Inheritance

Lab 04

Announcement: Lab Pair

- Say hi to your lab pair sitting next to you.
  - Every pair should help each other throughout the semester so that no one falls behind.
- However, we don’t want you to bother checking if your partner needs help or not
  - Everyone struggles when learning programming
- Instead, please feel free to ask your lab partner for help when you are in trouble.

Announcement: Lab Test Evaluation

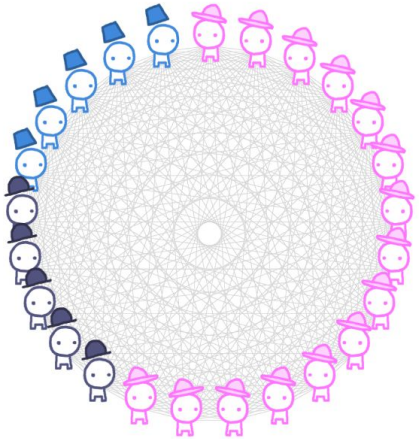
- You can check the strictly evaluated result of the first lab test
  - Note that it is not the official score.
- https://javelinsman.github.io/2019-CP-TA/result/labtest-0918-strict

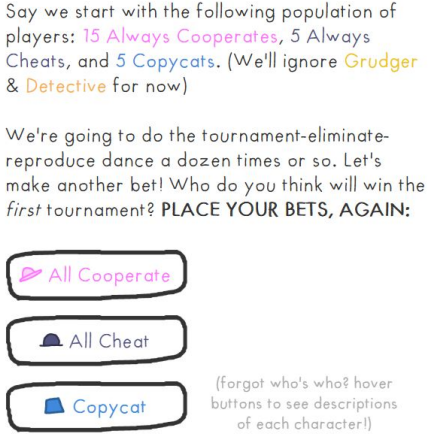
Announcement: Lab Test Evaluation

- Your output should be exactly the same as desired output, except trailing whitespaces at the very end of the output
  - Suppose desired output is ‘Apple\nBanana’
    - ‘Apple\nBanana ’ (O)
    - ‘Apple\nBanana \n’ (O)
    - ‘ Apple\nBanana’ (X)
    - ‘Apple \nBanana’ (X)

Topic: Evolution of Truth

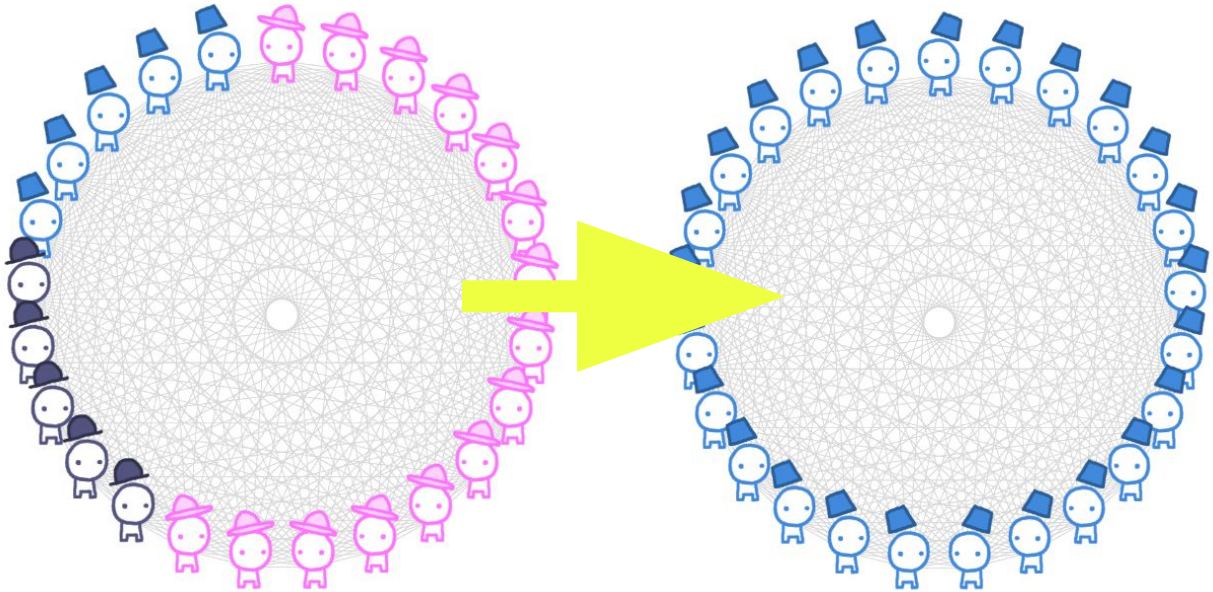
- https://ncase.me/trust/
- Simulation of the prisoner's dilemma
- Let's play the game for 10 minutes to grasp the concept!





