Principe de Développement:
Clean code (étude de cas) & Tests

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MGL7460- *Cours #9 - H20*

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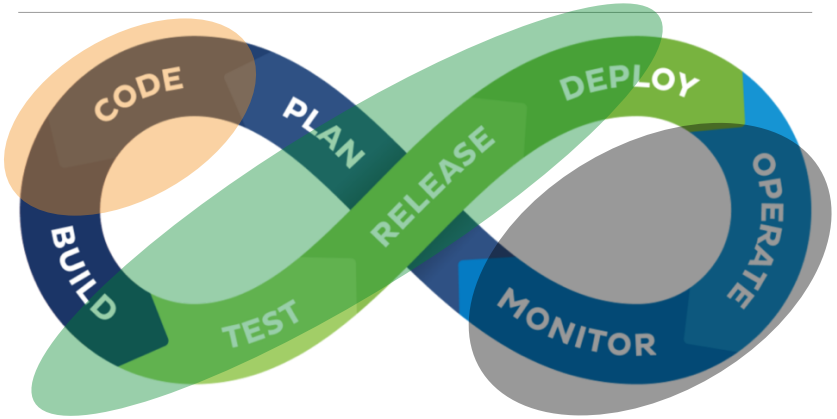
ace

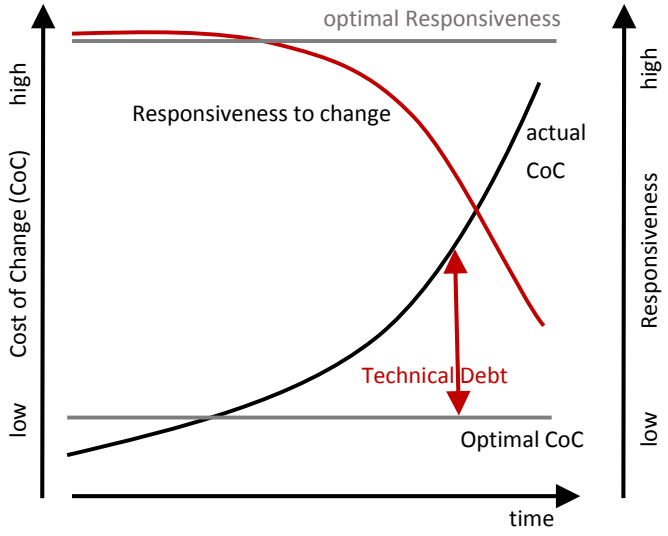
Clean Code

1

Périmètre du cours sur la boucle DevOps



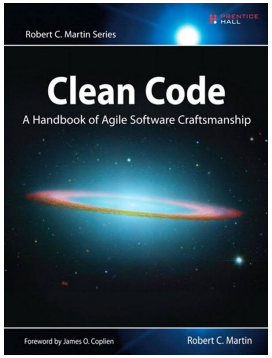
Pré-requis **MGL7460-H20** ***Hors-sujet (mais intéressant)***



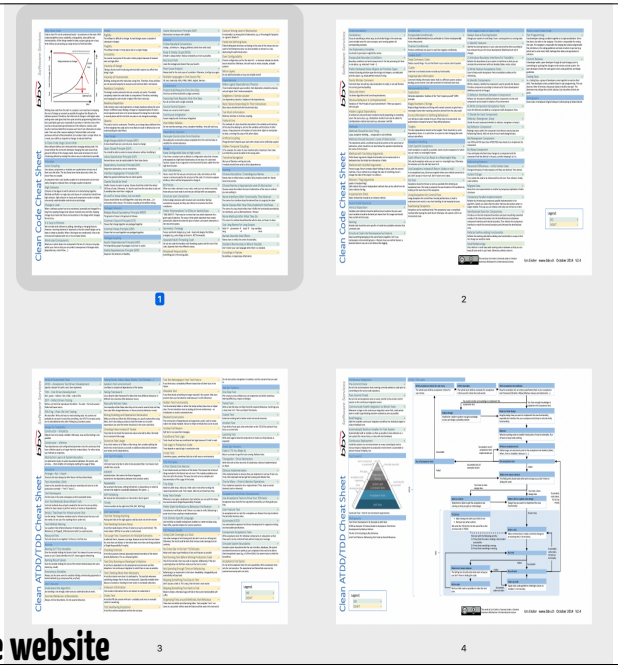
Clean code Cheat Sheet

Principles

- Loose coupling
- High cohesion
- Change is local
- Easy to remove
- Mind-sized components



It goes without saying, but it's better when it is said.



See course website

General

Follow Standard Conventions +

Coding-, architecture-, design guidelines (check them with tools)

Keep it Simple, Stupid (KISS) +

Simpler is always better. Reduce complexity as much as possible.

Boy Scout Rule +

Leave the campground cleaner than you found it.

Root Cause Analysis +

Always look for the root cause of a problem. Otherwise, it will get you again.

Multiple Languages in One Source File –

C#, Java, JavaScript, XML, HTML, XAML, English, German …

Strong points: Shows "don't"

```
/**
 * Default constructor.
 */
protected AnnualDateRule() {
}
```

No, *really?* Or how about this:

```
/** The day of the month. */
   private int dayOfMonth;
```

And then there's this paragon of redundancy:

```
/**
 * Returns the day of the month.
 *
 * @return the day of the month.
 */
public int getDayOfMonth() {
  return dayOfMonth;
}
```

```
/** The name. */
private String name;

/** The version. */
private String version;

/** The licenceName. */
private String licenceName;

/** The version. */
private String info;
```

E.g., the "bad comments" section

Etude de cas
PokerGame

2

Problem Description

> “Your job is to compare several pairs of poker hands and to indicate which, if either, has a higher rank.

http://codingdojo.org/kata/PokerHands/

Minimal & Viable Product

- Read simple cards from the CLI (e.g., “3 5 7 2”)
- Elect the winner using the “Highest Card” rule
- That’s all folks

```
public static void main(String[] args) {
    Scanner scanner = new Scanner(System.in);
    System.out.println("Black:");
    String[] line1 = scanner.nextLine().split(" ");
    System.out.println("White:");
    String[] line2 = scanner.nextLine().split(" ");
    Arrays.sort(line1);
    Arrays.sort(line2);
    if(line1[line1.length-1].compareTo(line1[line2.length-1]) > 0 ) {
        System.out.println("Black wins with: " + line1[line1.length-1]);
    } else {
        System.out.println("White wins with " + line2[line2.length-1]);
    }
}
```


Problems?

Readability?

Compliance with the specs?

Maintainability?

Testability?

Extension to fulfil the specs?

Technical Debt!

```
else if (h1.getType().equals("double paire") && h2.getType().equals("double paire")) {
    if (h1.typeHand.get(0).getValue().ordinal() > h2.typeHand.get(0).getValue().ordinal())
        this.handNumber = 1;
    else if (h1.typeHand.get(0).getValue().ordinal() == h2.typeHand.get(0).getValue().ordinal()) {
        if (h1.typeHand.get(1).getValue().ordinal() > h2.typeHand.get(1).getValue().ordinal()) {
            this.handNumber = 1;
        } else if (h1.typeHand.get(1).getValue().ordinal() == h2.typeHand.get(1).getValue().ordinal()) {
            if (h1.typeHand.get(2).getValue().ordinal() > h2.typeHand.get(2).getValue().ordinal()) {
                this.handNumber = 1;
            } else if (h1.typeHand.get(2).getValue().ordinal() == h2.typeHand.get(2).getValue().ordinal()) {
                this.handNumber = 0;
            } else this.handNumber = 2;
        } else {
            this.handNumber = 2;
        }
    } else this.handNumber = 2;
}
```

Real code, from real project!

