

CODE DEFENDERS

GAMIFICATION OF MUTATION TESTING

Phil Werli - Student Researcher
Chair of Software Engineering II, University of Passau
Prof. Gordon Fraser

eMadrid
www.emadridnet.org



UNIVERSITÄT
PASSAU

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TEACHING SOFTWARE TESTING



CHALLENGE

Find an interesting way to teach Software Testing

MUTATION TESTING

1970's — DeMillo (Georgia Tech), Lipton (Princeton), Sayward (Yale)

MUTATION TESTING

1970's — DeMillo (Georgia Tech), Lipton (Princeton), Sayward (Yale)

- Measure quality of existing tests
- Modify source code: *Mutants*
- **Tests** may detect and kill **Mutants**

EXAMPLE

Original Code

```
1 int abs(int x) {  
2     if (x >= 0) {  
3         return x  
4     } else {  
5         return -x;  
6     }  
7 }
```

EXAMPLE

Original Code

```
1 int abs(int x) {
2     if (x >= 0) {
3         return x
4     } else {
5         return -x;
6     }
7 }
```

Test

```
1 @Test
2 void testAbs() {
3     int res = abs(42);
4     assertEquals(42, res); // true
5 }
```

MUTATION

Mutant

```
1 int abs(int x) {  
2     if (x <= 0) {  
3         return x  
4     } else {  
5         return -x;  
6     }  
7 }
```


MUTATION

Mutant

```
1 int abs(int x) {
2     if (x <= 0) {
3         return x
4     } else {
5         return -x;
6     }
7 }
```

Killing Test

```
1 @Test
2 void testAbs() {
3     int res = abs(42);
4     assertEquals(42, res); // false -> mutant discovered
5 }
```

New Mutant

```
1 int abs(int x) {  
2     if (x >= 0) {  
3         return x  
4     } else {  
5         return -x + 1;  
6     }  
7 }
```

New Mutant

```
1 int abs(int x) {  
2     if (x >= 0) {  
3         return x  
4     } else {  
5         return -x + 1;  
6     }  
7 }
```

New Test

```
1 @Test  
2 void testAbs() {  
3     // ???  
4 }
```

EQUIVALENCES

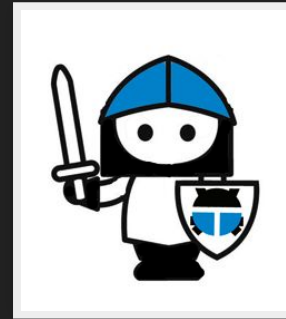
Original Code

```
1 int abs(int x) {  
2     if (x >= 0) {  
3         return x  
4     } else {  
5         return -x;  
6     }  
7 }
```

Equivalent Mutant

```
1 int abs(int x) {  
2     if (x >= 0) {  
3         return x  
4     } else {  
5         return -x + 0;  
6     }  
7 }
```

CODE DEFENDERS



Attackers vs. Defenders

- Attackers spawn Mutants
- Defenders defend with Tests

My Games

ID	Creator	Class	Attackers	Defenders	Level		
▼ 104	username	Lift	1	1	Hard	Observe	
Attacker	Mutants	Alive	Points	Defender	Tests	Mutants killed	Points
attacker	0	0	0	defender	0	0	0

[Create Battleground](#)

Open Games
LIVE DEMO

Enough talking...

Attackers	Defenders	Level
There are currently no open games.		