Today's Goal

- Let's demonstrate this



...Copycat inherits the earth.

So, in the long run, you were right - Copycat wins! Always Cheat may have won in the short run, but its exploitativeness was its downfall. This reminds me of a quote:

"We are punished by our sins, not for them."
~ Elbert Hubbard

(oh, and by the way...)

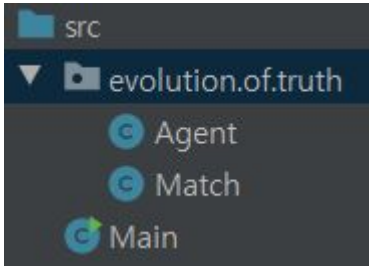
Source codes

Entire project

1. The simplest game
2. Angel vs. Devil
3. Copycat
4. Describing an agent
5. Pairwise match
6. Evolving the population

The simplest game

- Now let’s make the simplest game
  - Two agents only choose to cooperate
- Project initialization
  - Make a package named `evolution.of.truth`
    - (Actually, it isn’t good as a package name)
    - Inside, make two classes `Agent` and `Match`
  - Make a `Main` class at the top `src` directory
    - It is our entry point



21 src/evolution/of/truth/Agent.java

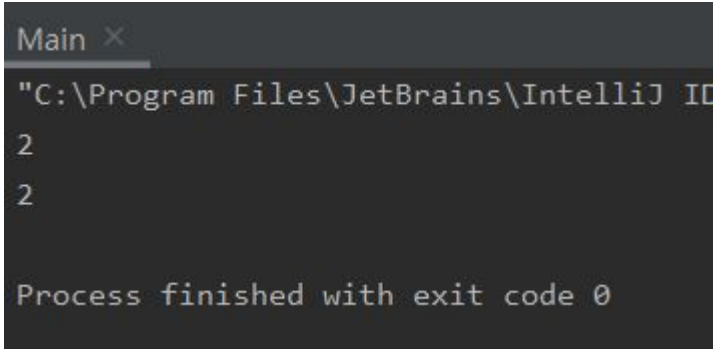
```
@@ -0,0 +1,21 @@
+ package evolution.of.truth;
+
+ public class Agent {
+     private int score;
+
+     public Agent() {
+         score = 0;
+     }
+
+     public int getScore() {
+         return score;
+     }
+
+     public void setScore(int newScore) {
+         score = newScore;
+     }
+
+     public int choice() {
+         return Match.COOPERATE;
+     }
+ }
```

src/evolution/of/truth/Match.java

```
@@ -0,0 +1,24 @@
+ package evolution.of.truth;
+
+ public class Match {
+     public static int CHEAT = 0;
+     public static int COOPERATE = 1;
+
+     private static int ruleMatrix[][][] = {
+             {
+                     {0, 0}, // A cheats, B cheats
+                     {3, -1} // A cheats, B cooperates
+             },
+             {
+                     {-1, 3}, // A cooperates, B cheats
+                     {2, 2} // A cooperates, B cooperates
+             }
+     };
+
+     public static void playGame(Agent agentA, Agent agentB) {
+         int choiceA = agentA.choice();
+         int choiceB = agentB.choice();
+         agentA.setScore(agentA.getScore() + ruleMatrix[choiceA][choiceB][0]);
+         agentB.setScore(agentB.getScore() + ruleMatrix[choiceA][choiceB][1]);
+     }
+ }
```

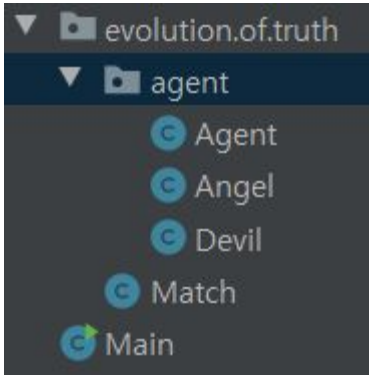
src/Main.java

```
@@ -0,0 +1,12 @@
+ import evolution.of.truth.Agent;
+ import evolution.of.truth.Match;
+
+ public class Main {
+     public static void main(String args[]) {
+         Agent agentA = new Agent();
+         Agent agentB = new Agent();
+         Match.playGame(agentA, agentB);
+         System.out.println(agentA.getScore());
+         System.out.println(agentB.getScore());
+     }
+ }
```