Software engineering rule of three

Readability
Readability
Readability

Focusing on readability

```
public static void main(String[] args) {
    HandReader reader = new HandReader(System.in);
    Hand black = reader.obtainForPlayer("Black");
    Hand white = reader.obtainForPlayer("White");

    Referee referee = new Referee();
    GameResult result = referee.decide(black, white);

    System.out.println(result);
}
```

WAT? No getters? no setters?

Are we coding in Java?

It does not even compile!

"One of the **great leaps in OO** is to be able to answer the question "**how does this work?**" with "**I don't care**".

- Alan Knight

```
GameResult result = referee.decide(black, white);
System.out.println(result);
```

How does the referee decides?

I don't care

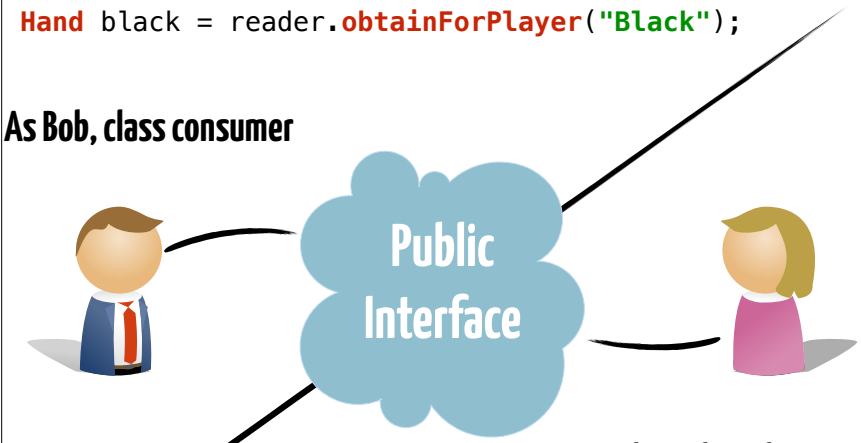
How does the game result is printed?

I don't care

You already got it, isn't it?

```
Hand black = reader.obtainForPlayer("Black");
```

As Bob, class consumer



As Alice, class designer

```
System.out.println("Black:");
String[] line1 = scanner.nextLine().split(" ");
```

SOLIDity applied to OO code (& Jedis)

- S : Single Responsibility
- O: Open / closed principle

- L: Liskov-compliant (substitution)
- I: Interface Segregation
- D: Dependency inversion

Maintenance: Open/Closed principle

Closed for **Modification**

Open for **Extension**


```
public static void main(String[] args) {
    HandReader reader = new HandReader(System.in);
    Hand b                                  Player("Black");
    Hand w                                  Player("White");
    Refere                                  ();
    GameRe                                  ecide(black, white);
    System
}
```



```
public class HandReader {}
```

```
public static void main(String[] args) {
    HandReader reader = new HandReader(System.in);
    Hand black = reader.obtainForPlayer("Bl
    Hand white = reader.obtainForPlayer("Wh
    Referee referee = new Referee();
    GameResult result = referee.decide(blac
    System.out.println(result);
}
```



```
public class HandReader {

    public HandReader(InputStream in) {}

}
```

```java
public static void main(String[] args) {
    HandReader reader = new HandReader(System.in);
    Hand black = reader.obtainForPlayer("Black");
    Hand white = reader.obtainForPl
    Referee referee = new Referee()
    GameResult result = referee.decide(black, white);
    System.out.println(result);
}
```

Create method 'obtainForPlayer'

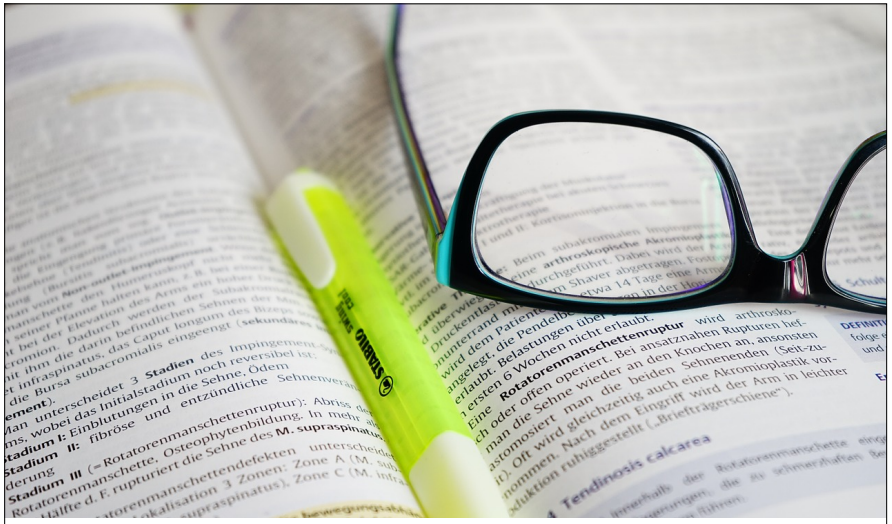
Split into declaration and assignment

```java
public class HandReader {

    public HandReader(InputStream in) {}

    public Hand obtainForPlayer(String playerName) {
        throw new UnsupportedOperationException();
    }
}
```

```
azrael:3A-PokerGame mosser$ mvn clean package
[INFO] Scanning for projects...
[INFO]
[INFO] ------------------------------------------------------------------------
[INFO] Building PS5 :: PokerGame 1.0
[INFO] ------------------------------------------------------------------------
[INFO]
[INFO] --- maven-clean-plugin:2.5:clean (default-clean) @ poker-game ---
[INFO] Deleting /Users/mosser/work/polytech/3A-PokerGame/target
[INFO]
[INFO] --- maven-resources-plugin:2.6:resources (default-resources) @ poker-game ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO]
[INFO] --- maven-compiler-plugin:3.1:compile (default-compile) @ poker-game ---
[INFO] Changes detected - recompiling the module!
[INFO] Compiling 5 source files to /Users/mosser/work/polytech/3A-PokerGame/target/classes
[INFO]
[INFO] --- maven-resources-plugin:2.6:testResources (default-testResources) @ poker-game ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO]
[INFO] --- maven-compiler-plugin:3.1:testCompile (default-testCompile) @ poker-game ---
[INFO] Nothing to compile - all classes are up to date
[INFO]
[INFO] --- maven-surefire-plugin:2.12.4:test (default-test) @ poker-game ---
[INFO] No tests to run.
[INFO]
[INFO] --- maven-jar-plugin:2.4:jar (default-jar) @ poker-game ---
[INFO] Building jar: /Users/mosser/work/polytech/3A-PokerGame/target/poker-game.jar
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time: 1.819 s
[INFO] Finished at: 2017-10-17T14:53:59+02:00
[INFO] Final Memory: 18M/304M
[INFO] ------------------------------------------------------------------------
```

Now it compiles.