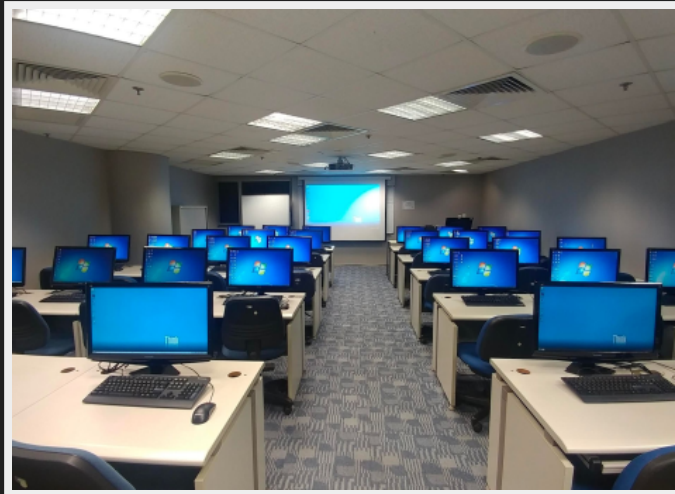
SOFTWARE TESTING COURSE @ UNI PASSAU

- 2h Lecture
- 1h Exercise
- **2h Lab Session**
- around 120 students

Lab Sessions

- 1 session per week per student
- Teams of 3-5 students
- Students play both roles
- Increasing difficulty
- Count towards grade

Four Challenges



Classroom Management

username (0)

Create Games Monitor Games Users Classes Puzzles Analysis Analytics System Settings

Current Games

ID	Class	Creator	Attackers	Defenders	Level	
106	Lift	username	1	1	HARD	[Stop]

Game Score	Name	Submissions	Last Action	Points	Total Score	Switch Role
13	attacker	8	00h 20m 48s	13	13	[Switch] [Remove]
3	defender	4	00h 27m 55s	4	3	[Switch] [Remove]

Start Games Stop Games

Games Management

Class Under Test

```

1 public class Lift {
2     private int topFloor;
3     private int currentFloor = 0; // default
4     private int capacity = 10; // default
5     private int numRiders = 0; // default
6
7     public Lift(int highestFloor) {
8         topFloor = highestFloor;
9     }
10
11     public Lift(int highestFloor, int maxRiders) {
12         this.highestFloor = highestFloor;
13         capacity = maxRiders;
14     }
15
16     public int getTopFloor() {
17         return topFloor;
18     }
19
20     public int getCurrentFloor() {
21         return currentFloor;
22     }
23
24     public int getCapacity() {
25
26     }
27 }
    
```

Write a new JUnit test here

```

1 import org.junit.Test;
2
3 import static org.junit.Assert.*;
4 import static org.hamcrest.MatcherAssert.assertThat;
5 import static org.hamcrest.Matchers.*;
6
7 public class TestLift {
8     @Test(timeout = 4000)
9     public void test() throws Throwable {
10         Lift lift = new Lift(10, 0);
11         lift.goUp();
12         lift.goUp();
13         assertEquals(2, lift.getCurrentFloor());
14     }
15 }
    
```

Existing Mutants

Alive (4) Killed (3) Flagged (0) Equivalent (1)

Mutant 389 | points: 5 | Claim Equivalent

Creator: attacker (uid 101)

JUnit tests

All Tests (4)

- Lift(in) (4)
- Lift(in, int) (2)
- getTopFloor() (1)

Course Management

Leaderboard

Battlegrounds

User	Mutants	Attacker Score	Tests	Defender Score	Mutants Killed	Total Score
kohlgr01	491	3093	350	618	355	3711
ahmed05	307	1874	19	0	0	1874
boehm45	258	962	224	701	306	1663
stegne01	515	1272	294	301	199	1573
lukasc01	146	416	320	1106	608	1522
christ38	121	851	269	655	272	1506
wendli01	294	1013	205	383	202	1396
ahmadi05	335	952	174	400	122	1352

Assessment

Create Games

Monitor Games

Manage Users

Manage Classes

Manage Puzzles

System Settings

Manage Analysis

Analytics

Current Games

<input type="checkbox"/>	ID		Class	Creator	Attackers	Defenders	Level	
<input type="checkbox"/>	104	Observe	Lift	username	1	1	HARD	

Game Score	Name	Submissions	Last Action	Points	Total Score	Switch Role	
0	attacker	0	never	0	9		Remove
0	defender	0	never	0	6		Remove

