretary = sn;
  }
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- Recall
  - `int[] a = new int[100];`
  - Why the seemingly redundant reference to `int` in `new`?

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- Recall
  - `int[] a = new int[100];`
  - Why the seemingly redundant reference to `int` in `new`?
- One can now presumably write

  `Employee[] e = new Manager[100];`

Dynamic dispatch

- Manager can redefine bonus()

```
double bonus(float percent){
   return 1.5*super.bonus(percent);
}
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  - Uses parent class bonus() via super
  - Overrides definition in parent class

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  - Static typechecking — `e` can only refer to methods in `Employee`

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  - Static: Use `Employee.bonus()`
  - Dynamic: Use `Manager.bonus()`
- Dynamic dispatch (dynamic binding, late method binding, . . .) turns out to be more useful
  - Default in Java, optional in languages like C++ (`virtual` function)

Polymorphism

- Every Employee in emparray "knows" how to calculate its bonus correctly!

```
Employee[] emparray = new Employee[2];
Employee e = new Employee(...);
Manager m = new Manager(...);

emparray[0] = e;
emparray[1] = m;

for (i = 0; i < emparray.length; i++){
  System.out.println(emparray[i].bonus(5.0))
}
```

Polymorphism

- Every `Employee` in `emparray` "knows" how to calculate its `bonus` correctly!
- Recall the event simulation loop that motivated Simula to introduce objects

```
Q := make-queue(first event)
repeat
  remove next event e from Q
  simulate e
  place all events generated
     by e on Q
until Q is empty
```

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- Also referred to as runtime polymorphism or inheritance polymorphism
- Different from structural polymorphism of Haskell etc — called generics in Java

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Functions, signatures and overloading

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- Java class `Arrays` has a method `sort` to sort arbitrary scalar arrays

```
double[] darr = new double[100];
int[] iarr = new int[500];
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Arrays.sort(darr);
  // sorts contents of darr
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- Java class `Arrays` has a method `sort` to sort arbitrary scalar arrays
- Made possible by overloaded methods defined in class `Arrays`

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  // sorts contents of darr
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class Arrays{
  ...
  public static void sort(double[] a){..}
     // sorts arrays of double[]
  public static void sort(int[] a){..}
     // sorts arrays of int[]
  ...
}
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Functions, signatures and overloading

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- Dynamic dispatch: multiple methods, same signature, choice made at run-time

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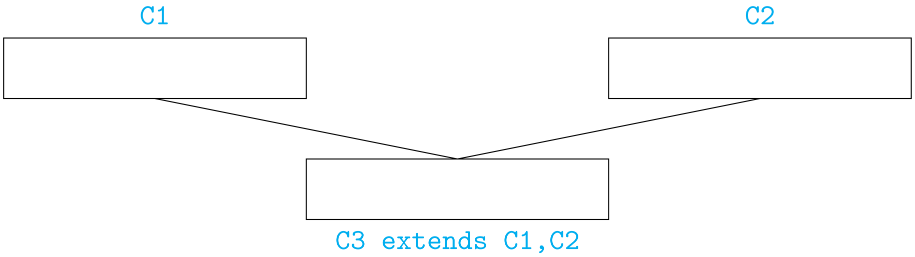
- A simple example of reflection in Java
  - "Think about oneself"
- Can also use type casting for basic types

  ```
  double d = 29.98;
  long nd = (long) d;
  ```

Multiple inheritance



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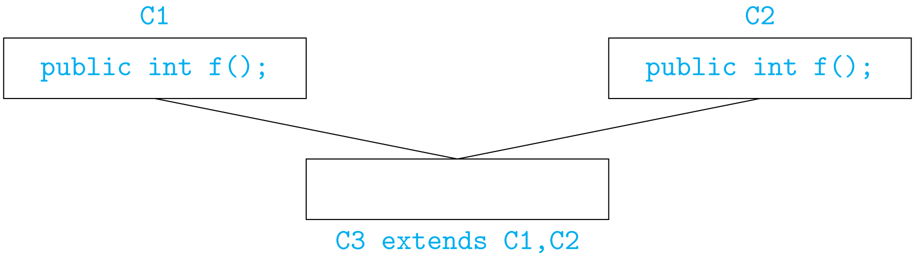

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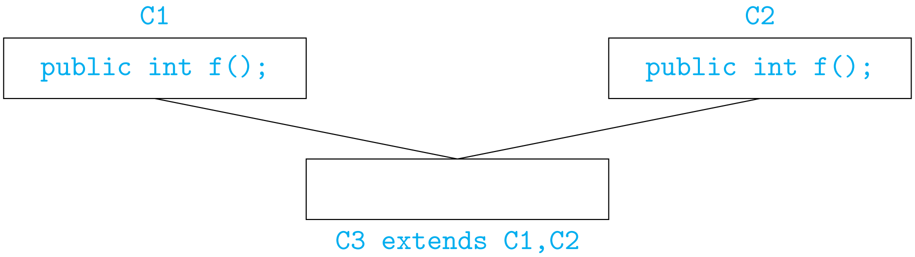

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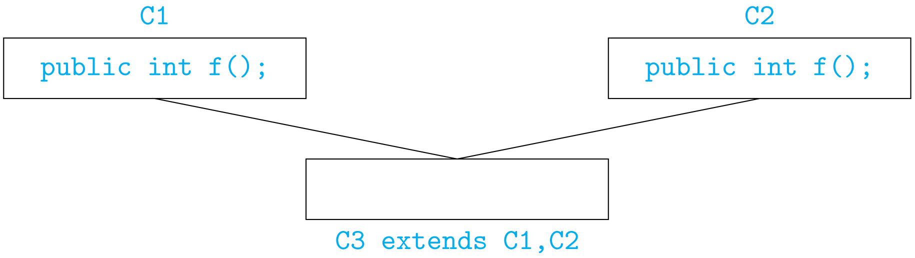

