

# Lecture 19: Verification, Validation and Testing

Test automation · Test coverage · Bug reporting · Alternatives to testing

**INF2-SEPP**

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# This Lecture

- Test automation with JUnit 5
  - Main components of a JUnit 5 test class
  - Assertion statements in JUnit 5
- Java inline assertions and their alternatives
- Test coverage and tools for it (IntelliJ IDEA)
- Bug reporting and tools for it (Trac, JIRA)
- Alternatives to testing:
  - Reviews / walkthroughs / inspections
  - Static Analysis and tools for it

# Test Automation and JUnit

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- JUnit is a framework for automated testing of Java programs.
- You will use JUnit 5 in Coursework 3.
- Similar frameworks are now available for most programming languages.

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- Contents: code to execute the code under test, assert method(s), usually an informative failure message.

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- `@Tag("<TagName>")` — tag the test; JUnit 5 allows running tests with a chosen tag.
- `@RepeatedTest(<Number>)` — repeat a test a specified number of times.

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- All methods accept an optional custom error message String.

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    assert x>=0;  
    /*..*/  
}
```

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numWheels += 2;  
/*...*/  
assert numWheels%2 ==0;
```

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Assertions checking can be switched on/off.

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- Proper exception-based error handling (e.g. throw `NegativeArgumentException`) is another option.

```
public static double sqrt (double x){
    if (x < 0){
        throw NegativeArgumentException("Cannot take the square
        root of a negative number!");
    }
    /*..*/
}
```

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- Proper exception-based error handling (e.g. throw `NegativeArgumentException`) is another option.
- Pro: program fails gracefully rather than crashing with `AssertionError`.
- Con: checking inputs everywhere leads to duplicated code across classes.
- Recommended: validate at the UI boundary; use inline assertions elsewhere to catch internal faults.

# Test Coverage

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- Other types: basic condition coverage, MC/DC, path coverage ...
- This course focuses on statement and branch coverage.

# Statement and branch coverage

```
void decideGreater(int a, int b){  
    if (a>b)  
        System.out.println("a is greater than b");  
}
```

a=5; b=4

# Statement and branch coverage

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- 100% statement coverage

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- 100% statement coverage
- 50% branch coverage

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- 100% statement coverage
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a=1; b=3

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# Statement and branch coverage

```
void decideGreater(int a, int b){  
    if (a>b)  
        System.out.println("a is greater than b");  
    else  
        System.out.println("b is greater or equal to a");  
}  
a=5; b=4
```

- 100% statement coverage
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a=1; b=3
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void decideGreater(int a, int b){  
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- Things can get complicated with nested or complex conditions

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- May be impossible to reach 100% — dead code, unreachable branches.
- Path coverage is exponentially more complex.
- Coverage-based (white-box) testing should be combined with black-box testing.

# Coverage Tools — General & IntelliJ IDEA

- Open-source tools for Java/JUnit: CodeCover, EMMA, Gretel, JaCoCo, Quilt.
- Commercial tools: Atlassian Clover, Testwell.

# Code Coverage in IntelliJ IDEA

The screenshot shows the IntelliJ IDEA interface with the Run/Debug Configurations dialog open. The dialog is titled "Run/Debug Configurations" and shows a configuration named "gettingstarted [test]". The "Code Coverage" tab is selected, and the "Choose coverage runner" dropdown is set to "IntelliJ IDEA". The "Track per test coverage" checkbox is checked. The "Packages and classes to include in coverage data" list contains "GettingStarted", "GettingStartedTest", and "Main". The "Packages and classes to exclude from coverage data" list is empty, with the message "No class patterns configured". The "Before launch" section is empty, with the message "There are no tasks to run before launch". The "OK", "Cancel", and "Apply" buttons are visible at the bottom of the dialog.

