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Behavior-driven Development and Testing in Ruby on Rails

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Agenda

1. Why Behavior-driven Development (BDD)?
2. Building Blocks of Tests and BDD
3. Testing Tests & Hints for Successful Test Design
4. Outlook

Agenda

1. Why Behavior-driven Development (BDD)?
   - **Goals of Automated Testing**
   - Writing Software that Matters
2. Building Blocks of Tests and BDD
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Goals of Automated Testing

Feature 1: Website registration

Developer 1 (no TDD/BDD, browser-based testing)	Developer 2 (with TDD/BDD, almost no browser testing)
Minute 5: working registration page Minute 8: feature is tested (3 times)	Minute 05.00: working test Minute 10.00: working implementation Minute 10.30: feature is tested (3 times)

Assumptions: 1min manual testing, 10s automatic test

Goals of Automated Testing

Feature 2: Special case for feature 1

Developer 1 (no TDD/BDD, browser-based testing)	Developer 2 (with TDD/BDD, almost no browser testing)
Minute 11: implemented Minute 14: tested (3 times)	Minute 12.30: test ready Minute 15.30: implemented Minute 16.00: tested (3 times)

Goals of Automated Testing

Feature 2: Special case for feature 1

Developer 1 (no TDD/BDD, browser-based testing)	**Developer 2 (with TDD/BDD, almost no browser testing)**
Minute 11: implemented	Minute 12.30: test ready
Minute 14: tested (3 times)	Minute 15.30: implemented
	Minute 16.00: tested (3 times)
Minute 17: refactoring ready	*Minute 19.00: refactoring ready*
Minute 19: tested feature 1	Minute 19.10: tested both features
Minute 21: tested feature 2	Minute 20.10: committed
Minute 22: committed	

Goals of Automated Testing

- Find errors **faster**
- Better code (correct, robust, maintainable)
- Less overhead when testing -> tests are used **more frequently**
- Easier to add new features
- Easier to modify existing features, **refactoring**

But

- Tests might have bugs
- Test environment != production environment
- Code changes break tests

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Writing Software that Matters

> *"BDD is about implementing an application by describing its behavior from the perspective of its stakeholders"*
>
> – Dan North

Principles

1. Enough is enough
2. Deliver stakeholder value
3. It's all behavior

BDD Cycle

1

red 2

3
red

Unit Tests

refactor
green 4

5

refactor
green 6

7

Acceptance Tests

Adapted from
[Chelimsky et al.:
The Rspec Book, 2010]

Definition of Done

How do I know when to stop?

- Acceptance criteria fulfilled
- All tests are green
- Code looks good
- Objective quality goals
- Second opinion
- Internationalization
- Security
- Documentation

Definition of Done:
A team's consensus of what it takes to complete a feature.

Maximum BDD Pyramid

Vision

Goals

Epics

Use Cases | Features

User Stories | Scenarios

Scenario Steps

Test Cases

Vision

All Stakeholders, one statement

- *Example:* Improve Supply Chain

Core stakeholders define the vision

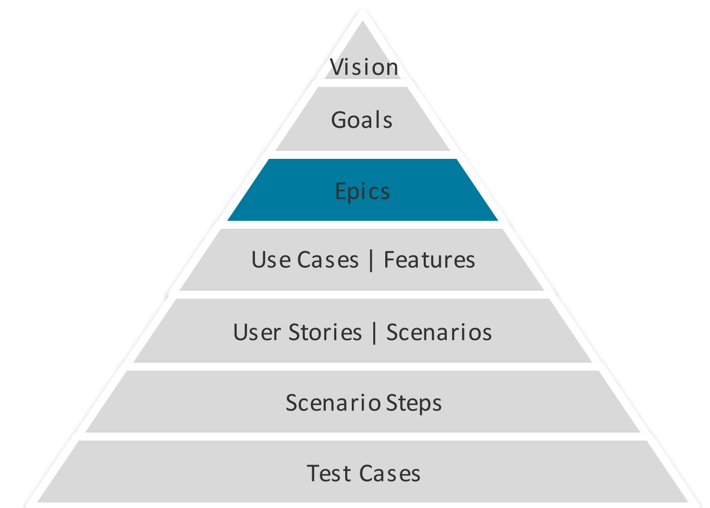
- Incidental stakeholders help understand
  - What is possible
  - At what cost
  - With what likelihood

Goals

- How the vision will be achieved.
- Examples
  - Easier ordering process
  - Better access to suppliers' information

Epics

- Huge themes / feature sets are described as an “epic”
- Too high level to start coding but useful for conversations
- Examples
  - Reporting
  - Customer registration

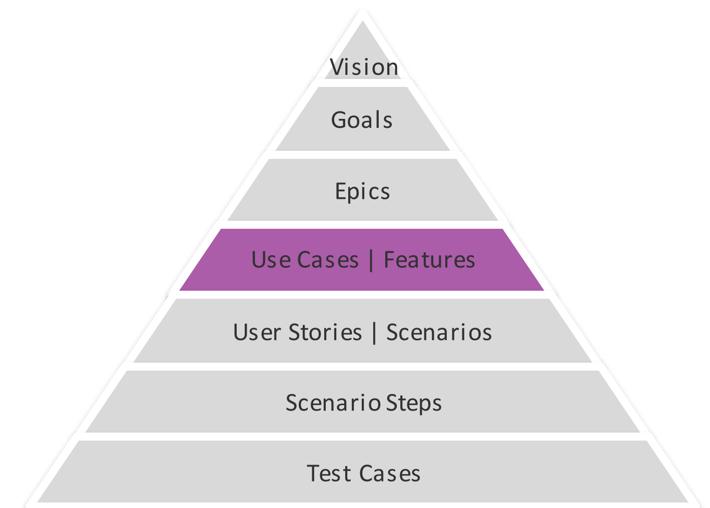


Use Cases / Features

- Describe the behavior we will implement in software
- Can be traced back to a stakeholder

- ***Warning:*** Do not directly start at this level

- Explain the value & context of a feature to stakeholders
  - Not too much detail
- Features deliver value to stakeholders

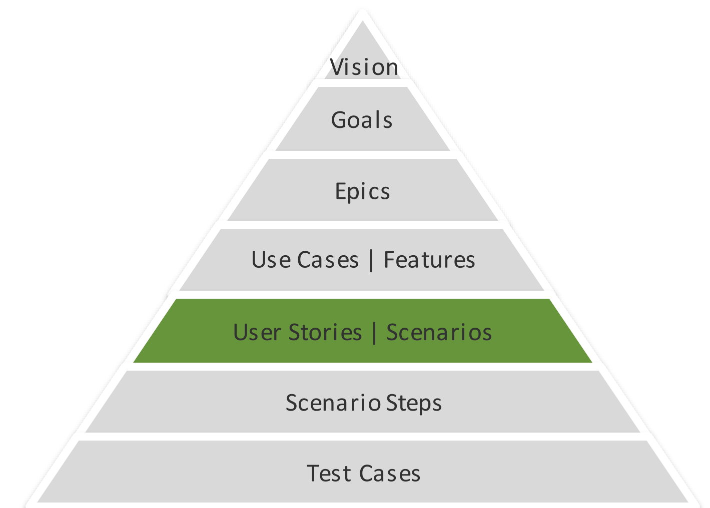


User Stories

User Stories are demonstrable functionality

- 1 Feature -> 1..n User Stories
- Stories should be vertical (e.g. no database-only stories)
- User stories are tokens for conversations
- Attributes (**INVEST**)
  - **I**ndependent
  - **N**egotiable
  - **V**aluable (from a business Point of View)
  - **E**stimable
  - **S**mall enough to be implemented in one iteration
  - **T**estable

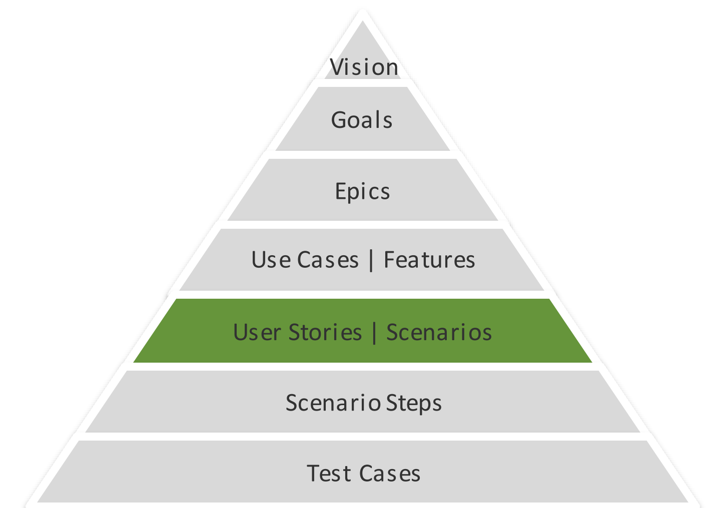
See http://xp123.com/articles/invest-in-good-stories-and-smart-tasks/