Angel vs. Devil


- Now let's implement and
  - Then see if angel loses a score while devil wins
- Make a new package `agent` inside `evolution.of.truth`
  - Move `Agent` to the package
    - Say 'yes' to refactoring option
  - Make two classes `Angel` and `Devil`



src/evolution/of/truth/agent/Angel.java

```
...  @@ -0,0 +1,10 @@
1  + package evolution.of.truth.agent;
2  +
3  + import evolution.of.truth.Match;
4  +
5  + public class Angel extends Agent {
6  +     @Override
7  +     public int choice() {
8  +         return Match.COOPERATE;
9  +     }
10 + }
```

src/evolution/of/truth/agent/Devil.java

```
...  @@ -0,0 +1,10 @@
1  + package evolution.of.truth.agent;
2  +
3  + import evolution.of.truth.Match;
4  +
5  + public class Devil extends Agent {
6  +     @Override
7  +     public int choice() {
8  +         return Match.CHEAT;
9  +     }
10 + }
```

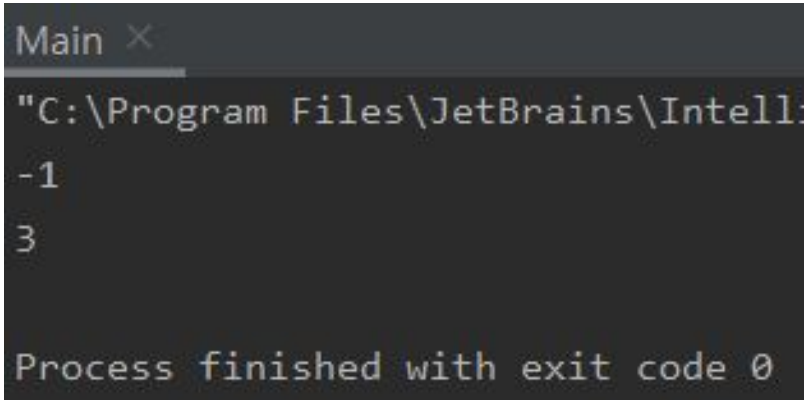
8 src/evolution/of/truth/Agent.java → src/evolution/of/truth/agent/Agent.java

```
@@ -1,6 +1,6 @@
- package evolution.of.truth;
+ package evolution.of.truth.agent;

- public class Agent {
+ abstract public class Agent {
      private int score;

      public Agent() {
          score = 0;
      }

      public int getScore() {
          return score;
      }

      public void setScore(int newScore) {
          score = newScore;
      }

-     public int choice() {
-         return Match.COOPERATE;
-     }
+     abstract public int choice();
  }
```

- Once subclasses `Angel` and `Devil` defined, the choice of `Agent` become ambiguous
- Let's make `Agent` an abstract class
  - It will serve as an outline of agents
  - It shouldn't be instantiated directly.

src/Main.java

```
...  @@ -1,10 +1,12 @@
     - import evolution.of.truth.Agent;
1    + import evolution.of.truth.agent.Agent;
2      import evolution.of.truth.Match;
3    + import evolution.of.truth.agent.Angel;
4    + import evolution.of.truth.agent.Devil;
5
6      public class Main {
7          public static void main(String args[]) {
     -          Agent agentA = new Agent();
     -          Agent agentB = new Agent();
8    +          Agent agentA = new Angel();
9    +          Agent agentB = new Devil();
10             Match.playGame(agentA, agentB);
11             System.out.println(agentA.getScore());
12             System.out.println(agentB.getScore());
```



- Okay, an angel is being exploited
- Note how we didn't change anything in Match.java
  - And very little change in Main.java

Copycat

COPYCAT: Hello! I start with Cooperate, and afterwards, I just copy whatever you did in the last round. Meow

```
public class Copycat extends Agent {
    @Override
    public int choice() {
        // ?????
    }
}
```