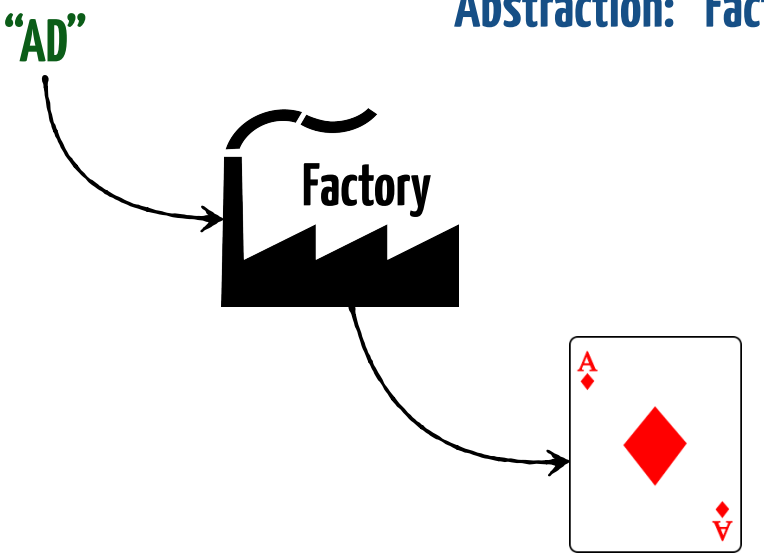
So what?



F_1: Reading a Poker Hand

From "AD" to "Ace of Diamonds"

Abstraction: "Factory"




```
public class HandReader {

    private InputStream stream;
    private HandFactory factory;

    public HandReader(InputStream in) {
        this.stream = in;
        this.factory = new HandFactory();
    }

    public Hand obtainForPlayer(String playerName) {
        Scanner scanner = new Scanner(stream);
        System.out.println("Player " + playerName + ": ");
        String data = scanner.nextLine();
        Set<Card> cards = factory.transform(data);
        return new Hand(playerName, cards);
    }
}
```

```
public enum CardValue {

    TWO(  '2', 2),  THREE('3', 3), FOUR( '4', 4),
    FIVE( '5', 5),  SIX(  '6', 6), SEVEN('7', 7),
    EIGHT('8', 8),  NINE( '9', 9), TEN(  'T', 10),
    JACK( 'J', 11), QUEEN('Q', 12), KING('K', 13);

    private final char symbol;
    private final int value;
    public int getValue() { return value; }

    CardValue(char symbol, int value) {
        this.symbol = symbol;
        this.value = value;
    }

    public static CardValue read(char c) {
        for(CardValue cv: CardValue.values()) {
            if(cv.symbol == c)
                return cv;
        }
        throw new IllegalArgumentException("Unknown card value: "+c);
    }

}
```

Order Relation mapped to Integer's one

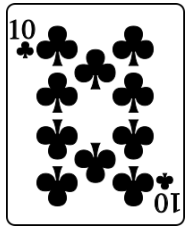
Char -> CardValue translation

```java
public enum Suit {

    CLUBS('C', "Clubs"),  DIAMONDS('D', "Diamonds"),
    HEARTS('H', "Hearts"), SPADES(  'S', "Spades");

    private final char symbol;
    private final String name;
    public String getName() { return name; }

    Suit(char c, String n) {
        this.name = n;
        this.symbol = c;
    }

    public static Suit read(char c) {
        return
          Arrays.stream(Suit.values())
            .filter((Suit s) -> s.symbol == c)
            .findFirst()
            .orElseThrow(() ->
              new IllegalArgumentException("Unknown suit symbol: " + c));
    }
}
```

Char -> Suit translation, using λ

```java
public Card build(String scalar) {
    if(scalar.length() != 2)
        throw new IllegalArgumentException("The data must be exactly two characters");
    CardValue value = CardValue.read(scalar.charAt(0));
    Suit suit =  Suit.read(scalar.charAt(1));
    return new Card(value, suit);
}
```

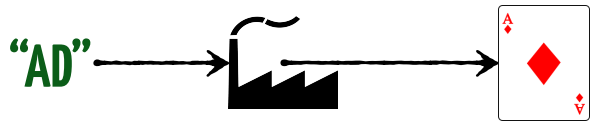
```java
public class Card {

    private CardValue value;
    private Suit suit;


    public Card(CardValue value, Suit suit) {
        this.value = value;
        this.suit = suit;
    }

    @Override
    public boolean equals(Object o) { … }

    @Override
    public int hashCode() { … }
}
```



Wait! Where are the tests?

```java
@Test public void buildClassicalCards() {
    Card queenOfHearts = factory.build("QH");
    assertEquals(new Card(QUEEN, HEARTS), queenOfHearts);

    Card tenOfDiamonds = factory.build("TD");
    assertEquals(new Card(TEN, DIAMONDS), tenOfDiamonds);

    Card twoOfSpades = factory.build("2S");
    assertEquals(new Card(TWO, SPADES), twoOfSpades);

    Card eightOfClubs = factory.build("8C");
    assertEquals(new Card(EIGHT, CLUBS), eightOfClubs);
}
```

Any Issues?




```
@Test public void buildAceOfDiamonds() {
    Card aceOfDiamonds = factory.build("AD");
}
```

```
java.lang.IllegalArgumentException: Unknown card value: A

    at poker.cards.CardValue.read(CardValue.java:26)
    at poker.io.HandFactory.build(HandFactory.java:16)
```

```
public enum CardValue {

    TWO(  '2', 2),  THREE('3', 3), FOUR( '4', 4),
    FIVE( '5', 5),  SIX(  '6', 6), SEVEN('7', 7),
    EIGHT('8', 8),  NINE( '9', 9), TEN(  'T', 10),
    JACK( 'J', 11), QUEEN('Q', 12), KING('K', 13);
}
```

```
@Test public void buildAllCards() {
    Set<Card> deck = new HashSet<>();
    for(CardValue val: CardValue.values()) {
        for(Suit suit: Suit.values()) {
            Card c = factory.build(""+ val.getSymbol() + suit.getSymbol());
            deck.add(c);
        }
    }
    assertEquals(52, deck.size());
}
```

Bug

=> **red Test** reproducing the **bug**

=> Code **fix**

while(breathing)

=> **Test** is now **green**

```
@Test(expected = IllegalArgumentException.class)
public void detectBadCardValueSymbol() { factory.build("UD"); }

@Test(expected = IllegalArgumentException.class)
public void detectBadSuitSymbol() { factory.build("2X"); }

@Test(expected = IllegalArgumentException.class)
public void detectBadSuitAndValueSymbols() { factory.build("UX"); }
```

We cannot test which exception was thrown

Do we (really) care?

```
public Set<Card> transform(String data) {
    Set<Card> cards = new HashSet<>();
    String[] raw = data.split(" ");
    for(String pair: raw)
        cards(build(pair));
    return cards;
}
```

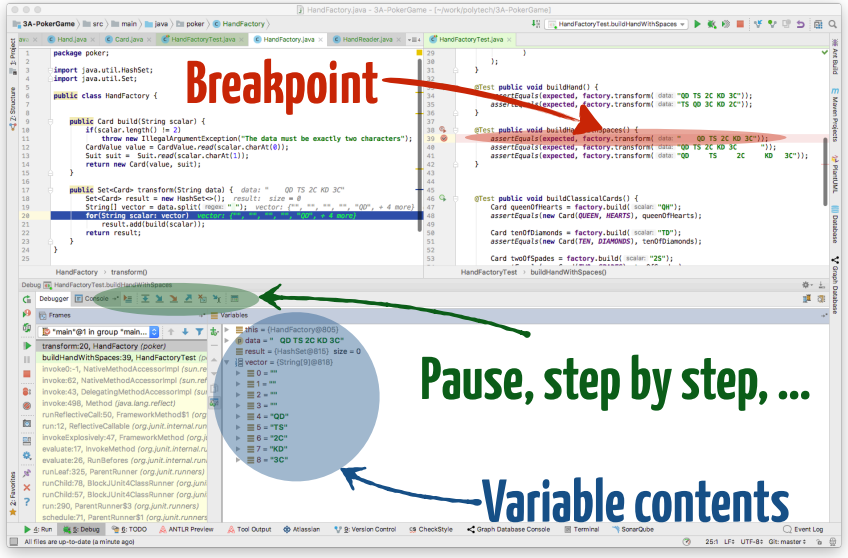
```
@Test public void buildHand() {
    Set<Card> expected = new HashSet<>(
            Arrays.asList(
                    new Card(QUEEN, DIAMONDS),
                    new Card(TEN, SPADES),
                    new Card(TWO, CLUBS),
                    new Card(KING, DIAMONDS),
                    new Card(THREE, CLUBS)
    ));
    assertEquals(expected, factory.transform("QD TS 2C KD 3C"));
    assertEquals(expected, factory.transform("TS QD 3C KD 2C"));
}
```