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- Java does not allow multiple inheritance
- C++ allows this if `C1` and `C2` have no conflict

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public boolean equals(Object o)  // defaults to pointer equality

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- For Java objects `x` and `y`, `x == y` invokes `x.equals(y)`
- To print `o`, use `System.out.println(o+"");`
  - Implicitly invokes `o.toString()`

Java class hierarchy

- Can exploit the tree structure to write generic functions
  - Example: search for an element in an array

```
public int find (Object[] objarr, Object o){
  int i;
  for (i = 0; i < objarr.length(); i++){
      if (objarr[i] == o) {return i};
  }
  return (-1);
}
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- Recall that `==` is pointer equality, by default
- If a class overrides `equals()`, dynamic dispatch will use the redefined function instead of `Object.equals()` for `objarr[i] == o`

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  does not override
  `boolean equals(Object o)`!

- Should write, instead

```
public boolean equals(Object d){
  if (d instanceof Date){
    Date myd = (Date) d;
    return ((this.day == myd.day) &&
            (this.month == myd.month)
            (this.year == myd.year));
  }
  return(false);
}
```

  - Note the run-time type check and the cast

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- Use `boolean equals(Employee e)`

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- Subtyping
  - Capabilities of the subtype are a superset of the main type
  - If `B` is a subtype of `A`, wherever we require an object of type `A`, we can use an object of type `B`
  - `Employee e = new Manager(...);` is legal

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- Inheritance
  - Subtype can reuse code of the main type
  - `B` inherits from `A` if some functions for `B` are written in terms of functions of `A`
  - `Manager.bonus()` uses `Employee.bonus()`

Subtyping vs inheritance

- Recall the following example
  - `queue`, with methods `insert-rear`, `delete-front`
  - `stack`, with methods `insert-front`, `delete-front`
  - `deque`, with methods `insert-front`, `delete-front`, `insert-rear`, `delete-rear`

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  - `queue`, with methods `insert-rear`, `delete-front`
  - `stack`, with methods `insert-front`, `delete-front`
  - `deque`, with methods `insert-front`, `delete-front`, `insert-rear`, `delete-rear`
- What are the subtype and inheritance relationships between these classes?

Subtyping vs inheritance

- Recall the following example
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- Subtyping
  - `deque` has more functionality than `queue` or `stack`
  - `deque` is a subtype of both these types

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- Subtyping
  - `deque` has more functionality than `queue` or `stack`
  - `deque` is a subtype of both these types
- Inheritance
  - Can suppress two functions in a `deque` and use it as a `queue` or `stack`
  - Both `queue` and `stack` inherit from `deque`

Subclasses, subtyping and inheritance

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  - `B` inherits from `A` if some functions for `B` are written in terms of functions of `A`.
- Using one idea (hierarchy of classes) to implement both concepts blurs the distinction between the two

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- These modifiers can be applied to classes, instance variables and methods
- Let's look at some examples of situations where different combinations make sense

`public` vs `private`

- Faithful implementation of encapsulation necessitates modifiers `public` and `private`
  - Typically, instance variables are `private`
  - Methods to query (accessor) and update (mutator) the state are `public`

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- Can `private` methods make sense?
- Example: a `Stack` class
  - Data stored in a private array
  - Public methods to push, pop, query if empty

```
public class Stack {
  private int[] values; // array of values
  private int tos;      // top of stack
  private int size;     // values.length

  /* Constructors to set up values array */

  public void push (int i){
    ....
  }

  public int pop (){
    ...
  }

  public boolean is_empty (){
    return (tos == 0);
  }
}
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- push() needs to check if stack has space

```
public class Stack {
  ...
  public void push (int i){
    if (tos < size){
      values[tos] = i;
      tos = tos+1;
    }else{
      // Deal with stack overflow
    }
    ...
  }
  ...
}
```

private methods

- Example: a Stack class
  - Data stored in a private array
  - Public methods to push, pop, query if empty
- push() needs to check if stack has space
- Deal gracefully with stack overflow
  - private methods invoked from within push() to check if stack is full and expand storage

```
public class Stack {
  ...
  public void push (int i){
    if (stack_full()){
      extend_stack();
    }
    ... // Usual push operations
  }
  ...
  private boolean stack_full(){
    return(tos == size);
  }

  private void extend_stack(){
    /* Allocate additional space,
       reset size etc */
  }
}
```

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- `Date` class
  - Private instance variables `day`, `month`, `year`
  - One public accessor/mutator method per instance variable

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public class Date {
  private int day, month year;

  public void getDay(int d) {...}
  public void getMonth(int m) {...}
  public void getYear(int y) {...}

  public void setDay(int d) {...}
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  - Private instance variables day, month, year
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- Inconsistent updates are now possible
  - Separately set invalid combinations of day and month
- Instead, allow only combined update

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public class Date {
  private int day, month year;

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  public void getYear(int y) {...}

  public void setDate(int d, int m, int y) {
    ...
    // Validate d-m-y combination
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  - Constructor sets unique id for each order

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public class Order {
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- Common to all objects in the class
- Be careful about concurrent updates!

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- A `final` method cannot be overridden