- Copycat needs a previous choice of an opponent
- But our `choice` function doesn't have any parameters

src/evolution/of/truth/agent/Agent.java

```
@@ -15,5 +15,5 @@ public void setScore(int newScore) {
15          score = newScore;
16      }
17
-       abstract public int choice();
18  +   abstract public int choice(int previousOpponentChoice);
19  }
```

src/evolution/of/truth/agent/Angel.java

```
@@ -4,7 +4,7 @@
4
5   public class Angel extends Agent {
6       @Override
-       public int choice() {
7   +   public int choice(int previousOpponentChoice) {
8           return Match.COOPERATE;
9       }
```

src/evolution/of/truth/agent/Devil.java

```
@@ -4,7 +4,7 @@
4
5   public class Devil extends Agent {
6       @Override
-       public int choice() {
7   +   public int choice(int previousOpponentChoice) {
8           return Match.CHEAT;
9       }
10  }
```

src/evolution/of/truth/Match.java

```
@@ -5,6 +5,7 @@
5   public class Match {
6       public static int CHEAT = 0;
7       public static int COOPERATE = 1;
8   +   public static int UNDEFINED = -1;
9
```

src/evolution/of/truth/agent/Copycat.java

```
...  @@ -0,0 +1,14 @@
1   + package evolution.of.truth.agent;
2   +
3   + import evolution.of.truth.Match;
4   +
5   + public class Copycat extends Agent {
6   +     @Override
7   +     public int choice(int previousOpponentChoice) {
8   +         if (previousOpponentChoice == Match.UNDEFINED) {
9   +             return Match.COOPERATE;
10  +         } else {
11  +             return previousOpponentChoice;
12  +         }
13  +     }
14  + }
```

HCSLAB

Copycat

- So where does `previousOpponentChoice` come from?
- It should be defined for every pair of agents
  - i.e., a copycat, having been cheated by a devil, shouldn’t take revenge on an innocent angel

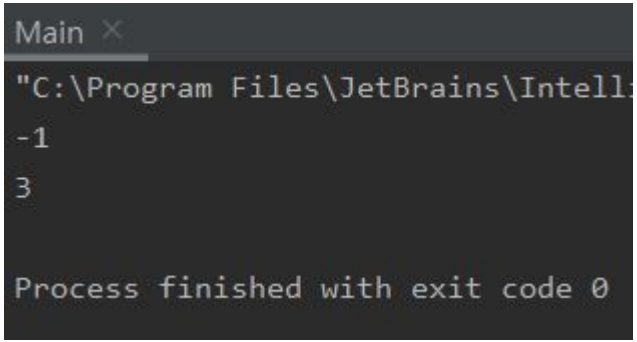
- → Let’s modify `Match` class!

```
21 +     Agent agentA, agentB;
22 +     int previousChoiceA, previousChoiceB;
23 +
24 +     public Match(Agent agentA, Agent agentB) {
25 +         this.agentA = agentA;
26 +         this.agentB = agentB;
27 +         previousChoiceA = UNDEFINED;
28 +         previousChoiceB = UNDEFINED;
29 +     }
30 +
31 +     public void playGame() {
32 +         int choiceA = agentA.choice(previousChoiceB);
33 +         int choiceB = agentB.choice(previousChoiceA);
34           agentA.setScore(agentA.getScore() + ruleMatrix[choiceA][choiceB][0]);
35           agentB.setScore(agentB.getScore() + ruleMatrix[choiceA][choiceB][1]);
36 +         previousChoiceA = choiceA;
37 +         previousChoiceB = choiceB;
38       }
39   }
```

- From now on, we will make an instance of Match for every pair of agents

src/Main.java

```
...  @@ -1,13 +1,19 @@
1    import evolution.of.truth.agent.Agent;
2    import evolution.of.truth.Match;
3    import evolution.of.truth.agent.Angel;
4  + import evolution.of.truth.agent.Copycat;
5    import evolution.of.truth.agent.Devil;
6
7    public class Main {
8        public static void main(String args[]) {
   -        Agent agentA = new Angel();
9  +        Agent agentA = new Copycat();
10           Agent agentB = new Devil();
   -        Match.playGame(agentA, agentB);
11 +        Match match = new Match(agentA, agentB);
12 +        match.playGame();
13 +        match.playGame();
14 +        match.playGame();
15 +        match.playGame();
16 +        match.playGame();
17           System.out.println(agentA.getScore());
18           System.out.println(agentB.getScore());
19       }
```



- A copycat won’t be fooled by a devil for more than once!