are we testing it RIGHT?

```
@Before public void initExpected() {
    expected = new HashSet<>(
            Arrays.asList(
                    new Card(QUEEN, DI
                    new Card(TEN,
                    new Card(TW
                    new Car
                    new
            )
    );
}

@Test
    ass                actory.transform("QD TS 2C KD 3C"));
    asse                , factory.transform("TS QD 3C KD 2C"));
}

@Test publ    void buildHandWithSpaces() {
    assertEquals(expected, factory.transform("    QD TS 2C KD 3C"));
    assertEquals(expected, factory.transform("QD TS 2C KD 3C      "));
    assertEquals(expected, factory.transform("QD     TS     2C     KD   3C"));
}
```

java.lang.IllegalArgumentException: The data must be exactly two characters
at poker.HandFactory.build(HandFactory.java:11)
at poker.HandFactory.transform(HandFactory.java:21)
at poker.HandFactoryTest.buildHandWithSpaces(HandFactoryTest.java:40)

The "Debug" mode (aka entering the matrix)



Extra white spaces !

Remove it!

```
public Set<Card> transform(String data) {
    Set<Card> result = new HashSet<>();
    String cleaned = data.replaceAll("\\s+"," ").trim();
    String[] vector = cleaned.split(" ");
    for(String scalar: vector)
        result.add(build(scalar));
    return result;
}
```

```java
@Test public void buildBigHand() {
    assertEquals(6, factory.transform("JC QD TS 2C KD 3C").size());
}

@Test public void buildSmallHand() {
    assertEquals(4, factory.transform("TS 2C KD 3C").size());
}
```

6 Cards in a Hand?

4 Cards in a Hand?

Who is responsible?

F_2: Validating Hands

Only 5 cards, no duplicates

"Only 5 cards" == Hand intrinsic definition

```java
public class Hand {

    private String playerName;
    private Set<Card> cards;

    public Hand(String playerName, Set<Card> cards) {
        this.playerName = playerName;
        if (cards.size() != 5)
            throw new IllegalArgumentException("A hand contains 5 cards!");
        this.cards = cards;
    }

}
```

```java
@Test(expected = IllegalArgumentException.class)
public void checkHandWith4Cards() {
    contents.remove(new Card(QUEEN, DIAMONDS));
    Hand myHand = new Hand("Seb", contents);
}

@Test(expected = IllegalArgumentException.class)
public void checkHandWith6Cards() {
    contents.add(new Card(THREE, DIAMONDS));
    Hand myHand = new Hand("Seb", contents);
}
```

"No duplicates" == Referee's knowledge

$$|cards_b| + |cards_w| = |cards_b \cup cards_w|$$

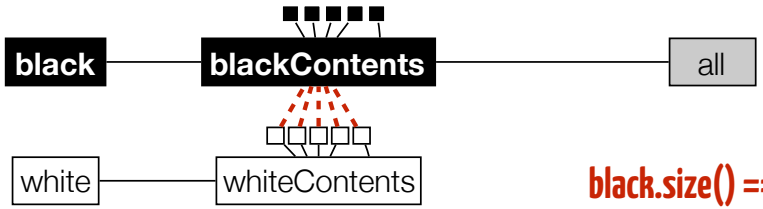
```
public boolean check(Hand black, Hand white) {
    Set<Card> all = black.getCards();
    all.addAll(white.getCards());
    return (all.size() == 10);
}
```

* can also be done using intersection

```
public class RefereeTest {

    private Referee referee;
    private Set<Card> blackContents;
    private Set<Card> whiteContents;

    @Before public void initR                          = new Referee(); }

    @Before public void initB
        blackContents = new H
                new Card(QUEE                          EN, SPADES),
                new Card(TWO,                          DIAMONDS),
                new Card(THRE
        ));
    }

    @Before public void initW
        whiteContents = new H
                new Card(KING                          , DIAMONDS),
                new Card(THRE                          ING, CLUBS),
                new Card(JACK
        ));
    }

    @Test public void checkCorrectHands() {
        Hand black = new Hand("Black", blackContents);
        Hand white = new Hand("White", whiteContents);
        assertTrue(referee.check(black, white));
    }
}
```

Wrong, Wrong, Wrong.

```
@Test public void checkCorrectHands() {
    Hand black = new Hand("Black", blackContents);
    Hand white = new Hand("White",whiteContents);
    assertTrue(referee.check(black, white));
    assertEquals(5, black.getCards().size());
    assertEquals(5, white.getCards().size());
}
```



black.size() == 10

```
public boolean check(Hand black, Hand white) {
    Set<Card> all = black.getCards();
    all.addAll(white.getCards());
    return (all.size() == 10);
}
```

```
public boolean check(Hand left, Hand right) {
    Set<Card> all = new HashSet<>(left.getCards());
    all.addAll(right.getCards());
    return (all.size() == 10);
}
```

Copy ≠ Reference !

```
@Test public void checkCorrectHands() {
    Hand black = new Hand("Black", blackContents);
    Hand white = new Hand("White",whiteContents);
    assertTrue(referee.check(black, white));
    assertEquals(5, black.getCards().size());
    assertEquals(5, white.getCards().size());
}

@Test public void checkDuplicatedCardsInHands() {
    blackContents.remove(new Card(QUEEN, DIAMONDS));
    blackContents.add(new Card(JACK, HEARTS));
    Hand black = new Hand("Black", blackContents);
    Hand white = new Hand("White",whiteContents);
    assertFalse(referee.check(black, white));
}
```