User Stories

Story content

- Title
- Narrative
  - **Description, reason, benefit** *(why?)*
  - “As a <stakeholder>, I want <feature> so that <benefit>”
  - “In order to <benefit>, a <stakeholder> wants to <feature>”
- Acceptance criteria
  - Criteria for what needs to be implemented for PO to accept story
  - Related to Definition of Done



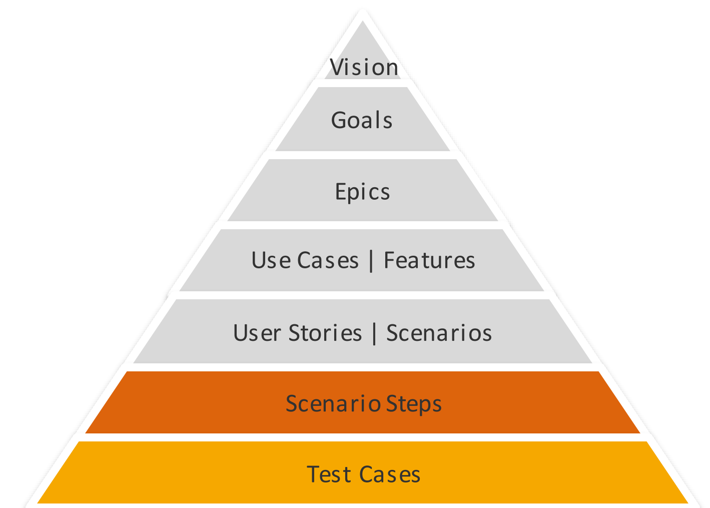
Scenarios, Scenario Steps, Test Cases

Scenarios

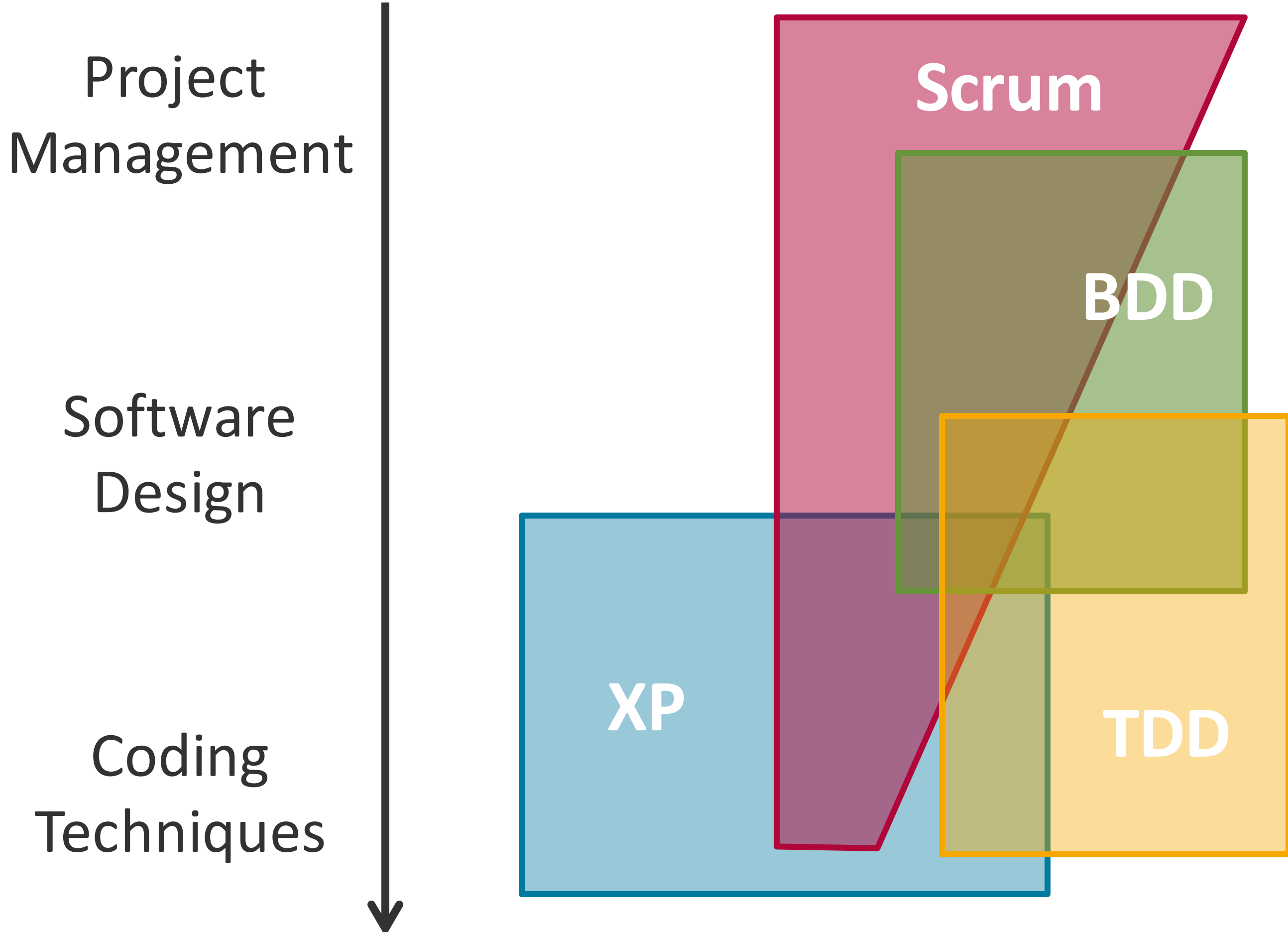
- 1 User Story -> 1..n scenarios
- Each scenario describes one aspect of a User Story
- Describe high-level behavior

Scenario steps

- 1 scenario -> m scenario steps + step implementation
- 1 scenario step -> 0..i tests
- Describe low-level behavior



Agile Methodologies



Behavior-driven Development

Principles

- Story-based definition of application behavior
- Definition of features
- **Driven by business value**

For the developer

- BDD / TDD Cycle
- Coding with TDD
- Automated Testing

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Test::Unit vs. RSpec

- Test::Unit comes with Ruby

```ruby
class UserTest < Test::Unit::TestCase

  def test_first_name
    user = User.new
    assert_nil user.name, "User's name was not nil."
    user.name = "Chuck Norris"
    assert_equal user.first_name, "Chuck", "user.first_name did not return 'Chuck'."
  end

end
```

Test::Unit vs. RSpec

- RSpec offers syntactical sugar, different structure
- Many “built-in” modules (e.g. mocking)
- “rspec” command with tools to constrain what examples are run

```
describe User do

  it "should determine first name from name" do
    user = User.new
    expect(user.name).to be_nil
    user.name = "Chuck Norris"
    expect(user.first_name).to eq "Chuck"
  end

end
```

We’ll use RSpec

- http://blog.thefirehoseproject.com/posts/test-driven-development-rspec-vs-test-unit/

RSpec Basic structure

- Using "*describe*" and "*it*" like in a conversation
  - *"Describe an order!" "It sums prices of items."*

- *describe* creates a test / example group
- *it* declares examples within group
- *context* for nested groups / structuring

```
describe Order do
  context "with one item" do
    it "sums prices of items" do
      # ...
    end
  end

 context "with no items" do
    it "shows a warning" do
      # ...
    end
  end
end
```

- Aliases
  - Declare example groups using *describe* or *context*
  - Declare examples using *it*, *specify*, or *example*

- https://github.com/rspec/rspec-core/blob/master/README.md

RSpec Matchers

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- General structure of RSpec expectation (assertion):
  - `expect(…).to <matcher>, expect(…).not_to <matcher>`

```
# Object identity
expect(actual).to be(expected) # passes if actual.equal?(expected)
# Object equivalence
expect(actual).to eq(expected) # passes if actual == expected
# Comparisons
expect(actual).to be >= expected
expect(actual).to be_between(minimum, maximum).inclusive
expect(actual).to match(/expression/) # regular expression
expect(actual).to start_with expected
# Collections
expect([]).to be_empty
expect(actual).to include(expected)
```

Tip:
RSpec also comes with many highly specialized matchers, that can make tests easier to write and understand, e.g.:

```
expect(actual).to
  respond_to(expected)
```

The docs are worth checking out.