Describing an agent

- It will be helpful to override toString() of `Object` class

- Maybe we can override it for every Agent subclasses?
  - Too redundant :(

```java
public class Angel extends Agent {
    @Override
    public String toString() {
        return "Angel: " + getScore();
    }
```

```java
public class Devil extends Agent {
    @Override
    public String toString() {
        return "Devil: " + getScore();
    }
```

```java
public class Copycat extends Agent {
    @Override
    public String toString() {
        return "Copycat: " + getScore();
    }
```

src/evolution/of/truth/agent/Agent.java

```
@@ -2,9 +2,16 @@

  abstract public class Agent {
      private int score;
+     private String name;

-     public Agent() {
+     protected Agent(String name) {
          score = 0;
+         this.name = name;
      }
+
+     @Override
+     public String toString() {
+         return name + ": " + getScore();
      }

      public int getScore() {
```

```
public class Angel extends Agent {
+     public Angel() {
+         super("Angel");
+     }
```

```
public class Devil extends Agent {
+     public Devil() {
+         super("Devil");
+     }
```

```
public class Copycat extends Agent {
+     public Copycat() {
+         super("Copycat");
+     }
+
```

src/Main.java

```
@@ -14,7 +14,7 @@ public static void main(String args[]) {
14              match.playGame();
15              match.playGame();
16              match.playGame();
-               System.out.println(agentA.getScore());
-               System.out.println(agentB.getScore());
17+             System.out.println(agentA.toString());
18+             System.out.println(agentB.toString());
19          }
20      }
```

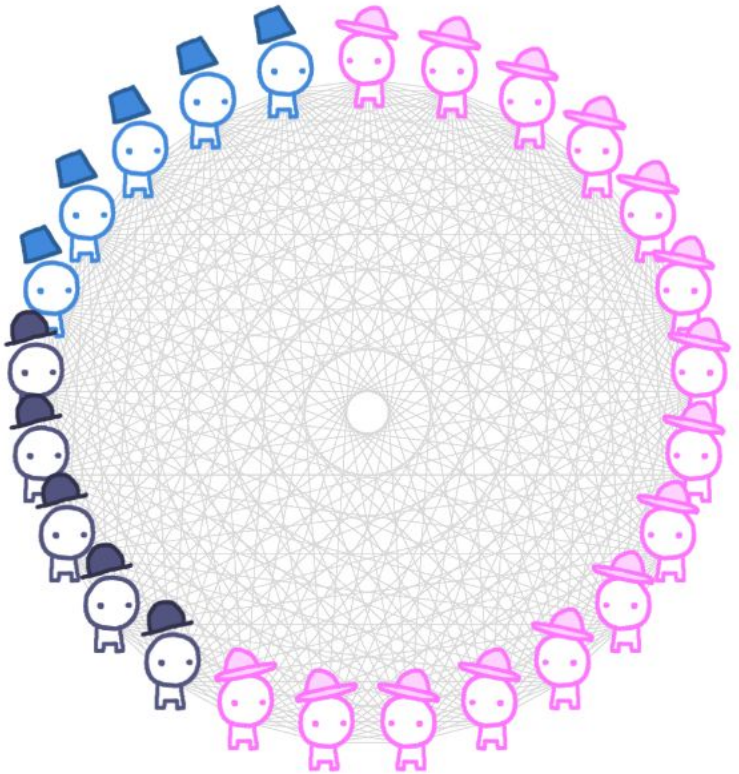
Main

```
"C:\Program Files\JetBrains\IntelliJ
Copycat: -1
Devil: 3

Process finished with exit code 0
```

Pairwise match

- We want to register a set of agents and play all games between them

- Also, we want to specify the number of games to play within each pair



Design Consideration: (1)

- The number of games within each pair
  - Option: class HundredMatches extends Match
    - Very Bad!
    - HundredAndOneMatches, HundredAndTwoMatches, ...
  - Instead, let’s pass the number as a paramter of some function

Design Consideration: (2)

- Playing games for all pair of agents
  - Option 1: playGame(boolean allPairMatch)
    - Bad! Too different logic to be wrapped in a single function
  - Option 2: directly modify `Match` class
  - Option 3: class PairwiseMatch extends Match
  - Option 4: create class `Tournament` that uses `Match`

Option 2: directly modifying `Match`

- In fact, it is a good option for now.
- But we are in a practice session ;)
  - Let’s assume the `Match` class is already being used in a number of different classes
  - Then we will want to keep it intact.

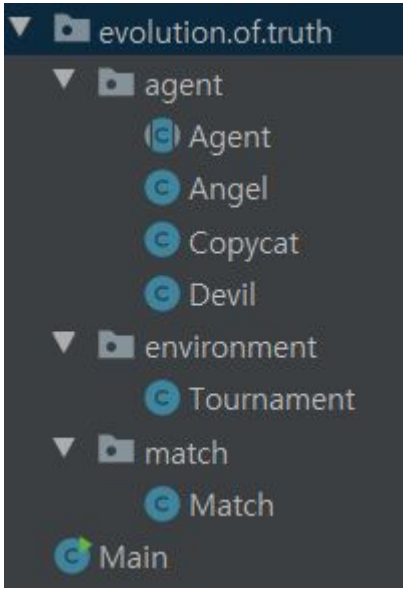
Option 3: inheriting from `Match`

- “Is every PairwiseMatch a Match?”
  - Not very clear
- A subclass must share all properties its parent has
  - However, `constructor(Agent, Agent)` does not make any sense to class `PairwiseMatch`

```
public class PairwiseMatch extends Match {
    public PairwiseMatch() {
        super( agentA: null,  agentB: null);
    }
}
```