Process finished with exit code 0

# Code Coverage in IntelliJ IDEA

The screenshot displays the IntelliJ IDEA interface with the following components:

- Main Editor:** Shows the source code of `GettingStarted.java`. The code includes a class `GettingStarted` extending `Application`, with methods `add`, `start`, and `main`. A red bar on the left side of the editor indicates code coverage for the `start` method.
- Gradle Tool Window:** Shows the project structure for `ippo-gettingstarted`. The `Coverage` tab is active, displaying a table of coverage data for the `GettingStartedTest` class.
- Coverage Table:**

Element	Class, %	Method, %	Line, %
javax			
jdk			
META-INF			
netscape			
org			
sun			
toolbarButtonGraphics			
GettingStarted	100% (1/1)	33% (1/3)	33% (4/12)
GettingStartedTest	100% (1/1)	100% (3/3)	100% (7/7)
Main	0% (0/1)	0% (0/1)	0% (0/2)

- Test Results Window:** Shows the results of the `GettingStartedTest` test. The test passed, and the output includes the following text:

```
--- IntelliJ IDEA coverage runner ---
sampling ...
include patterns:
exclude patterns:
Class transformation time: 0.2636036s for 784 classes or 3.3622908163265307E-4s per class

Process finished with exit code 0
```

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- Open-source tools for Java/JUnit: CodeCover, EMMA, Gretel, JaCoCo, Quilt.
- Commercial tools: Atlassian Clover, Testwell.
- IntelliJ IDEA has its own coverage runner and integrates JaCoCo and EMMA.
- Run with coverage: Edit Configurations → Code Coverage tab → choose runner (IntelliJ IDEA / JaCoCo).
- Results shown inline (green/red gutter) and in a Coverage summary panel showing Class %, Method %, Line %.

# Example

Emma is working on building a library system (contains classes such as Book, BookCopy, User, LibraryMember etc). She wants to check if her code handles borrowing books well. Specifically, she wants to test the following situation: if a LibraryMember has already borrowed 12 items, they cannot borrow more, unless 2 or more of the borrowed items are journals. This functionality should only be available for a LibraryMember, not a regular user.





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- Features: receiving, tracking, notifying, monitoring, prioritising issues.
- JIRA is very popular; free for teams smaller than 10.

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- Issues (tickets) have: summary, component, version, milestone, type, owner, status, created date.
- Each ticket has a detail page: priority, keywords, description, workarounds, attachments.

# Bug Tracking: Trac

Ticket	Summary	Component	Version	Milestone	Type	Owner	Status	Created
#3292	OOS on rejoin with new pathfinder	Core engine		Alpha 19	defect		new	Jun 13, 2015
#3471	Units not detecting invalid path.	Core engine		Alpha 19	defect		new	Sep 30, 2015
#3505	Pathfinder - Units in formation stuck frequently	Core engine		Alpha 19	defect		new	Oct 8, 2015
#3551	[PATCH] Prohibit developer overlay cheats in rated games	UI & Simulation		Alpha 19	defect		new	Oct 26, 2015
#3549	Secure authentication - prevent joins as a different player	Core engine		Alpha 20	defect		new	Oct 24, 2015
#3255	[PATCH] Prevent replay overwrites by using date and sequential ID	Core engine		Alpha 19	defect	elexis	new	May 20, 2015
#3271	OOS on rejoin - different mirage order	Core engine		Alpha 19	defect		new	May 27, 2015
#3526	Build a tower in enemy territory	UI & Simulation		Alpha 19	defect		new	Oct 14, 2015
#3545	[PATCH] Crash the game using cheats	UI & Simulation		Alpha 19	defect	stanislas69	assigned	Oct 23, 2015
#3241	[PATCH] Kick / ban players from a match	UI & Simulation		Alpha 19	enhancement	elexis	new	May 10, 2015
#1791	Units command queue is reset when they enter new formation	UI & Simulation		Alpha 20	defect		new	Dec 19, 2012
#2001	Melee units with big maximum range can attack through walls	UI & Simulation		Alpha 20	defect		new	Jun 24, 2013
#2303	Update tutorials and increase their visibility	UI & Simulation		Alpha 20	defect		new	Dec 8, 2013
#2427	[PATCH] AtlasUI does not open on on commandline Mavericks 10.9	Atlas editor		Alpha 20	defect	trompetin17	new	Feb 8, 2014