- https://www.relishapp.com/rspec/rspec-expectations/docs/built-in-matchers

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Model Tests

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A Rails model

- Accesses data through an **Object-relational mapping** (ORM) tool
  - Object-oriented programming languages deal with "objects"
  - Relational databases deal with scalar values (*int, string*) in tables
  - ORM translates between these worlds
- Implements **business logic**
- Is “fat”, i.e. contains the most code and application logic

Model tests in Rails

- Easiest tests to write
- Test most of application logic

Hints for Model Tests

Model Tests

- Tests should cover **circa 100% of the model code**
- Do not test framework functionality like "*belongs_to*"
- Test your validations
- How many tests? Let tests drive the code -> perfect fit

Minimal model test set

- One test for the **"happy-path case"** (the usual, normal way)
- One test for each code branch
- Corner cases (nil, wrong values, …), if appropriate

- **Keep each test small!** *(why?)*

Model Test Example

app/models/contact.rb

```ruby
class Contact < ActiveRecord::Base
  validates :name, presence: true

  def self.by_letter(letter)
    where("name LIKE ?", "#{letter}%").order(:name)
  end
end
```

spec/models/contact_spec.rb

```ruby
require 'rails_helper'

describe Contact, type: :model do

  before :each do #do this before each test
    @john= Contact.create(name: 'John')
    @tim = Contact.create(name: 'Tim')
    @jerry = Contact.create(name: 'Jerry')
  end

  #the actual test cases
  context "with matching letters" do
    it "returns a sorted array of results that match" do
      expect(Contact.by_letter("J")).to eq [@john, @jerry]
    end

    it "omits results that do not match" do
      expect(Contact.by_letter("J")).not_to include @tim
    end
  end

end
```

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View Tests

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A Ruby on Rails view

- Has only minimal logic
- Should never call the database! *(why?)*
- Presents the data passed by the controller

Challenges for view tests

- Time-intensive
- How to test look & feel?
- Brittle regarding interface redesigns

Info:

If you are familiar with **Django**, the Python web framework, the terminology is different:

view (RoR) ~ *template* (Django)

controller (RoR) ~ *view* (Django)

Django can be called a 'MTV' framework.

View Tests

Specify and verify **logical** and **semantic structure** of views

Goals

- Validate that view layer runs without error
- Render view templates in isolation
- Check that passed data is presented as expected
- Validate conditional display of information, e.g. based on user's role

Possible anti-patterns *(why?)*

- Validation of HTML markup
- Evaluating the "look & feel"
- Testing for the existence of specific text

View Tests in RSpec

```
describe "users/index", type: :view do
  it "displays user name" do
    assign(:user,
        User.create! :name => "Bob"
    )

    # path could be inferred from test file
    render :template => "users/index.html.erb"

    expect(rendered).to match /Hello Bob/
  end
end
```

Tip:
`user.save!` (notice the "bang") raises `ActiveRecord::RecordInvalid` error when **`user.save`** returns **`false`**.

https://railsadventures.wordpress.com/2012/07/20/rspec-bang-them-all/

- https://www.relishapp.com/rspec/rspec-rails/v/3-2/docs/view-specs/view-spec

RSpec View Tests (with Capybara)

```ruby
require 'capybara/rspec'

Rspec.describe "users/index" do
  it "displays user name" do
    assign(:user,
        User.create! :name => "Bob"
    )

    # path could be inferred from test file
    render :template => "users/index.html.erb"

    # same as before
    expect(rendered).to have_content('Hello Bob')
    # a better idea
    expect(rendered).to have_css('a#welcome')
    expect(rendered).to have_xpath('//table/tr')
  end
end
```

- https://github.com/jnicklas/capybara

Tip:

For exploring in *irb*, using Capybara matchers on strings, use:

`Capybara.string`

robots.thoughtbot.com/use-capybara-on-any-html-fragment-or-page

Another Tip:

Capybara features a whole range of helpful "matchers", including `has_button`, `has_table`, `has_unchecked_field`.

rubydoc.info/github/jnicklas/capybara/master/Capybara/Node/Matchers

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Controller Tests

A Rails controller

- Is “skinny”, i.e. contains little code and little logic
- Retrieves the appropriate models from the database
- Calls model methods
- Passes data to the view

Goal of controller tests

- Simulate a HTTP request
- Test multiple paths through controller code, e.g. for authentication
- Verify result and the correct handling of parameters

What to Test in Controller Tests?

- Verify that user requests trigger
  - Model / ORM calls
  - That the correct data is forwarded to view
- Verify handling of invalid user requests, e.g. through redirects
- Verify handling of exceptions raised by model calls
- Verify security roles / role-based access control

Remember: Model functionality is tested in model tests!

Inside Controller Tests

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Rails provides helpers to implement controller tests

- 3 important variables are automatically imported
  - `controller`
  - `request`
  - `response`
- Variable getter and setter for
  - session – `session[:key]`
  - controller variables – `assigns[:key]`
  - flash – `flash[:key]`
- Methods to simulate a single HTTP request
  - *get, post, put, delete*

Info:
RSpec includes this Rails functionality for functional tests from ActionController::TestCase::Behavior & ActionDispatch:TestProcess

Testing the Controller Response

```ruby
require "rails_helper"

describe TeamsController, :type => :controller do
  describe "GET index" do
    it "assigns @teams in the controller" do
      team = Team.create
      get :index
      expect(assigns(:teams)).to eq([team])
    end

    it "renders the index template" do
      get :index
      expect(response).to render_template("index")
    end
  end
end
```

- http://www.relishapp.com/rspec/rspec-rails/v/3-2/docs/controller-specs

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Setup and Teardown – RSpec

As a developer using RSpec
I want to execute arbitrary code before and after examples
So that I can control the environment in which tests are run

```
before(:example) # run before each example
before(:context) # run one time only, before all of the examples in a group

after(:example) # run after each example
after(:context) # run one time only, after all of the examples in a group
```

Setup RSpec – before(:example)

```ruby
require "rspec/expectations"

class Thing
  def widgets
    @widgets ||= []
  end
end

describe Thing do
  before(:example) do
    @thing = Thing.new
  end

  describe "initialized in before(:example)" do
    it "has 0 widgets" do
      expect(@thing.widgets.count).to eq(0)
    end
  end
end
```

- `before(:example)` blocks are run before each example
- `:example` scope is also available as `:each`

- https://www.relishapp.com/rspec/rspec-core/v/3-2/docs/hooks/before-and-after-hooks

Setup RSpec – before(:context)

```ruby
require "rspec/expectations"
class Thing
  ... #as before

describe Thing do
  before(:context) do
    @thing = Thing.new
  end

  context "initialized in before(:context)" do
    it "can accept new widgets" do
      @thing.widgets << Object.new
    end

    it "shares state across examples" do
      expect(@thing.widgets.count).to eq(1)
    end
  end
end
```

- `before(:context)` blocks are run before all examples in a group
- `:context` scope is also available as `:all`
- **Warning:** Mocks are only supported in `before(:example)`

- https://www.relishapp.com/rspec/rspec-core/v/3-2/docs/hooks/before-and-after-hooks