Option 4: `Tournament` class

- class Tournament
  - ~~void registerAgents(Agent[] agents)~~
    - Try it yourself, later!
  - void playAllGames(int numRounds)
  - void describe()



src/evolution/of/truth/environment/Tournament.java

```
@@ -0,0 +1,51 @@
+ package evolution.of.truth.environment;
+
+ import evolution.of.truth.agent.Agent;
+ import evolution.of.truth.agent.Angel;
+ import evolution.of.truth.agent.Copycat;
+ import evolution.of.truth.agent.Devil;
+ import evolution.of.truth.match.Match;
+
+ public class Tournament {
+     Agent[] agents;
+
+     public Tournament() {
+         agents = new Agent[25];
+         for (int i = 0; i < 15; i++) {
+             agents[i] = new Angel();
+         }
+         for (int i = 0; i < 5; i++) {
+             agents[15 + i] = new Devil();
+         }
+         for (int i = 0; i < 5; i++) {
+             agents[20 + i] = new Copycat();
+         }
+     }
+
+     private Match[] createAllMatches() {
+         int n = agents.length;
+         Match[] matches = new Match[n * (n - 1) / 2];
+         int index = 0;
+         for (int i = 0; i < n; i++) {
+             for (int j = i + 1; j < n; j++) {
+                 matches[index++] = new Match(agents[i], agents[j]);
+             }
+         }
+         return matches;
+     }
+
+     public void playAllGames(int numRounds) {
+         Match[] matches = createAllMatches();
+         for (int round = 0; round < numRounds; round++) {
+             for (Match match : matches) {
+                 match.playGame();
+             }
+         }
+     }
+
+     public void describe() {
+         for(Agent agent: agents) {
+             System.out.print(agent.toString() + " / ");
+         }
+     }
+ }
```

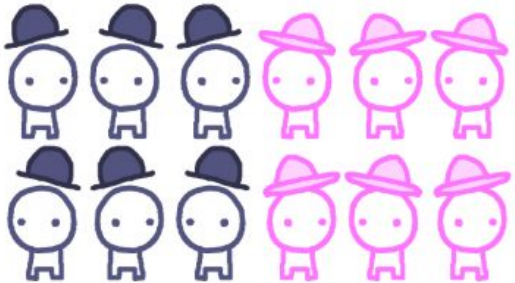
src/Main.java

```
...  @@ -1,20 +1,13 @@
1    import evolution.of.truth.agent.Agent;
   - import evolution.of.truth.Match;
   - import evolution.of.truth.agent.Angel;
2  + import evolution.of.truth.environment.Tournament;
3  + import evolution.of.truth.match.Match;
4    import evolution.of.truth.agent.Copycat;
5    import evolution.of.truth.agent.Devil;
6
7    public class Main {
8        public static void main(String args[]) {
   -        Agent agentA = new Copycat();
   -        Agent agentB = new Devil();
   -        Match match = new Match(agentA, agentB);
   -        match.playGame();
   -        match.playGame();
   -        match.playGame();
   -        match.playGame();
   -        match.playGame();
   -        System.out.println(agentA.toString());
   -        System.out.println(agentB.toString());
9  +        Tournament tournament = new Tournament();
10 +        tournament.playAllGames(10);
11 +        tournament.describe();
12       }
13   }
```

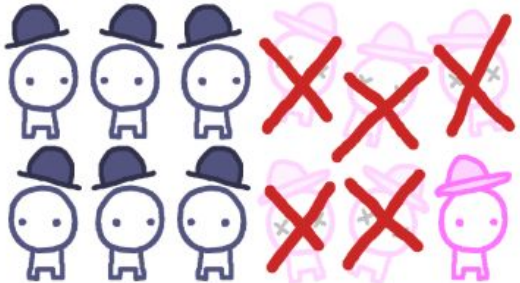
```
Main
"C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2019.2.3\jbr\bin\java.exe"
Angel: 330 / Angel: 330 / Angel: 330 / Angel: 330 / Angel: 330 / Angel: 330 / Angel: 3
Process finished with exit code 0
```