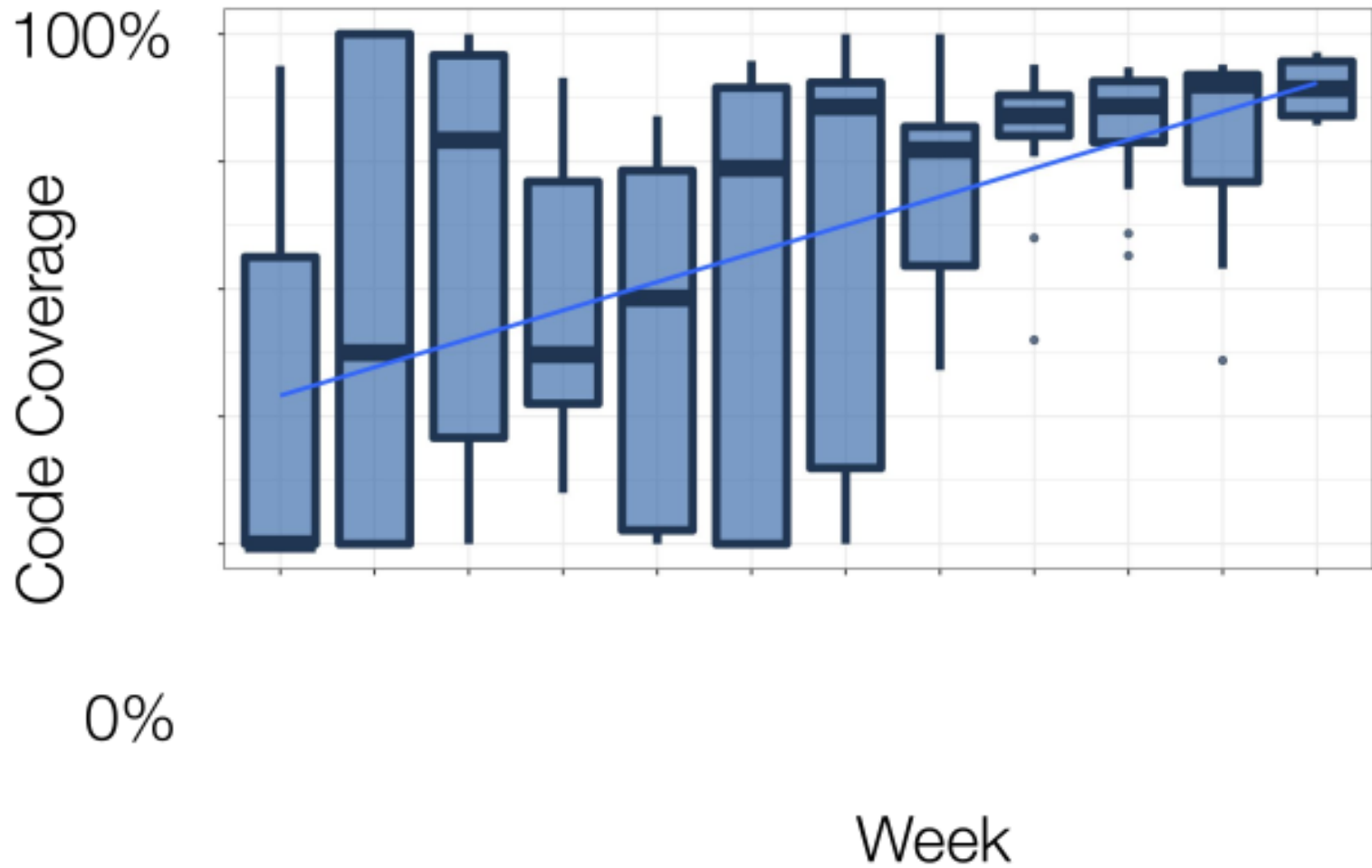
LIVE DEMO

Admin interface

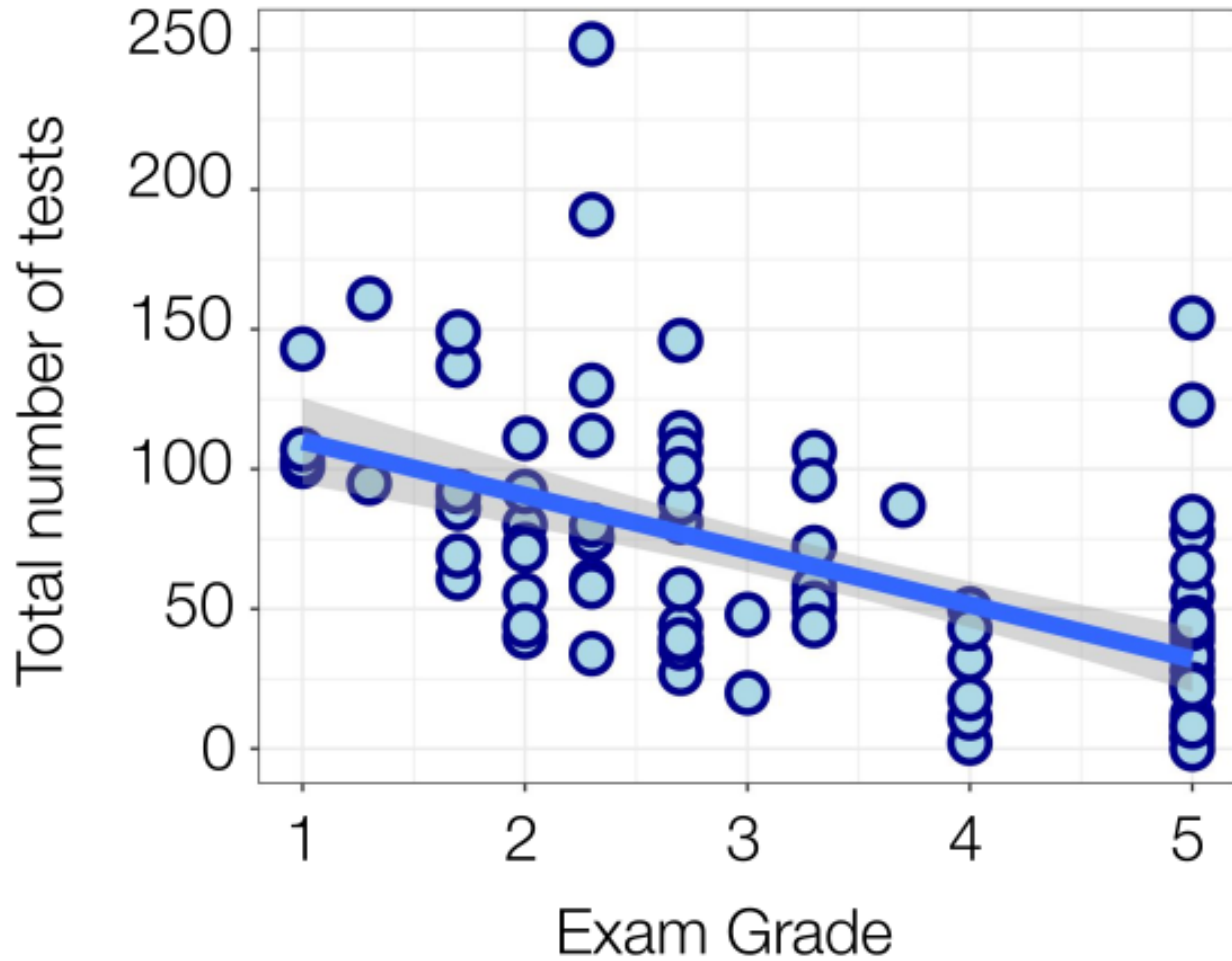
COURSE DATA & STUDY

- Data per game
- Data per student
- Study with data from our course

IMPROVEMENT THROUGHOUT SEMESTER



GAME ACTIVITY VS. EXAM GRADES



ANONYMOUS SURVEY

- 84% learned useful skills as defenders
- 60% learned useful skills as attackers