Teardown RSpec

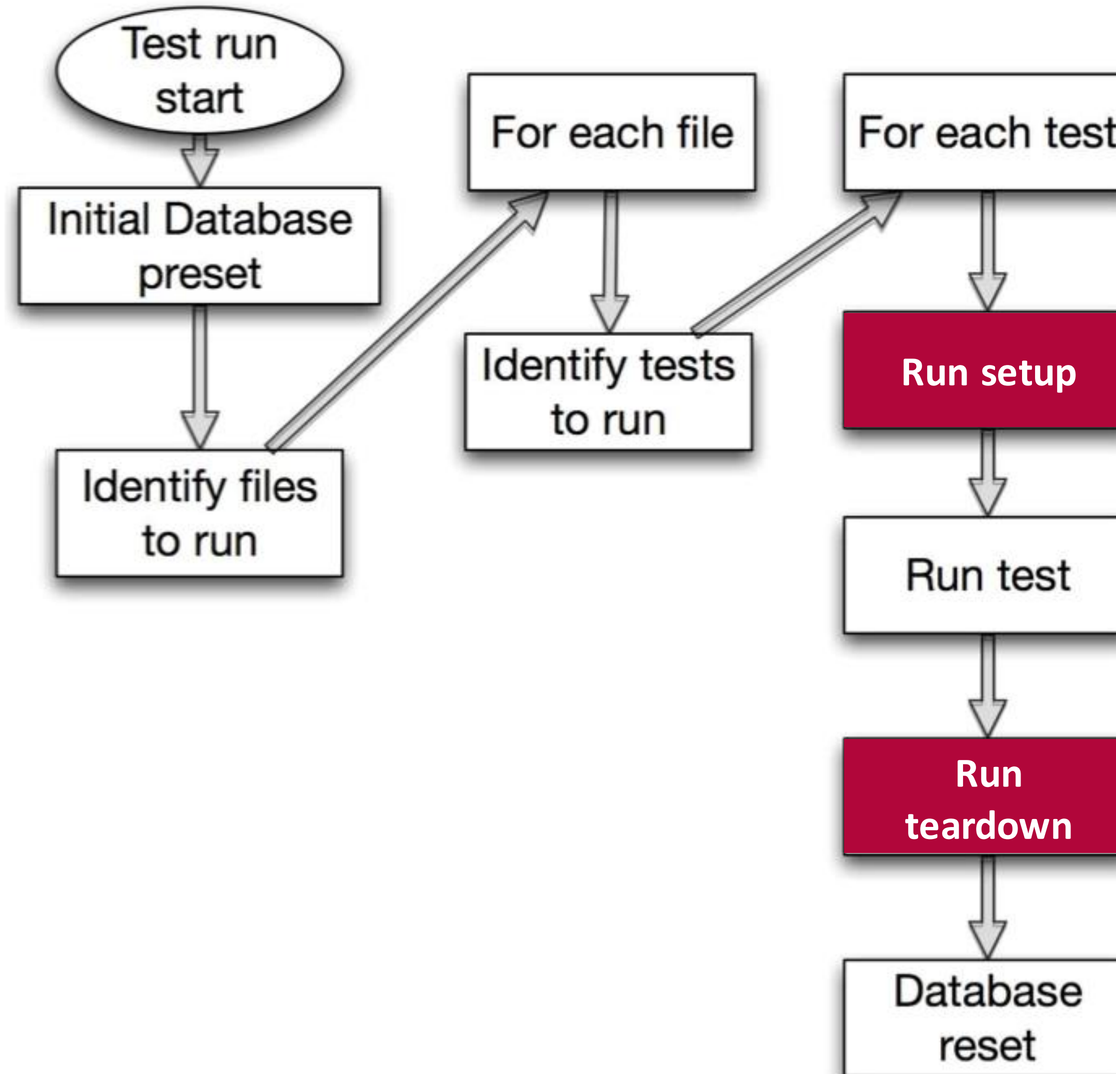
```
describe "Test the website with a browser" do
  before(:context) do
    @browser = Watir::Browser.new
  end

  it "should visit a page" do
    ...
  end

  after(:context) do
    @browser.close
  end
end
```

- `after(:context)` blocks are run after all examples in a group
- For example to clean up

Test Run



- Rails Test Prescriptions. Noel Rappin. 2010. p. 37. http://zepho.com/rails/books/rails-test-prescriptions.pdf

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Isolation of Test Cases

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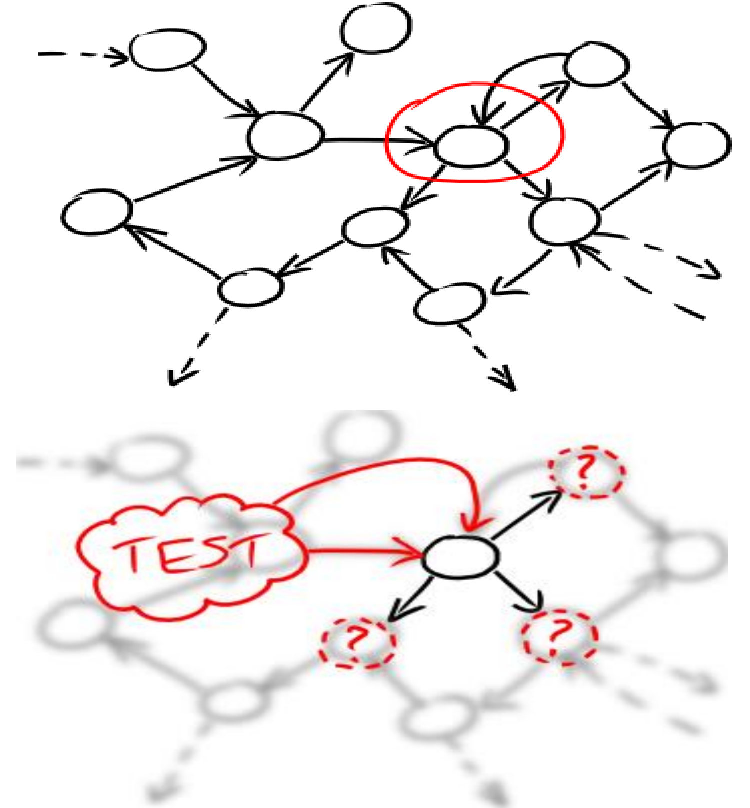
Tests should be independent

- If a bug in a model is introduced
  - Only tests related to this model should fail
  - Allow localization of bug

How to achieve this?

- Don't write complex tests
- Don’t use complex objects
- **Don’t share complex test data**



Steve Freeman, Nat Pryce: Growing Object-Oriented Software, Guided by Tests

Test Data Overview

Two main ways to **provide data to test cases**:

Fixtures

- Fixed state at the beginning of a test
- Assertions can be made against this state

Factories

- Blueprints for models
- Used to generate test data locally in the test

Fixture Overview

- Fixtures represent sample data
- Populate testing database with predefined data before tests run
- Stored in database independent YAML files (.yml)
- One file per model, location: `test/fixtures/<name>.yml`

```yaml
# test/fixtures/users.yml
david: # Each fixture has a name
  name: David Heinemeier Hansson
  birthday: 1979-10-15
  profession: Systems development

steve:
  name: Steve Ross Kellock
  birthday: 1974-09-27
  profession: guy with keyboard
```

- http://api.rubyonrails.org/classes/ActiveRecord/FixtureSet.html
- http://guides.rubyonrails.org/testing.html

Info:
By default, `test_helper.rb` (`require 'test_helper'`) will load all fixtures into the database.
To ensure consistent data, fixtures are deleted before loading.

Another Info:
Fixture data can be accessed by using a special dynamic method, with the same name as the model:
```
users(:steve).name
# => Steve Ross Kellock
```

Drawbacks of Fixtures

Fixtures are global

- Only one set of data, every test has to deal with all test data

Fixtures are spread out

- Own directory
- One file per model -> data for one test is spread out over many files
- Tracing relationships is challenging

Fixtures are distant

- Fixture data is not immediately available in the test
- `expect(users(:ernie).age + users(:bert).age).to eq(20)`

Fixtures are brittle

- Tests rely on fixture data, they break when data is changed
- Data requirements of tests may be incompatible

Alternative: Factories

Test data should be:

Local

- Defined as closely as possible to the test

Compact

- Easy and quick to specify; even for complex data sets

Robust

- Independent from other tests

Our choice to achieve this: **Data factories**

Data Factories

Provide blueprints for sample instances

Rails tool support

- **Factory Bot** (was renamed from 'Factory Girl')
- Machinist
- Fabrication
- FixtureBuilder
- Cf. https://www.ruby-toolbox.com/categories/rails_fixture_replacement

Similar structure

- Syntax for creating the factory blueprint
- API for creating new objects

Defining Factories

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```ruby
# This will guess the User class
FactoryBot.define do
  factory :user do
    first_name "John"
    last_name "Doe"
    admin false
  end

  # This will use the User class
  # (Admin would have been guessed)
  factory :admin, class: User do
    first_name "Admin"
    last_name "User"
    admin true
  end
end
```

Tip:
Factories can be defined anywhere, but are automatically loaded if they are defined in:

- `test/factories.rb`
- `spec/factories.rb`
- `test/factories/*.rb`
- `spec/factories/*.rb`

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Using Factories

- Build strategies: *build, create* (standard), *attributes_for, build_stubbed*

```
# Returns a User instance that's _not_ saved
user = build(:user)

# Returns a _saved_ User instance
user = create(:user)

# Returns a hash of attributes that can be used to build a User instance
attrs = attributes_for(:user)

# Passing a block to any of the methods above will yield the return object
create(:user) do |user|
  user.posts.create(attributes_for(:post))
end
```

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Attributes

```ruby
# Lazy attributes
factory :user do
  activation_code { User.generate_activation_code }
  date_of_birth { 21.years.ago }
end

# Dependent attributes
factory :user do
  first_name "Joe"
  last_name "Blow"
  email { "#{first_name}.#{last_name}@example.com".downcase }
end

# override the defined attributes by passing a hash
create(:user, last_name: "Doe").email
# => "joe.doe@example.com"
```

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Associations