# Bug Tracking: Trac

#3471 new defect

Opened 5 weeks ago  
Last modified 2 days ago

## Units not detecting invalid path.

Reported by:	stanislas69	Owned by:	
Priority:	Release Blocker	Milestone:	Alpha 19
Component:	Core engine	Keywords:	pathfinding
Cc:	Itms		

Description (last modified by elexis) [Δ](#)

We played a match today with elexis and ffm, and we noticed that units would often try to go from a point 'a' to a point 'b' without realising they wouldn't be able to reach it. So they just walk into the void.



The only we could workaround it, is by cancelling orders, and removing formations (setting it to none)

FFM stated formation should be disabled whereas I think it should be set to none by default.

► Attachments (6)

# Bug Tracking: JIRA

- Widely-used commercial issue tracker by Atlassian.
- Issue list view shows: type, key, summary, assignee, reporter, priority, status, created date.
- Individual issue view: description, attachments, environment, original estimate, time tracking, due date, priority.
- Supports comments, history, work log, sub-tasks, and linked issues.

# Bug Tracking: JIRA

Jira Software Your work **Projects** Filters Dashboards People Apps [Create](#)

Projects / JiraDemo-Project

**Issues** [Export Issues](#) [Go to advanced search](#)

[Reset](#) [Switch to detail view](#)

Type	Key	Summary	Assignee	Reporter	P ↓	Status	Created
	JP-5	Secure authentication- prevent joins as a different player	John	George	↑	IN PROGRESS	Mar 9, 2021
	JP-4	Prohibit developer overlay cheats in rated games	Adriana	George	↑	TO DO	Mar 9, 2021
	JP-3	Pathfinder- units in formation stuck frequently	Adriana	Cristina	↑	TO DO	Mar 9, 2021
	JP-2	Units not detecting invalid path	John	Intan	↑	TO DO	Mar 9, 2021
	JP-1	OOS on rejoin with new pathfinder	Ash	Cristina	↑	TO DO	Mar 9, 2021
	JP-12	Players through each other out of the game	Cristina	Cristina	↑	IN REVIEW	Mar 9, 2021
	JP-11	Units command queue is reset when they enter new formation	Cristina	Cristina	↑	IN REVIEW	Mar 9, 2021
	JP-10	Kick/bad players from the game	Cristina	Cristina	↑	IN PROGRESS	Mar 9, 2021
	JP-9	Crash the game using cheats	John	Intan	↑	IN PROGRESS	Mar 9, 2021
	JP-8	Build a tower in enemy territory	Adriana	Adriana	↑	IN PROGRESS	Mar 9, 2021
	JP-7	OOS on rejoin-different mirage order	John	Ash	↑	DONE	Mar 9, 2021
	JP-6	Prevent replay overwrites by using date and sequential ID	John	John	↑	DONE	Mar 9, 2021

**Filters**

- All issues
- My open issues
- Reported by me
- Open issues
- Done issues
- Viewed recently
- Resolved recently
- Updated recently
- [View all filters](#)

# Bug Tracking: JIRA

Jira Software Your work Projects Filters Dashboards People Apps Create

JiraDemo-Project Classic software project

Board Reports Issues Components Code Releases Project pages Add item Project settings

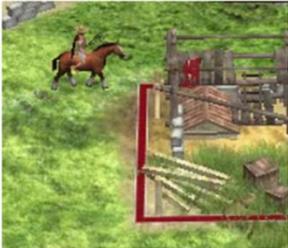
Projects / JiraDemo-Project / JP-1

## OOS on rejoin with new pathfinder

Attach Create subtask Link issue

Description - Unsaved changes

I played a game today and noticed that units would often try to go from a point 'a' to a point 'b' without realising they wouldn't be able to reach it. So they just walk into the void.