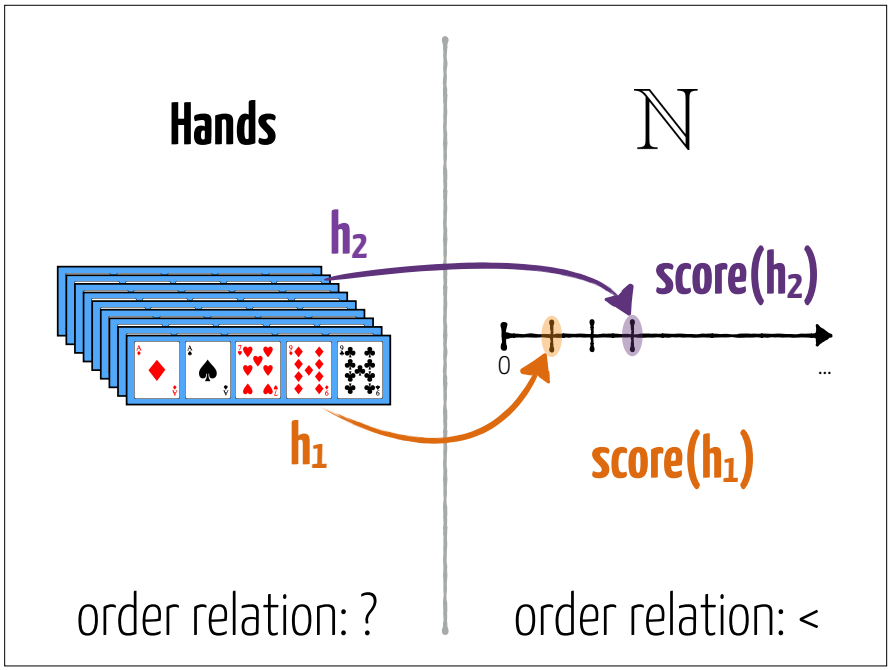
F_3: Scoring Hands

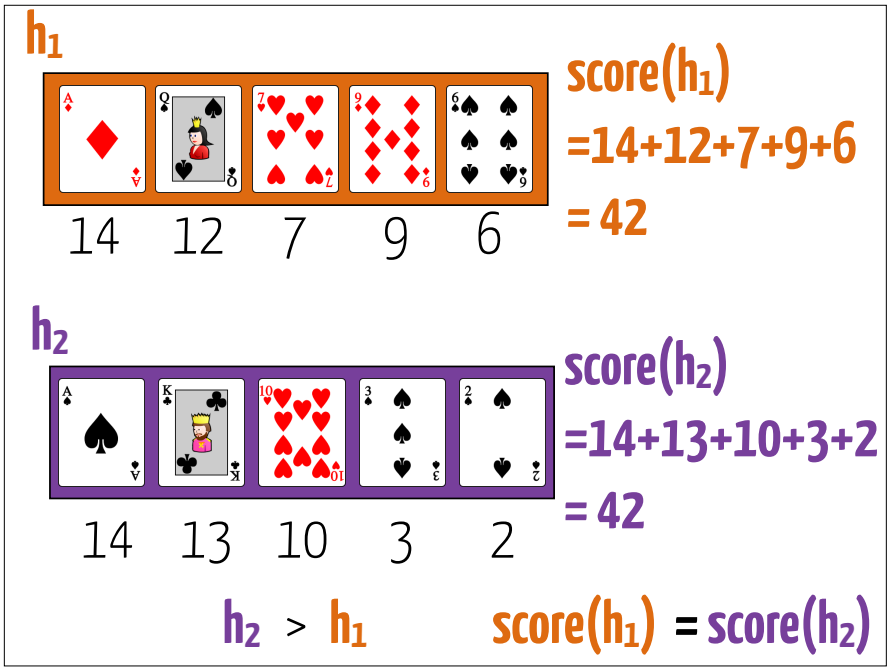
How to compare two hands?

How to score "Hands" ?

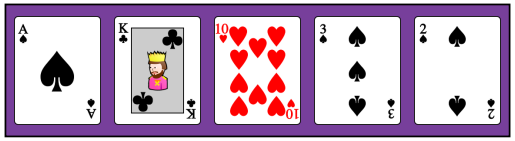
|Hands| = ?

Hint: Reducing to a "simpler" problem, e.g., an already solved one.





h_2



14 13 10 3 2

$score'(h_2) = 2 + 3*10 + 10*100 + 13*1000 + 14*10000 = 154,032$

$score'(h_1) = 152,976$

$h_2 > h_1$

$score'(h_2) > score'(h_1)$

SorTing a Hand

Card

```
public class Card implements Comparable<Card> {
…
    @Override public int compareTo(Card that) {
        Integer thisValue = this.value.getValue();
        Integer thatValue = that.value.getValue();
        return thisValue.compareTo(thatValue);
    }
}
```

Hand

```
public List<Card> getOrderedCards() {
    Card[] raw = cards.toArray(new Card[cards.size()]);
    Arrays.sort(raw);
    return Arrays.asList(raw);
}
```

HandTest

```
@Test public void checkCardsSorting() {
    Hand myHand = new Hand("Seb", contents);
    List<Card> sorted = myHand.getOrderedCards();
    assertEquals(new Card(KING, DIAMONDS), sorted.get(4));
    assertEquals(new Card(QUEEN, DIAMONDS), sorted.get(3));
    assertEquals(new Card(TEN, SPADES), sorted.get(2));
    assertEquals(new Card(THREE, CLUBS), sorted.get(1));
    assertEquals(new Card(TWO, CLUBS), sorted.get(0));
}
```

Scoring a Hand

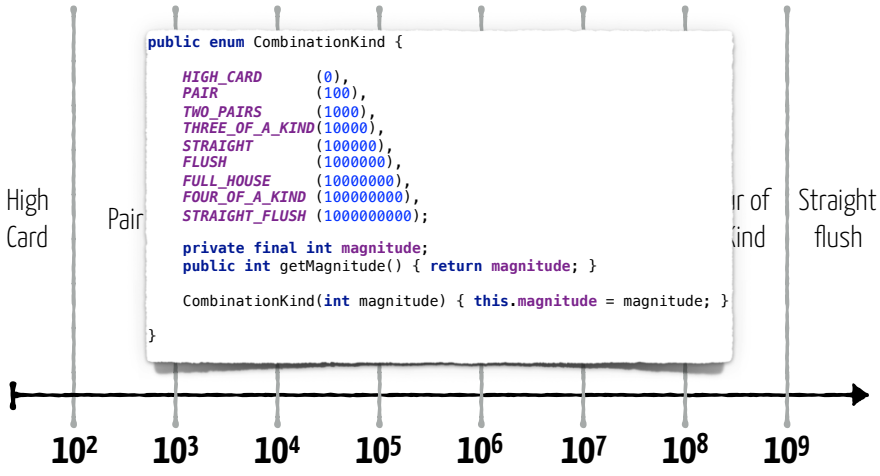
```
public int score() {
    List<Card> sorted = getOrderedCards();
    return  sorted.get(0).getValue().getValue() +
            sorted.get(1).getValue().getValue() * 10 +
            sorted.get(2).getValue().getValue() * 100 +
            sorted.get(3).getValue().getValue() * 1000 +
            sorted.get(4).getValue().getValue() * 10000;
}
```

```
@Test public void checkScore() {
    Hand myHand = new Hand("Seb", contents);
    assertEquals(143032, myHand.score());
}
```

F_4: Detecting Combinations

Highest card, Pair, Three of a …

Scoring Combination instead of Hands

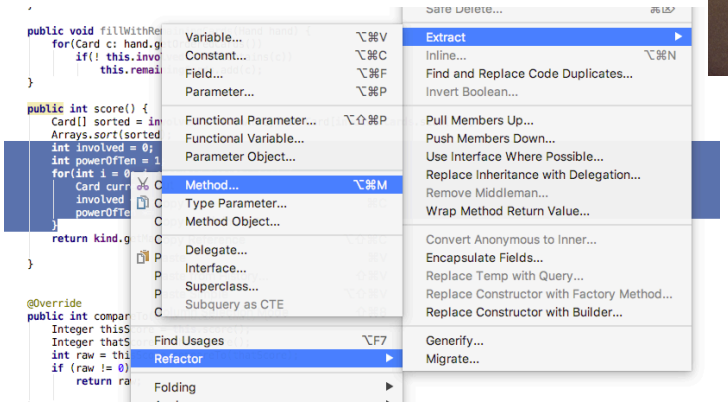



```
public enum CombinationKind {

    HIGH_CARD       (0),
    PAIR            (100),
    TWO_PAIRS       (1000),
    THREE_OF_A_KIND (10000),
    STRAIGHT        (100000),
    FLUSH           (1000000),
    FULL_HOUSE      (10000000),
    FOUR_OF_A_KIND  (100000000),
    STRAIGHT_FLUSH  (1000000000);

    private final int magnitude;
    public int getMagnitude() { return magnitude; }

    CombinationKind(int magnitude) { this.magnitude = magnitude; }
}
```

```
public class Combination {

    private CombinationKind kind;
    private Set<Card> involvedCards = new HashSet<>();

    public int score() {
        Card[] sorted = involvedCards.toArray(n
        Arrays.sort(sorted);
        int involved = 0;
        int powerOfTen = 1;
        for(int i = 0; i < so
            Card current
            involved
            powe
        }
        return kind.getMagnitude() + involved;
    }
}
```