Evolving the population

Now, let's let our population of players *evolve over time*. It's a 3-step dance:



1. PLAY A TOURNAMENT
Let them all play against each other, and tally up their scores.



2. ELIMINATE LOSERS
Get rid of the 5 worst players. (if there's a tie, pick randomly between them)

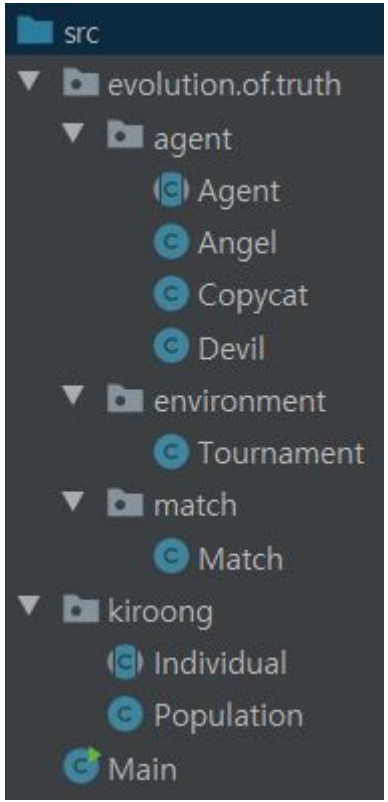
3. REPRODUCE WINNERS
Clone the 5 best players. (if there's a tie, pick randomly between them)

Evolving the population

- This involves a bit cumbersome logic like
  - Sorting an array
  - Choosing top k and bottom k elements
  - Removing multiple elements in an array
- Luckily, you've found an external library that does the similar job
  - We can utilize this to reduce our work

Evolving the population

- To simulate this, I wrote two classes for you
- Make a new package named `kiroong`
  - create two classes `Population` and `Individual`
- Copy and paste the following code
  - Population (<- click this)
  - Individual (<- click this)



abstract class `Individual`

- protected Individual()
  - constructor
- abstract public int sortKey()
  - An integer to be used for sorting
- abstract public Individual clone()
  - It should return a copy of the object

class `Population`

- public Population()
  - Constructor
- public int size()
  - a size of the population
- Public Individual[] getIndividual()
  - returns an array of Individuals, sorted in ascending order
- public void addIndividual(Individual newIndividual)
  - Add a new Individual to the population
- public void toNextGeneration(int numReplace)
  - 1. Sort the population by sortKey()
  - 2. remove the lowest `numReplace` individuals
  - 3. clone the highest `numReplace` individuals

Integrating with our code

- Currently we have…
  - external package
    - class Population
    - class Individual (should be inherited)
  - our package
    - class Agent
    - class Tournament
- How should we compose them together?

Integrating with our code

- Think about relationship
  - A tournament **has** a population
  - Every agent **is** an individual
- So
  - Change `Agent[] agents` into `Population agentPopulation`
  - Let `Agent` be inherited from `Individual`
    - Implement sortKey() to return its score
    - Implement clone() to return a new instance of agent

src/evolution/of/truth/agent/Agent.java

```
...  @@ -1,6 +1,8 @@
1    package evolution.of.truth.agent;
2
     - abstract public class Agent {
3    + import kiroong.Individual;
4    +
5    + abstract public class Agent extends Individual {
6        private int score;
7        private String name;
8
     @@ -9,6 +11,10 @@ protected Agent(String name) {
11           this.name = name;
12       }
13
14   +   public int sortKey() {
15   +       return getScore();
16   +   }
17   +
18       @Override
19       public String toString() {
20           return name + ": " + getScore();
```

```java
public class Angel extends Agent {

    public Angel() {
        super("Angel");
    }

    @Override
    public Individual clone() {
        return new Angel();
    }
```

```java
@Override
public Individual clone() {
    return new Copycat();
}
```

```java
@Override
public Individual clone() {
    return new Devil();
}
```