```
factory :post do
  # If factory name == association name, the factory name can be left out.
  author
End

factory :post do
  # specify a different factory or override attributes
  association :author, factory: :user, last_name: "Writely“
End

# Builds and saves a User and a Post
post = create(:post)
post.new_record?              # => false
post.author.new_record?       # => false

# Builds and saves a User, and then builds but does not save a Post
post = build(:post)
post.new_record?              # => true
post.author.new_record?       # => false
```

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Inheritance

```
# The title attribute is required for all posts
factory :post do
  title "A title"
End

# An approved post includes an extra field
factory :approved_post, parent: :post do
  approved true
end
```

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Sequences for Unique Values

```ruby
# Defines a new sequence
FactoryBot.define do
  sequence :email do |n|
    "person#{n}@example.com"
  end
end

generate :email # => "person1@example.com"
generate :email # => "person2@example.com"

# Sequences can be used as attributes
factory :user do
  email
end
```

```ruby
# in lazy attribute
factory :invite do
  invitee { generate(:email) }
end

# In-line sequence for a factory
factory :user do
  sequence(:email) {|n| "person#{n}@example.com"}
end
```

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Callbacks

factory_bot makes four callbacks available for injecting code:

- *after*(:build)- called after the object is built (via `FactoryBot.build`, `FactoryBot.create`)
- *before*(:create) - called before the object is saved (via `FactoryBot.create`)
- *after*(:create) - called after the object is saved (via `FactoryBot.create`)
- *after*(:stub) - called after the object is stubbed (via `FactoryBot.build_stubbed`)

```
# Call customize() after the user is built
factory :user do
  after(:build) { |user| customize(user) }
end

# multiple types of callbacks on the same factory
factory :user do
  after(:build) { |user| customize(user) }
  after(:create) { |user| customize_further(user) }
end
```

- http://www.rubydoc.info/gems/factory_bot/file/GETTING_STARTED.md

Factory Bot – Further Reading

- Much documentation still uses the earlier ‘FactoryGirl‘ name

- Faster tests with `build_stubbed`
  - Nothing is saved to the database
  - Makes objects look like they’ve been persisted
  - Creates stubbed out associations, whereas build creates them in the db
  - https://robots.thoughtbot.com/use-factory-girls-build-stubbed-for-a-faster-test

- Tips and tricks
  - http://arjanvandergaag.nl/blog/factory_girl_tips.html

Agenda

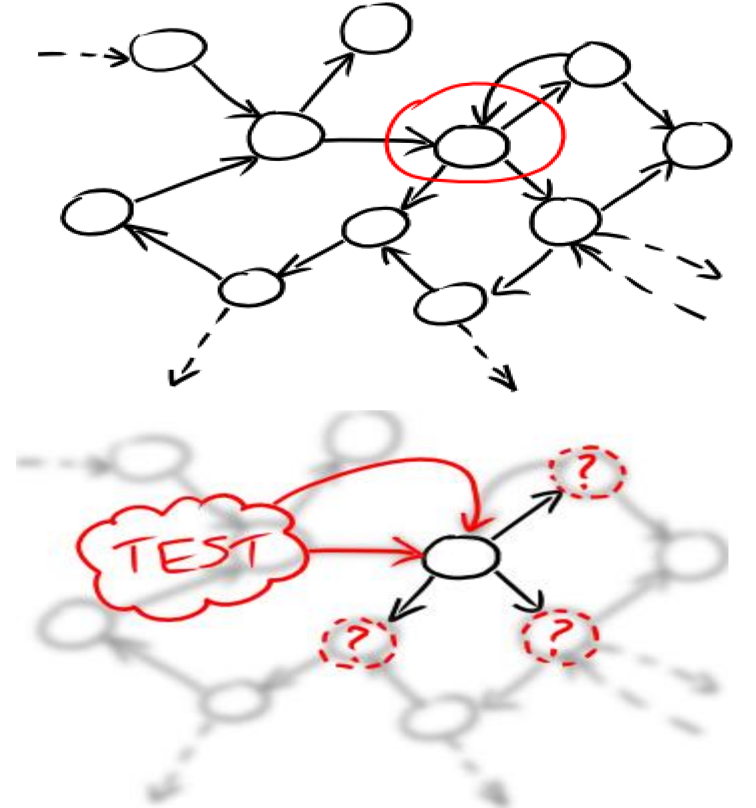
1. Why Behavior-driven Design (BDD)?
2. Building Blocks of Tests and BDD
   - Model Tests
   - View Tests
   - Controller Tests
   - Setup and Teardown
   - Test Data
   - **Test Doubles**
   - Integration & Acceptance Tests
   - Specialized Tests
3. Testing Tests & Hints for Successful Test Design
4. Outlook

Isolation of Test Cases

HPI

Tests should be independent

- If a bug in a model is introduced
  - Only tests related to this model should fail
  - Allow localisation of bug



How to achieve this?

- Don't write complex tests
- **Don’t use complex objects**
- Don’t share complex test data

Steve Freeman, Nat Pryce: Growing Object-Oriented Software, Guided by Tests

Test Doubles

HPI

Generic term for object that stands in for a real object during a test

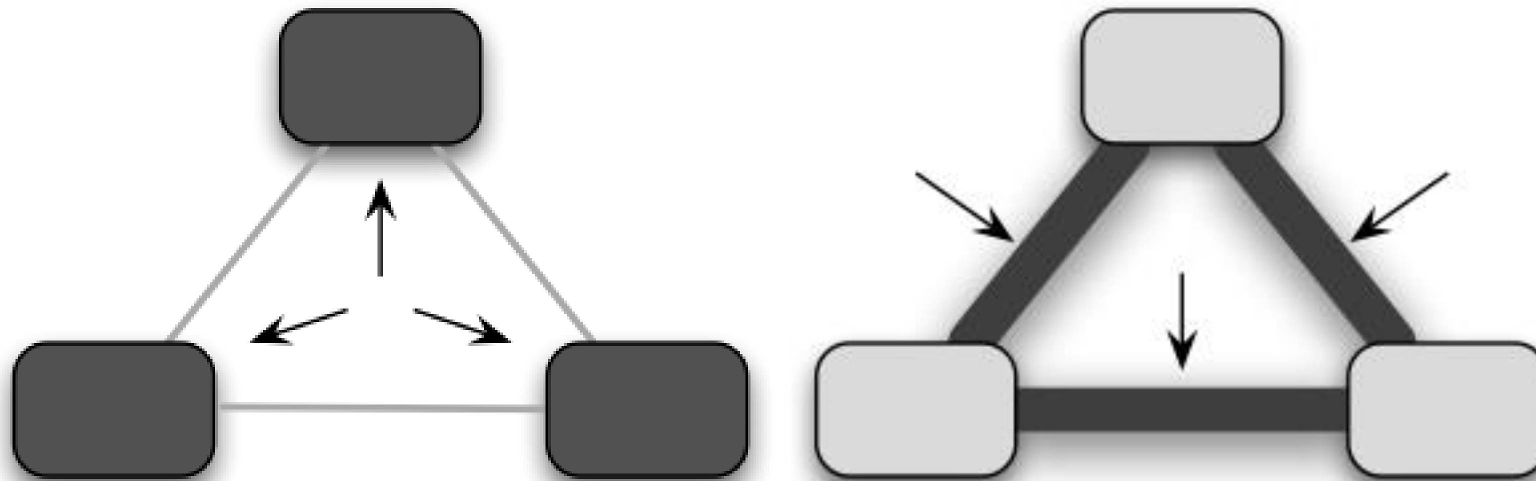
- Think “stunt double”
- Purpose: automated testing

Used when

- Real object is unavailable
- Real object is difficult to access or trigger
- Following a strategy to re-create an application state
- Limiting scope of the test to the object/method currently under test

Verifying Behavior During a Test

- Usually: test system state **after** a test
  - Only the result of a call is tested, intermediate steps are not considered
- With test doubles: Test **system behavior**
  - E.g. How often a method is called, in which order, with which parameters



Ruby Test Double Frameworks

Many frameworks available:

- RSpec-mocks (http://github.com/rspec/rspec-mocks)
- Mocha (https://github.com/freerange/mocha)
- FlexMock (https://github.com/jimweirich/flexmock)

A collection of mocking frameworks (as well as many others):

- https://www.ruby-toolbox.com/categories/mocking

We recommend **RSpec-Mocks** as it shares a common syntax with RSpec

Tip:

```
require(
  "rspec/mocks/standalone"
)
```

exposes the mock framework outside the Rspec environment. This is especially useful for exploring in *irb*.

Stubs

- Method call on the real object does not happen
- Returns a predefined value if called
- Strict by default (error when messages received that have not been allowed)