Comparing cards => include remaining cards

Magic trick: Method extraction

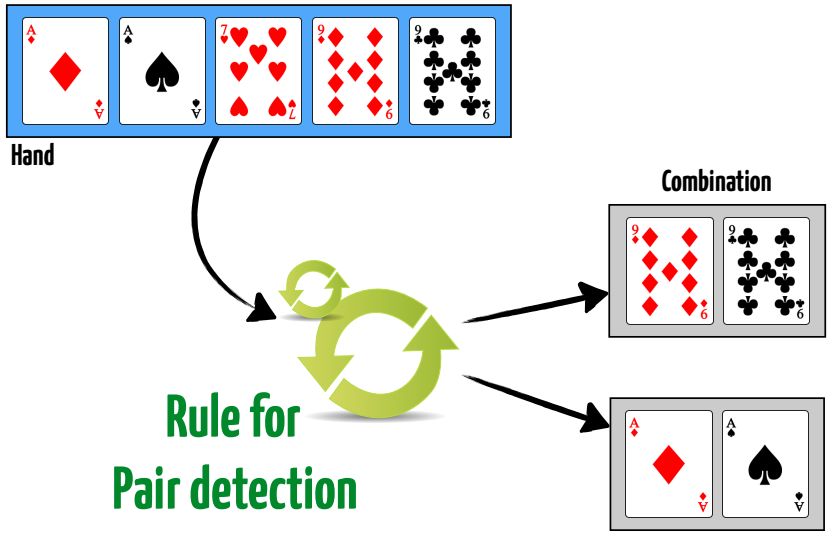


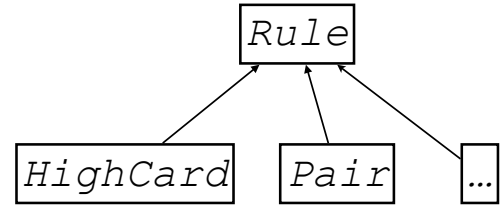

```
public int score() {
    int involved = getIntegerValue(involvedCards);
    return kind.getMagnitude() + involved;
}

@Override public int compareTo(Combination that) {
    Integer thisScore = this.score();
    Integer thatScore = that.score();
    int raw = thisScore.compareTo(thatScore);
    if (raw != 0) { // Different combination !
        return raw;
    } else {        // Same Combination => using remaining cards
        thisScore = getIntegerValue(remainingCards);
        thatScore = getIntegerValue(that.remainingCards);
        return thisScore.compareTo(thatScore);
    }
}

private int getIntegerValue(Collection<Card> cards) {
    Card[] sorted = cards.toArray(new Card[cards.size()]);
    Arrays.sort(sorted);
    int result = 0;
    int powerOfTen = 1;
    for(int i = 0; i < sorted.length; i++) {
        Card current = sorted[i];
        result += current.getFace().getValue() * powerOfTen;
        powerOfTen *= 10;
    }
    return result;
}
```

DRY!

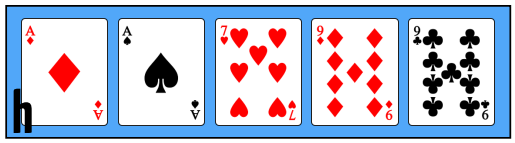
```java
private Combination c1;
@Before public void initCombination1() {
    Hand h = new Hand("p1", factory.transform("QD JH 5C 2H 7D"));
    c1 = new Combination(CombinationKind.HIGH_CARD);
    c1.addInvolvedCards(Arrays.asList(new Card(QUEEN, DIAMONDS)));
    c1.fillWithRemainingCards(h);
}

@Test public void highCardCombination() {

    Hand h2 = new Hand("p2", factory.transform("KC JH 5C 2H 7D"));
    Combination c2 = new Combination(CombinationKind.HIGH_CARD);
    c2.addInvolvedCards(Arrays.asList(new Card(KING, CLUBS)));
    c2.fillWithRemainingCards(h2);

    int comparison = c1.compareTo(c2);
    assertTrue(comparison < 0);

    int reverse = c2.compareTo(c1);
    assertTrue(reverse > 0);

    assertEquals(0, c1.compareTo(c1));
    assertEquals(0, c2.compareTo(c2));
}
```

Abstraction: "Checking Rules"

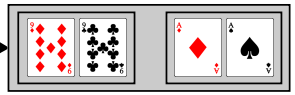


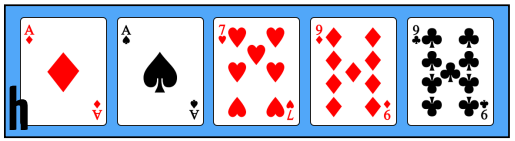



```java
public interface Rule {
   public Set<Combination> apply(Hand h);
}
```

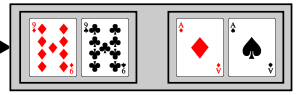


Rule r = new Pair();
r.apply(h);



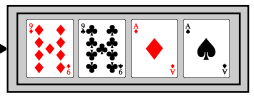


Rule r = new Pair();
r.apply(h);

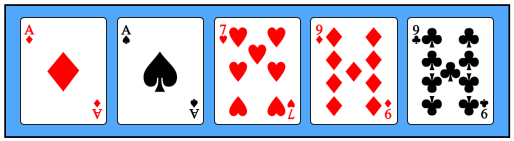


Rule r = newThreeOfAKind();
r.apply(h);

Rule r = new DoublePair();
r.apply(h);



Rule Implementation



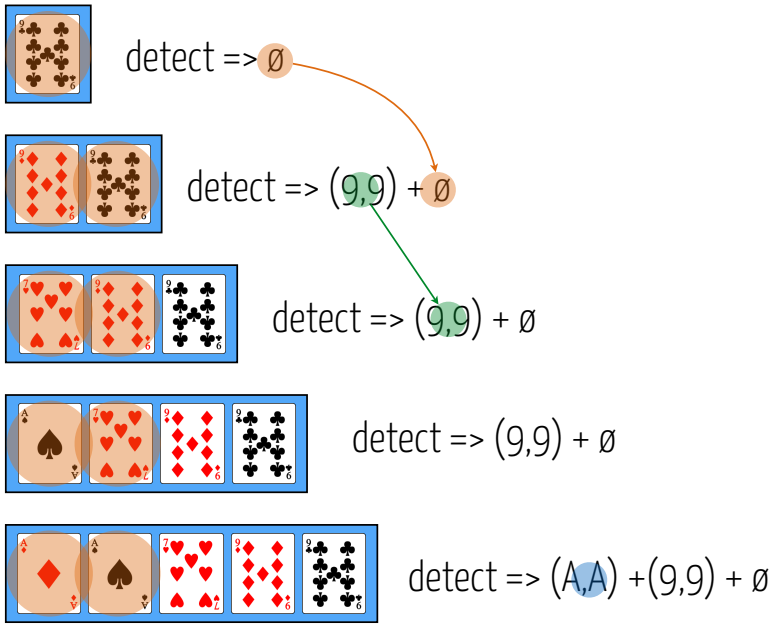
|cards| < 2 => No pairs

|cards| ≥ 2 => {

card[0] = cards[1] => Pair!