The only way we can work around it is to cancel orders and remove formations.

Environment

This did not work on Windows 10 OS.

Attachments (1)



game.png  
09 Mar 2021, 07:12 PM

Activity

Show: Comments History Work log

CA Add a comment...

Pro tip: press **IM** to comment

To Do

Assignee: Ash

Reporter: Cristina

Labels: None

Original estimate: 3d

Time tracking: No time logged 2d remaining

Due date: 2021/03/11

Priority: High

Show 4 more fields  
Epic Link, Components, Fix versions and Affects versions

Created 6 hours ago Updated 6 hours ago Configure

# Alternatives to Testing: Reviews

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  - Works on non-executable artefacts: requirements specifications, UML models, test plans.
- Outside views complement the author's own perspective.
- Reviews, walkthroughs, and inspections are treated as equivalent in this course ('Review').

# Alternatives to Testing: Static Analysis

- Automatically inspecting code to determine properties without running it — very active research area.
  - Type-checking during compilation is a basic form of static analysis.
  - Tools address runtime exception issues: null pointer exceptions, array index out of bounds.
  - Tools address correctness of pre/post-condition specifications.
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  - Tools address concurrency bugs: race conditions, deadlocks.
- More complex properties checked  $\Rightarrow$  smaller programs, less automation, more annotations required.
- More automated / large-scale tools: may flag false positives and miss some bugs.

# Alternatives to Testing: Static Analysis

- Automatically inspecting code to determine properties without running it — very active research area.
  - Type-checking during compilation is a basic form of static analysis.
  - Tools address runtime exception issues: null pointer exceptions, array index out of bounds.
  - Tools address correctness of pre/post-condition specifications.
  - Tools address concurrency bugs: race conditions, deadlocks.
- More complex properties checked  $\Rightarrow$  smaller programs, less automation, more annotations required.
- More automated / large-scale tools: may flag false positives and miss some bugs.
- Think of them as bug-hunting aids, not correctness guarantors.

# Static Analysis Tools for Java

- SpotBugs (formerly FindBugs) — looks for bug patterns and incorrect code idioms; widely used.
- ThreadSafe (Contemplate, Informatics spin-out) — focuses on concurrency bugs.
- Infer (Meta/Facebook) — lightweight analysis scaling to  $10^6+$  LOC; finds null pointer and concurrency issues.
- Give SpotBugs or Infer a try!

# Reading & Resources

- JUnit 5: <http://www.junit.org>
- JUnit Tutorial: [vogella.com/articles/JUnit/article.html](http://vogella.com/articles/JUnit/article.html)
- JUnit 5 Assertions API: [petrikainulainen.net](http://petrikainulainen.net) (JUnit 5 tutorial series)
- Writing tests in IntelliJ IDEA: [jetbrains.com/help/idea/tests-in-ide.html](http://jetbrains.com/help/idea/tests-in-ide.html)
- Inline assertions in Java (Preconditions, Postconditions, Invariants): [docs.oracle.com/javase/7/docs/technotes/guides/language/assert.html](http://docs.oracle.com/javase/7/docs/technotes/guides/language/assert.html)
- Statement & branch coverage: [guru99.com/code-coverage.html](http://guru99.com/code-coverage.html)
- Unit testing & coverage in IntelliJ IDEA (video): [youtube.com/watch?v=QDFI19lj4OM](http://youtube.com/watch?v=QDFI19lj4OM)
- JIRA bug tracking: [atlassian.com/software/jira/bug-tracking](http://atlassian.com/software/jira/bug-tracking)
- SpotBugs: [spotbugs.github.io](http://spotbugs.github.io) | Infer: [fbinfer.com](http://fbinfer.com)