```
dbl = double(“user”)
allow(dbl).to receive_messages (:name => “Fred”, :age => 21 )
expect (dbl.name).to eq(“Fred”) #this is not really a good test :)
dbl.height #raises error (even if your original object had that property)
```

- Alternatively, if all method calls should succeed: **Null object double**

```
dbl = double(“user”).as_null_object
dbl.height # this is ok! Returns itself (dbl)
```

- http://www.relishapp.com/rspec/rspec-mocks/v/3-2/docs/basics/null-object-doubles

Spies

- Stubs with *Given-When-Then* structure
- Allows to expect that a message has been received after the message call

```
dbl = spy("user")
dbl.height
dbl.height
expect(dbl).to have_received(:height).at_least(2).times
```

- Alternatively, spy on specific messages of real objects

```
user = User.new
allow(user).to receive(:height)          # Given a user
user.measure_size                        # When I measure the size
expect(user).to have_received(:height) # Then height is called
```

- http://www.relishapp.com/rspec/rspec-mocks/v/3-2/docs/basics/spies

Mocks

HPI

Mocks are Stubs with attitude

- Demands that mocked methods are called

```
book = double("book", :title => "The RSpec Book")
expect(book).to receive(:open).once # 'once' is default
book.open # this works
book.open # this fails
```

- Or as often as desired

```
user = double("user")
expect(user).to receive(:email).exactly(3).times
expect(user).to receive(:level_up).at_least(4).times
expect(user).to receive(:notify).at_most(3).times
```

- If test ends with expected calls missing, it fails!

- https://relishapp.com/rspec/rspec-mocks/v/3-2/docs/configuring-responses/returning-a-value

Stubs vs. Mocks

Stub (passive)

- Returns a predetermined value for a method call

```
dbl = double("a user")
allow(dbl).to receive (:name) => { "Fred" }
expect (dbl.name).to eq("Fred") #this is not really a good test :)
```

Mock (more aggressive)

- In addition to stubbing: set a “message expectation”
- If expectation is not met, i.e. the method is not called → test failure

```
dbl = double(“a user”)
expect(dbl).to receive(:name)
dbl.name     #without this call the test would fail
```

➔ Stubs don‘t fail your tests, mocks can!

Info:
In **RSpec** the `allow` keyword refers to a stub, `expect` to a mock.
This might vary by framework.

Partially Stubbing Instances

- Sometimes you want only part of your object to be stubbed
  - Many methods on object, only expensive ones need stubbing for a test
- Extension of a real object in a system that is instrumented with stub like behaviour
- "Partial test double" (in RSpec terminology)

```
s = "a user name" # s.length == 11
allow(s).to receive(:length).and_return(9001)
expect (s.length).to eq(9001) # the method was stubbed
s.capitalize! # this still works, only length was stubbed
```

- http://www.relishapp.com/rspec/rspec-mocks/v/3-2/docs/basics/partial-test-doubles

Class Methods

- Class methods can also be stubbed
- **Example:** Stubbing the User class
  - The database is not touched, a specific instance is returned
  - “find” cannot be verified anymore but tests based on “find” can be isolated
  - -> just test the logic that is under test

```
u = double("a user")
allow(User).to receive(:find) {u} # “User” is a class
expect (User.find(1)).to eq(u) # the class method was stubbed
```

- http://www.relishapp.com/rspec/rspec-mocks/v/3-2/docs/basics/partial-test-doubles

Multiple Return Values

- A stub might have to be invoked more than once
- Return values for each call (in the given order)

```
die = double("a rigged die")
allow(die).to receive(:roll).and_return(4,5,6) # a better version

puts die.roll # => 4
puts die.roll # => 5
puts die.roll # => 6
puts die.roll # => 6
# last value is returned for any subsequent invocations
```

- https://relishapp.com/rspec/rspec-mocks/v/3-2/docs/configuring-responses/returning-a-value

Method Stubs with Parameters

HPI

- Failure when calling stub with wrong parameters
- Respond differently based on passed parameters

- A mock / expectation will only be satisfied when called with matching arguments

```
calc = double("calculator")
allow(calc).to receive(:double).with(4).and_return(8)
expect(calc.double(4)).to eq(8) # this works
```

- Calling mock with wrong parameters fails:

```
dbl = double("spiderman")
# anything matches any argument
expect(dbl).to receive(:injury).with(1, anything, /bar/)
dbl.injure(1, 'lightly', 'car') # this fails, "car" does not match /bar/
```

Info:
These are only a few of the matchers *RSpec-mocks* provides.

- https://relishapp.com/rspec/rspec-mocks/v/3-2/docs/setting-constraints/matching-arguments

Raising Errors

- A stub can raise an error when it receives a message
- Allows easier testing of exception handling

```
dbl = double()
allow(dbl).to receive(:foo).and_raise("boom")
dbl.foo # This will fail with:

#    Failure/Error: dbl.foo
#    RuntimeError:
#      boom
```

Warning:
There is a semantic difference between *raise & rescue* (exception handling) and *throw & catch* (control flow) in Ruby.
https://hasno.info/ruby-gotchas-and-caveats/

- https://relishapp.com/rspec/rspec-mocks/v/3-2/docs/configuring-responses/raising-an-error

Verifying Doubles

HPI

- Stricter alternative to normal doubles
- Check that methods being stubbed are actually present on the underlying object (if it is available)
- Verify that provided arguments are supported by actual method signature

```
class Post
  attr_accessor :title, :author, :body
end

post = instance_double("Post") # reference to the class Post
allow(post).to receive(:title)
allow(post).to receive(:message).with (‘a msg’) # this fails (not defined)
```

Tip:
`class_double()` & `object_double()` (create from existing "template" object) also exist.

- https://relishapp.com/rspec/rspec-mocks/v/3-2/docs/verifying-doubles

Why Use Mocks?

- Using mocks makes (some) tests more concise

```
digger = Digger.new # a tracked vehicle
initial_left = digger.left_track.position
initial_right = digger.right_track.position
digger.turn_right # run method being tested

expect(digger.left_track.position - initial_left).to eq(+5)
expect(digger.right_track.position - initial_right).to eq(-5)
```

vs.

```
left_track = double('left_track')
right_track = double('right_track')
digger = Digger.new(left_track, right_track)
left_track.expects(:move).with(+5)
right_track.expects(:move).with(-5)