+ detectPair(cards[1..n])

}

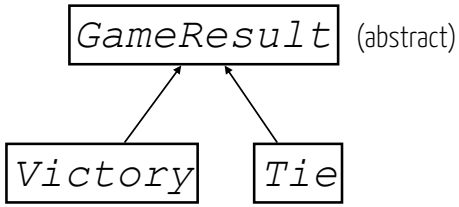



```java
public class Pair implements Rule {

    @Override public Set<Combination> apply(Hand h) {
        List<Card> cards = h.getOrderedCards();
        return collectPairs(cards);
    }

    private Set<Combination> collectPairs(List<Card> cards) {
        if (cards.size() < 2)
            return new HashSet<>();
        Set<Combination> detected = collectPairs(cards.subList(1,cards.size()));

        Card first = cards.get(0);
        Card second = cards.get(1);
        if (first.getFace() == second.getFace()) {
            Combination c = new Combination(CombinationKind.PAIR);
            c.addInvolvedCards(Arrays.asList(first,second));
            c.fillWithRemainingCards(cards);
            detected.add(c);
        }
        return detected;
    }

}
```

Referee's logic

```java
public class Referee {

    private List<Rule> rules;

    public Referee() {
        this.rules = new LinkedList<>();
        rules.add(new HighCard());
        rules.add(new Pair());
    }

    public Combination findBest(Hand h){
        Set<Combination> detected = new HashSet<>();
        for(Rule r: rules)
            detected.addAll(r.apply(h));

        Combination result = null;
        for(Combination c: detected) {
            if (result == null)
                result = c;
            else if (result.compareTo(c) < 0)
                result = c;
        }
        return result;
    }
```

```java
public GameResult decide(Hand left, Hand right) {
    Combination lc = findBest(left);
    Combination rc = findBest(right);
    int comparison = lc.compareTo(rc);
    if (comparison < 0)
        return new Victory(right, rc);
    else if (comparison == 0) {
        return new Tie(left, right, lc);
    } else {
        return new Victory(left, lc);
    }
}
```



https://pedrorijo.com/blog/intro-mutation/

Tests par Propriétés

3

Tests demonstrate expected result in given situations

$$3 \times (2 + 5) = (3 \times 2) + (3 \times 5)$$

```java
@Test public void zeroIsNeutralForAddition() {
    assertEquals(42, 42 + 0);
    assertEquals(0, 0 + 0);
    assertEquals(Integer.MIN_VALUE, Integer.MIN_VALUE + 0);
    assertEquals(Integer.MAX_VALUE, Integer.MAX_VALUE + 0);
}
```

```java
  @Test public void multiplicationIsDistributiveOverAddition() {
      assertEquals((42*(31+5)) , (42*31) + (42*5));
  }
```

```java
                    @Test public void additionIsCommutative() {
                        assertEquals(0 + 1, 1 + 0);
                        assertEquals(-1+1, 1 + -1);
                        assertEquals(42 + 24, 24 + 42);
                    }
```

```java
  @Test public void additionLeadsToBiggerNumbers() {
      int a = 1234567;
      int b = 4567890;
      assertTrue(a+b > a);
      assertTrue(a+b > b);
  }
```

Property-based testing

Express **Properties** on top of **symbols**

Automatically **explore** the values space


```java
  @Test public void multiplicationIsDistributiveOverAddition() {
      assertEquals((42*(31+5)) , (42*31) + (42*5));
  }
```

Express **Properties** on top of **symbols**

Automatically **explore** the values space


```java
@Property
public void multiplicationIsDistributiveOverAddition(
  Integer a, Integer b, Integer c) {
    assertEquals(a * (b + c), (a * b) + (a * c));
}
```

QuickCheck Framework

Exploring the value space

Does it work only for integers?

```
@Property
public void additionLeadsToBiggerIntegers(Integer a, Integer b) {
    assertTrue(a+b >= a);
    assertTrue(a+b >= b);
}
```

```
@Property
public void additionLeadsToBiggerIntegers_minBound(
 @InRange(minInt = 0) Integer a,
 @InRange(minInt = 0) Integer b) {
      assertTrue(a+b >= a);
      assertTrue(a+b >= b);
}
```

```
@Property
public void additionLeadsToBiggerIntegers(
 @InRange(minInt = 0, maxInt = Integer.MAX_VALUE/2) Integer a,
 @InRange(minInt = 0, maxInt = Integer.MAX_VALUE/2) Integer b) {
  assertTrue(a+b >= a);
  assertTrue(a+b >= b);
}
```

```
public interface Heap {

    boolean isEmpty();

    void insert(Integer elem);
    void merge(Heap that);

    Integer head();
    Integer next();
    List<Integer> flush();

    Heap copy();

}
```

abstraction

```
public class MyHeap implements Heap {

    public static Heap empty() { return new MyHeap(); }

    private MyHeap() { … }

    @Override public boolean isEmpty() { … }
    @Override public void insert(Integer elem) { … }
    @Override public void merge(Heap that) { … }
    @Override public Integer head() { … }
    @Override public Integer next() { … }
    @Override public List<Integer> flush() { … }
    @Override public Heap copy() { … }

    @Override public String toString() { … }
}
```

implementation

How to Generate a Heap ?

targeted classifier

```
public class EmptyHeapGenerator extends Generator<Heap> {

    public EmptyHeapGenerator() { super(Heap.class); }

    @Override
    public Heap generate(SourceOfRandomness sourceOfRandomness,
              GenerationStatus generationStatus) {
        return MyHeap.empty();
    }

}
```

Generation process

```
@Property
public void theEmptyHeapIsEmpty(
   @From(EmptyHeapGenerator.class) Heap theHeap) {
     assertTrue(theHeap.isEmpty());
}
```

```
@Property
public void gettingNextElementRemovesIt(
    @From(EmptyHeapGenerator.class) Heap theHeap, Integer e) {
      theHeap.insert(e);
      theHeap.next();
      assertTrue(theHeap.isEmpty());
}
```

How to Generate a Heap ?

```
public class NonEmptyHeapGenerator extends Generator<Heap> {

    public NonEmptyHeapGenerator() { super(Heap.class); }

    private int minElements = 1;
    private int maxElements = 100;

    @Override
    public Heap generate(SourceOfRandomness sor,
      GenerationStatus generationStatus) {
        int howManyElements = sor.nextInt(minElements,maxElements);
        Heap theHeap = MyHeap.empty();
        for(int i = 0; i < howManyElements; i++) {
            theHeap.insert(sor.nextInt()());
        }
        return theHeap;
    }
}
```

Expected expressiveness

```
@Property
public void mergeIsCommutative(Heap left, Heap right) {
    Heap lr = left.copy();  lr.merge(right.copy());
    Heap rl = right.copy(); rl.merge(left.copy());
    assertEquals(lr.flush(), rl.flush());
}
```

```
@Property
public void theHeapSortsElements(@Empty Heap h,
   List<Integer> elems) {
     for(Integer i: elems)
         h.insert(i);
     elems.sort(Integer::compareTo);
     assertEquals(elems, h.flush());
}
```