=> Make people defend more

FUTURE CHALLENGES

- Communication mechanism to foster collaboration
- Many opportunities to spice up gameplay
- Integrate more technologies & features



Code Defenders: A Mutation Testing Game

Currently active multiplayer games:

Creator	Class	Attackers	Defenders	Level
zenunomacedo	Lift	1	2	Hard
danpina	ByteVector	3	2	Easy
wendyd	Cal	5	6	Hard
ft	Lift	1	2	Hard
er1	Lift	2	2	Hard
brianrg	vendingMachine	3	3	Hard
ft	CoffeeMachine	1	2	Hard
salmatest1	Lift	1	1	Hard
taohansi	Lift	4	6	Hard
battlelord	Lift	2	2	Hard

PUBLICLY AVAILABLE

- code-defenders.org
- github.com/CodeDefenders

Log in or sign up

Research ▼

Overview

TEACHING SOFTWARE TESTING



Class Under Test

```
1 public class Lift {
2
3   private int topFloor;
4   private int currentFloor = 0; // default
5   private int capacity = 10; // default
6   private int numRiders = 0; // default
7
8   public Lift(int highestFloor) {
9     topFloor = highestFloor;
10  }
11
12  public Lift(int highestFloor, int maxRiders) {
13    this(highestFloor);
14    capacity = maxRiders;
15  }
16
17  public int getTopFloor() {
18    return topFloor;
19  }
20
21  public int getCurrentFloor() {
22    return currentFloor;
23  }
24
25  public int getCapacity() {
```

Write a new JUnit test here Defend!

```
1 import org.junit.Test;
2
3 import static org.junit.Assert.*;
4 import static org.hamcrest.MatcherAssert.assertThat;
5 import static org.hamcrest.Matchers.*;
6
7 public class TestLift {
8   @Test(timeout = 4000)
9   public void test() throws Throwable {
10     Lift lift = new Lift(10, 0);
11     lift.goUp();
12     assertThat(2, lift.getCurrentFloor());
13   }
14 }
15 }
```

Existing Mutants

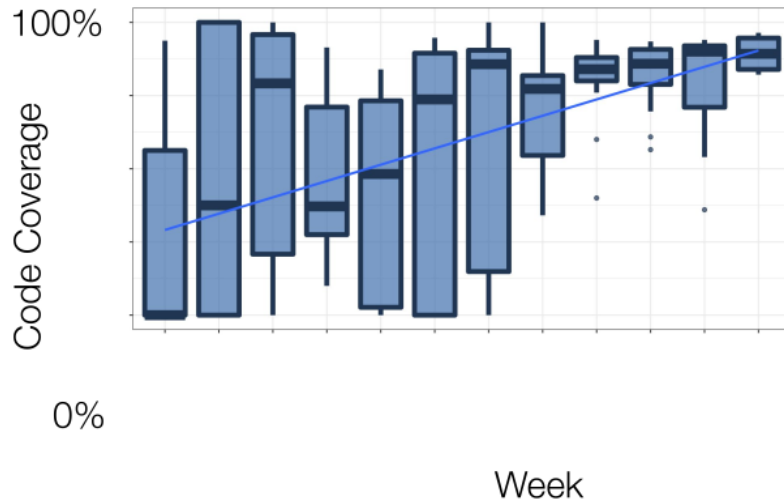
Alive (4)	Killed(3)	Flagged(0)	Equivalent(1)
Search...			

Mutant 389 | points: 5 | Claim Equivalent

Creator: altacker (uid 101)

JUnit tests

All Tests (4)
Lift(int) (4)
Lift(int, int) (2)
getTopFloor() (1)



Play online
<https://code-defenders.org>

Source Code
github.com/CodeDefenders

CHAIR & SPEAKER CONTACT

- Chair of Software Engineering II
- github.com/werli

Presentation created using [reveal.js](#)