digger.turn_right # run method being tested
```

Test Doubles Pro and Contra

HPI

Disadvantages

- Mock objects have to accurately model the behaviour of the object they are mocking
- Risk to test a value set by a test double (false positives)
- Possibility to run out of sync with real implementation

  -> Brittle while refactoring

Advantages

- The test is focused on behavior
- Speed (e.g. not having to use an expensive database query)
- Isolation of tests (e.g. failure in model does not affect controller test)

Info:

It's considered a best practice to try to minimize the amount of mocked objects.

Agenda

1. Why Behavior-driven Design (BDD)?
2. Building Blocks of Tests and BDD
   - Model Tests
   - View Tests
   - Controller Tests
   - Setup and Teardown
   - Test Data
   - Test Doubles
   - **Integration & Acceptance Tests**
   - Demo & Optimizations
3. Testing Tests & Hints for Successful Test Design
4. Outlook

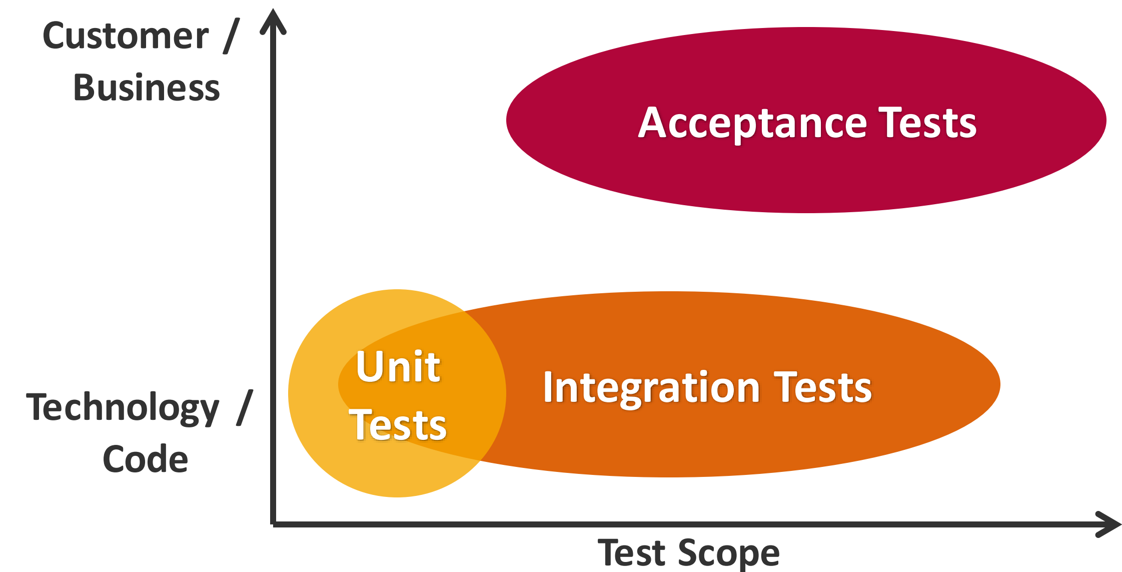
Levels of Testing

Level	Question	Automation
Staging Tests	Can the program be deployed?	Partially automatable
Quality Tests	Does the program meet quality standards?	Partially automatable
Requirement Tests (User Acceptance Tests)	Do the requirements meet the users‘ needs?	Not automatable!
Functional Tests (User Story Acceptance Tests)	Does the program functionality meet the requirements?	automatable
Integration Tests	Does the program function?	automatable
Unit Tests	Does the code unit function?	automatable

Integration & Acceptance Tests

- Perform tests on the full system, across multiple components
- Test end-to-end functionality

- **Integration Tests**
  - Build on unit tests, **written for developers**
  - Test component interactions
  - Consider environment changes
    (e.g. database instead of volatile memory)
- **Acceptance Tests**
  - Check if functionality satisfies the specification from a **user perspective**
  - Accessible for the stakeholders
    (e.g. using webpage via a browser)



- http://www.testfeed.co.uk/integration-vs-acceptance-tests/

BDD vs Test Levels

Use Cases | Features

User Stories | Scenarios

Scenario Steps

Test Cases

Requirement Tests

Functional Tests

Integration Tests

Unit Tests

BDD Implementations

Behavior-driven development (BDD)

- Story-based definition of application behavior
- Definition of features
- Driven by business value

Implementations on different abstraction levels:

- Domain-specific languages (e.g. Cucumber)
  - Pro: Readable by non-technicians
  - Cons: Extra layer of abstraction, translation to Ruby
- Executable Code (e.g. using testing frameworks, RSpec, Mini::Test)
  - Pro: No translation overhead
  - Con: Barely readable by domain experts

Capybara Test Framework

- Simulate how a real user would interact with a web application
- Well suited for writing acceptance & integration tests for web applications
- Provides DSL for “surfing the web”
  - e.g. `visit`, `fill_in`, `click_button`
- Integrates with RSpec
- Supports different “drivers”, some support Javascript evaluation
  - Webkit browser engine (used in Safari)
  - Selenium
    - Opens an actual browser window and performs actions within it

- https://github.com/jnicklas/capybara#using-capybara-with-rspec

Integration & Acceptance Tests (with Capybara)

```ruby
require 'capybara/rspec'

describe "the signin process", :type => :feature do
  before :each do
    User.make(:email => 'user@example.com', :password => 'password')
  end

  it "signs me in" do
    visit '/sessions/new'
    within("#session") do
      fill_in 'Email', :with => 'user@example.com'
      fill_in 'Password', :with => 'password'
    end
    click_button 'Sign in'
    expect(page).to have_css('div#success')
  end
end
```

Tip:
Capybara includes aliases for RSpec syntax:
`feature` instead of `describe …, :type => :feature,`
`scenario` instead of `it,`
`background` instead of `before,`
`given/given!` instead of `let/let!`

- https://github.com/jnicklas/capybara

Agenda

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   - Model Tests
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   - Controller Tests
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   - **Demo & Optimizations**
3. Testing Tests & Hints for Successful Test Design
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Demo of TDD and Tests

https://github.com/hpi-swt2/Ruby-on-Rails-TDD-example

GitHub - hpi-swt2/Ruby- ×

GitHub, Inc. [US] | https://github.com/hpi-swt2/Ruby-on-Rails-TDD-example

Vagrantfile | initial version | 2 years ago

README.md

Ruby-on-Rails-TDD-example

Example Ruby on Rails application developed using Test-Driven Development (TDD).

The application is a very simple contact management solution, showing a list of contacts with their names and ages.

Tests are written in RSpec and include:

- Model tests (documentation)
- Controller tests (documentation)
- View tests (documentation)
- Feature tests (documentation)

Details

1. Writing feature tests

- Writing model tests
- Making model tests pass
- Writing controller tests
- Making controller tests pass
- Writing view tests
- Making view tests pass (this also completes the feature)
- Everything from start to finish

Optimizing the Testing Process

- Automate test execution
  - e.g. Guard (https://github.com/guard/guard-rspec)
  - Automatically launch tests when files are modified
  - Run only the tests related to the change
- Parallelize tests
  - E.g. parallel_tests (https://github.com/grosser/parallel_tests)
  - Especially relevant with many time-consuming acceptance tests

Agenda

- Why Behavior-driven Design (BDD)?
- Building Blocks of Tests and BDD
- **Testing Tests & Hints for Successful Test Design**
  - Test Coverage
  - Fault Seeding
  - Mutation Testing
  - Metamorphic Testing
- Outlook

Test Coverage

Most commonly used metric for evaluating test suite quality

- Test coverage = executed code during test suite run / all code * 100
- e.g. 85 loc / 100 loc = 85% test coverage

Line coverage

- Absence of line coverage indicates a potential problem
- Existence of line coverage can mean very little
- In combination with good testing practices, coverage might say something about test suite reach
- Circa 100% test coverage is a by-product of BDD

How to Measure Coverage?

Most common approaches

- Line coverage
- Branch coverage

Tool

- SimpleCov (https://github.com/colszowka/simplecov)
- Uses line coverage

```
if (i > 0); i += 1 else i -= 1 end
```

-> 100% line coverage even if one branch is not executed

SimpleCov

```ruby
16.  def new
17.    @job_offer = JobOffer.new
18.  end
19.
20.  # GET /job_offers/1/edit
21.  def edit
22.  end
23.
24.  # POST /job_offers
25.  # POST /job_offers.json
26.  def create
27.    @job_offer = JobOffer.new(job_offer_params)
28.
29.    respond_to do |format|
30.      if @job_offer.save
31.        format.html { redirect_to @job_offer, notice: 'Job offer was successfully created.' }
32.        format.json { render action: 'show', status: :created, location: @job_offer }
33.      else
34.        render_errors_and_redirect_to(@job_offer, 'new', format)
35.      end
36.    end
37.  end
38.
39.  # PATCH/PUT /job_offers/1
40.  # PATCH/PUT /job_offers/1.json
41.  def update
42.    respond_to do |format|
43.      if @job_offer.update(job_offer_params)
44.        format.html { redirect_to @job_offer, notice: 'Job offer was successfully updated.' }
45.        format.json { head :no_content }
```

- Methods related to failed tests are marked

```ruby
39. unless Devise.rack_session?
40.   # We cannot use Rails Indifferent Hash because it messes up the flash object.
41.   class Devise::IndifferentHash < Hash
42.     alias_method :regular_writer, :[]= unless method_defined?(:regular_writer)
43.     alias_method :regular_update, :update unless method_defined?(:regular_update)
44.
45.     def [](key)
46.       super(convert_key(key))
47.     end
```

https://github.com/colszowka/simplecov

Test Tips

Independence

- Of external test data
- Of other tests (or test order)

Repeatability

- Same results each test run
- Potential Problems
  - Dates, e.g. Timecop (https://github.com/travisjeffery/timecop)
  - Random numbers

Test Tips

Clarity

- Test purpose should be immediately understandable
- Tests should be simple, readable
- Make it clear how the test fits into the larger test suite
- Worst case:

```
it "sums to 37" do
  expect(37).to eq(User.all_total_points)
end
```

- Better:

```
it "rounds total points to nearest integer" do
  User.add_points(32.1)
  User.add_points(5.3)
  expect(37).to eq(User.all_total_points)
end
```

Test Tips

Conciseness

- Use the minimum amount of code and objects
- Clear beats concise
- Writing the minimum required amount of tests for a feature

-> Test suite will be faster