Annotating the Empty heap

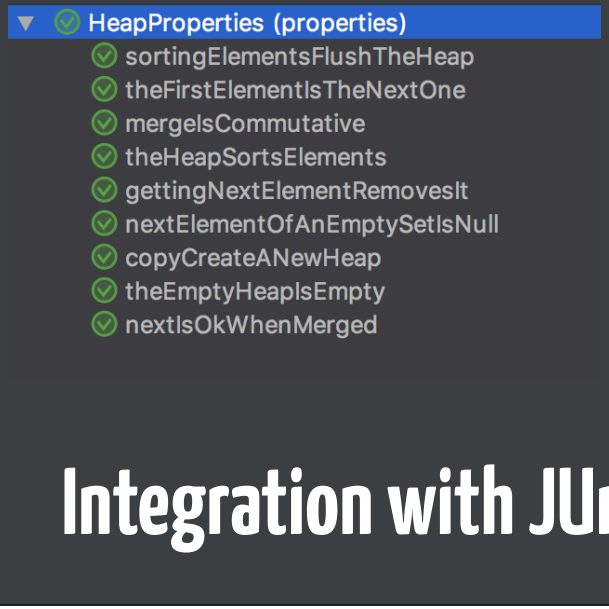
```
@Target({PARAMETER, FIELD, ANNOTATION_TYPE, TYPE_USE})
@Retention(RUNTIME)
@GeneratorConfiguration
public @interface Empty { }
```

Declaring a "Generator Service"

`generators.HeapGenerator`

src/test/resources/META-INF/services/com.pholser.junit.quickcheck.generator.Generator

```
public class HeapGenerator extends Generator<Heap> {

    public HeapGenerator() { super(Heap.class); }

    private boolean isEmpty;

    @Override
    public Heap generate(SourceOfRandomness sor,
      GenerationStatus generationStatus) {
        if(isEmpty) {
            return gen().make(EmptyHeapGenerator.class)
                    .generate(sor, generationStatus);
        } else {
            return gen().make(NonEmptyHeapGenerator.class)
                    .generate(sor, generationStatus);
        }
    }

    public void configure(Empty empty) { this.isEmpty = true; }

}
```



Integration with JUnit & IDE

Tests par Mutation

4

General idea

- Problem : How to measure test suite quality?
  - Coverage is not enough (can be easily fooled)
- Fact : Unit tests are here to catch bugs
- Proposition :
  - If I voluntarily introduce a bug in my source code (create a mutant)
    - If the unit tests do not catch it, the mutant is still alive, so the tests are poor
  - Compute the coverage as the number of mutants killed by the tests

Relies on fault injection principles (coined in 1972)

Kind of mutations

Mutators	"DEFAULTS" group	"NEW_DEFAULTS" group	"STRONGER" group	"ALL" group
Conditionals Boundary	yes	yes	yes	yes
Increments	yes	yes	yes	yes
Invert Negatives	yes	yes	yes	yes
Math	yes	yes	yes	yes
Negate Conditionals	yes	yes	yes	yes
Return Values	yes		yes	yes
Void Method Calls	yes	yes	yes	yes

https://pitest.org/quickstart/mutators/

Introducing Bugs ?

```
if (a == b) {
  // do something
}
```

will be mutated to

```
if (a != b) {
  // do something
}
```

```
int a = b + c;
```

will be mutated to

```
int a = b - c;
```

```
public float negate(final float i) {
  return -i;
}
```

will be mutated to

```
public float negate(final float i) {
  return i;
}
```

```
public int method(int i) {
  i++;
  return i;
}
```

will be mutated to

```
public int method(int i) {
  i--;
  return i;
}
```

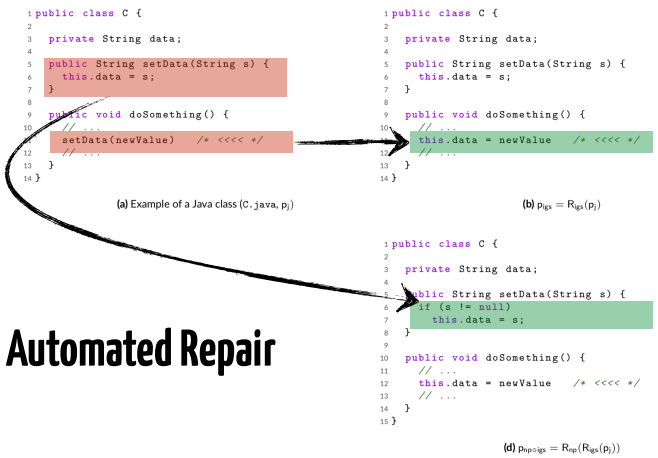
How to modify source code ?

Program result = apply(p, transformation)

```
public class LogProcessor extends AbstractProcessor<CtExecutable> {

    @Override
    public void process(CtExecutable element) {
        CtCodeSnippetStatement snippet = getFactory().Core().createCodeSnippetStatement();

        // Snippet which contains the log.
        final String value = String.format("System.out.println(\"Enter in the method %s from class %s\");",
                element.getSimpleName(),
                element.getParent(CtClass.class).getSimpleName());
        snippet.setValue(value);

        // Inserts the snippet at the beginning of the method body.
        if (element.getBody() != null) {
            element.getBody().insertBegin(snippet);
        }
    }
}
```

Code transformation tooling (e.g., Spoon in Java)

Other applications of code transfos.



Automated Repair

Repairnator (Montperrus et al)

- Jan 12, 2018, aaime/geowebcache/pull/1, “Thanks for the patch!”
- Mar 23, 2018, parkito/BasicDataCodeU[…]/pull/3 “merged commit 140a3e3 into parkito:develop”
- April 5, 2018, dkarv/jdcallgraph/pull/2 “Thanks!”
- May 3, 2018, eclipse/ditto/pull/151 “Cool, thanks for going through the Eclipse process and for the fix.”
- June 25, 2018, donnelldebnam/CodeU[…]/pull/151 “Thanks!!”

A bot crawling GitHub to fix bugs and propose patches. Real developers think it is a human.

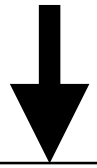
Coccinelle (Linux Kernel)

857,452

"commits"

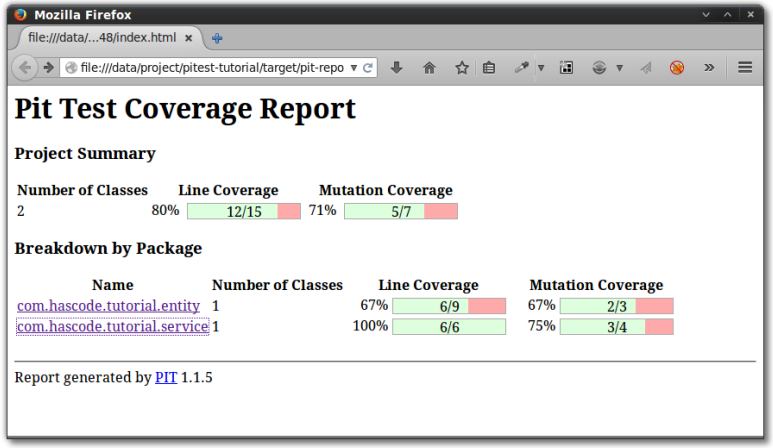
03.09.2019, 09:57 (CEST)

```
...
x = kmalloc(sizeof(*a), 0);
memset(a, 0, sizeof(*a))
...
```



```
...
x = kzalloc(sizeof(*a), 0);
...
```

Coccinelle (Lawall, Muller et al)




```
6   1. negated conditional → SURVIVED
7   1. replaced return of integer sized value with (x == 0 ? 1 : 0) → KILLED
10  1. Replaced integer subtraction with addition → KILLED
11  1. Replaced integer subtraction with addition → KILLED
12  1. negated conditional → KILLED
    2. negated conditional → SURVIVED
    3. replaced return of integer sized value with (x == 0 ? 1 : 0) → KILLED
    4. replaced return of integer sized value with (x == 0 ? 1 : 0) → SURVIVED
```

Limitations

- Time consuming approach :
  1. Create the mutants
  2. Run the tests
  3. Rinse and repeat
- Equivalent mutations
- Which operator to apply ? Where ?
- Reproducibility ?