src/evolution/of/truth/environment/Tournament.java

```
@@ -5,30 +5,45 @@
 import evolution.of.truth.agent.Copycat;
 import evolution.of.truth.agent.Devil;
 import evolution.of.truth.match.Match;
+import kiroong.Individual;
+import kiroong.Population;

 public class Tournament {
-    Agent[] agents;
+    Population agentPopulation;

     public Tournament() {
-        agents = new Agent[25];
+        agentPopulation = new Population();
         for (int i = 0; i < 15; i++) {
-            agents[i] = new Angel();
+            agentPopulation.addIndividual(new Angel());
         }
         for (int i = 0; i < 5; i++) {
-            agents[15 + i] = new Devil();
+            agentPopulation.addIndividual(new Devil());
         }
         for (int i = 0; i < 5; i++) {
-            agents[20 + i] = new Copycat();
+            agentPopulation.addIndividual(new Copycat());
         }
     }
```

```
     private Match[] createAllMatches() {
-        int n = agents.length;
+        int n = agentPopulation.size();
+        Individual[] agents = agentPopulation.getIndividuals();
         Match[] matches = new Match[n * (n - 1) / 2];
         int index = 0;
         for (int i = 0; i < n; i++) {
             for (int j = i + 1; j < n; j++) {
-                matches[index++] = new Match(agents[i], agents[j]);
+                matches[index++] = new Match((Agent)agents[i], (Agent)agents[j]);
             }
         }
         return matches;
@@ -44,8 +59,11 @@ public void playAllGames(int numRounds) {
     }

     public void describe() {
-        for(Agent agent: agents) {
+        Individual[] agents = agentPopulation.getIndividuals();
+        for(Individual _agent: agents) {
+            Agent agent = (Agent)_agent;
             System.out.print(agent.toString() + " / ");
         }
+        System.out.println();
     }
 }
```

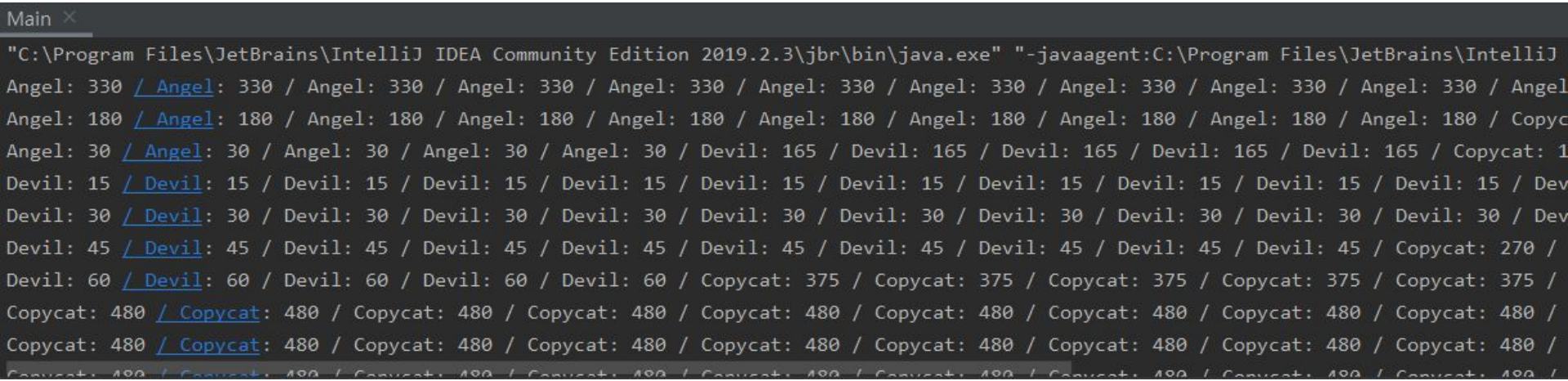
src/evolution/of/truth/environment/Tournament.java

```
27  +     public void evolvePopulation() {
28  +         agentPopulation.toNextGeneration(5);
29  +     }
30  +
31  +     public void resetAgents() {
32  +         Individual[] agents = agentPopulation.getIndividuals();
33  +         for(Individual _agent: agents) {
34  +             Agent agent = (Agent)_agent;
35  +             agent.setScore(0);
36              }
37          }
```

src/Main.java

```
@@ -7,7 +7,11 @@
7       public class Main {
8           public static void main(String args[]) {
9               Tournament tournament = new Tournament();
-               tournament.playAllGames(10);
-               tournament.describe();
10  +           for(int i=0;i<10;i++) {
11  +               tournament.resetAgents();
12  +               tournament.playAllGames(10);
13  +               tournament.describe();
14  +               tournament.evolvePopulation();
15  +           }
16          }
17      }
```

Copycat inherits the world!



Exercise

- Create a new agent `Copykitten`

COPYKITTEN:
Hello! I'm like Copycat, except I Cheat back only after you Cheat me twice in a row. After all, the first one could be a mistake! Purrrrr

- Create a new class `MistakeMatch` inherited from `Match`
  - In this match, every agent's choice is reversed by 5% chance

- Replace all angels to copykittens in the population, and see if kittens prosper in the world with mistakes