```
def assert_user_level(points, level)
  user = User.make(:points => points)
  expect(level).to eq(user.level)
end

it test_user_point_level
  assert_user_level(   0, "novice")
  assert_user_level(   1, "novice")
  assert_user_level( 500, "novice")
  assert_user_level( 501, "apprentice")
  assert_user_level(1001, "journeyman" )
  assert_user_level(2001, "guru")
  assert_user_level( nil, "novice")
end
```

- Rails Test Prescriptions. Noel Rappin. 2010. p. 277. http://zepho.com/rails/books/rails-test-prescriptions.pdf

Conciseness: How many Assertions per Test?

If a single call to a model results in many model changes:

- High number of assertions **->** High clarity and cohesion
- High number of assertions **->** Low test independence

-> Use context & describe and have 1 assertion per test

Test Tips

Robustness

- Underlying code is correct **->** test passes
- Underlying code is wrong **->** test fails
- *Example:* view testing

```
describe "the signin process", :type => :feature do
  it "signs me in (text version)" do
    visit '/dashboard'
    expect(page).to have_content “My Projects”
  end
  # version below is more robust against text changes
  it "signs me in (css selector version)" do
    visit '/dashboard'
    expect(page).to have_css "h2#projects"
  end
end
```

Test Tips

HPI

Robustness

- Reusable code increases robustness
- E.g. constants instead of magic numbers

```
def assert_user_level(points, level)
  user = User.make(:points => points)
  expect(level).to eq(user.level)
end

def test_user_point_level
  assert_user_level(User::NOVICE_BOUND + 1, "novice")
  assert_user_level(User::APPRENTICE_BOUND + 1, "apprentice")
  # ...
end
```

- But be aware of tests that always pass regardless of underlying logic

- Rails Test Prescriptions. Noel Rappin. 2010. p. 278. http://zepho.com/rails/books/rails-test-prescriptions.pdf

Troubleshooting

Reproduce the error

- **Write a test!**

What has changed?

- Isolate commit/change that causes failure

Isolate the failure

- `thing.inspect`
- Add assertions/prints to your test
- `Rails.logger.error`
- `save_and_open_page` (take a snapshot of a page)

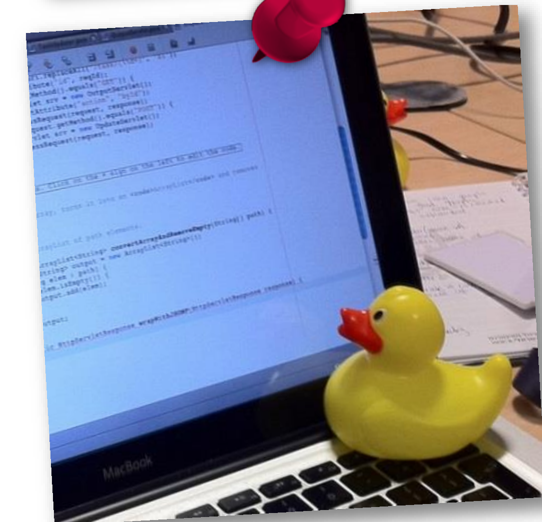
Explain to someone else

- Rubber duck debugging

Tip:

`git-bisect` is a powerful git tool that can help isolate the change that caused a bug by binary search through the commit history.

http://git-scm.com/docs/git-bisect



http://commons.wikimedia.org/wiki/File:Rubber_duck_assisting_with_debugging.jpg

Manual Fault Seeding

Conscious introduction of faults into the program

- Run tests
- Minimum 1 test should fail

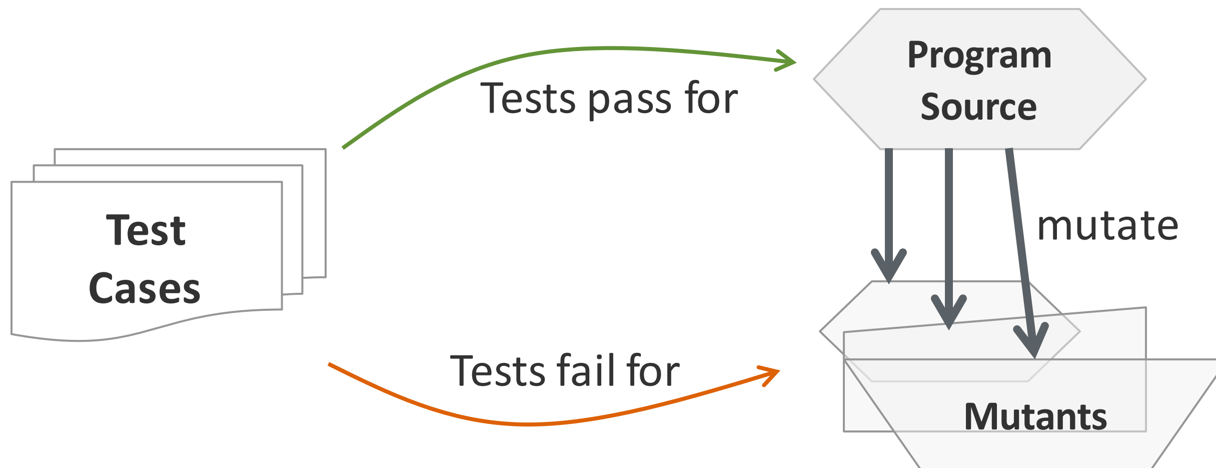
If no test fails, then a test is missing

- Possible even with 100% line coverage
- Asserts functionality coverage

Mutation Testing

Mutant: Modified version of the program with small change

- Tests correctly cover code -> Test should notice change and fail



next_month:

```
if month > 12 then
  year += month / 12
  month = month % 12
end
```

```
if not month > 13 then
  year -= month / 12
  month = month % 12
end
```

(The line `month = month % 12` is struck through in the mutant.)

- **Mutation Coverage**: How many mutants did not cause a test to fail? Asserts functionality & behavior coverage
  - For Ruby: *Mutant* (https://github.com/mbj/mutant)

Metamorphic Testing

When testing, often hard to find test oracle

- Establish whether a test has passed or failed
- Require understanding of input-output-relation
- May be more convenient to **reason about relations between outputs**

Compare outputs of program runs

- Describe inherent behavior of the program
- No need to know exact outputs

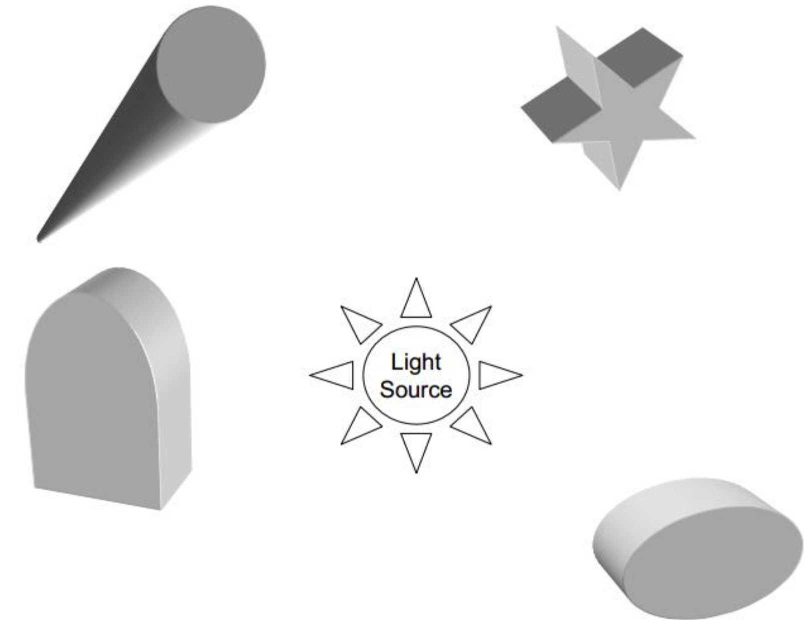
Example: Rendering Lighting

Not easy to verify all pixels were rendered correctly

Use relations of outputs for test cases

Position of light source changes

- Points closer to light source will be brighter
  - Exception: White pixels
- Points further away from light source will be darker
  - Exception: Black pixels
- Points hidden behind other objects don't change brightness



Summary

BDD

- Motivation
- BDD Cycle

TDD

- Pros & Cons

Automated Testing

- Model/View/Controller
- Test Data
- Test Doubles

Testing Hierarchy

- Integration Tests
- Acceptance Tests

Test Quality

- Coverage
- Mutation Tests

Further Reading

http://betterspecs.org – Collaborative RSpec best practices documentation effort

Everyday Rails Testing with RSpec by Aaron Sumner, leanpub

The RSpec Book: Behaviour-Driven Development with RSpec, Cucumber, and Friends by David Chelimsky et al.

Rails 4 Test Prescriptions: Build a Healthy Codebase by Noel Rappin, Pragmatic Programmers 2014

Quizzes

http://www.codequizzes.com/rails/rails-test-driven-development/controller-specs

http://www.codequizzes.com/rails/rails-test-driven-development/model-specs

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Enterprise Platform and Integration Concepts