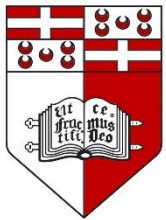


Verifying Web Applications: From Business Level Specifications to Automated Model-Based Testing

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University of Malta

Process Engineering
Software Testing
Research Lab





Business practice



Theory

Agile Development

- Customers operate in a dynamic market
- Constantly changing specs

The logo for BetClic, featuring the word "Bet" in a bold, italicized red font and "Clic" in a bold, italicized grey font.

Agile Development

- Customers operate in a dynamic market
- Constantly changing specs



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Agile Development

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Connecting Specs to Code



Connecting Specs to Code

Given I am on the home page

When I log in as a doctor

Then I should see my patient list



Connecting Specs to Code

Given I am on the home page

When I log in as a doctor

Then I should see my patient list



Written by the customer

Connecting Specs to Code

Given I am on the home page
When I log in as a doctor
Then I should see my patient list

 *Cucumber*

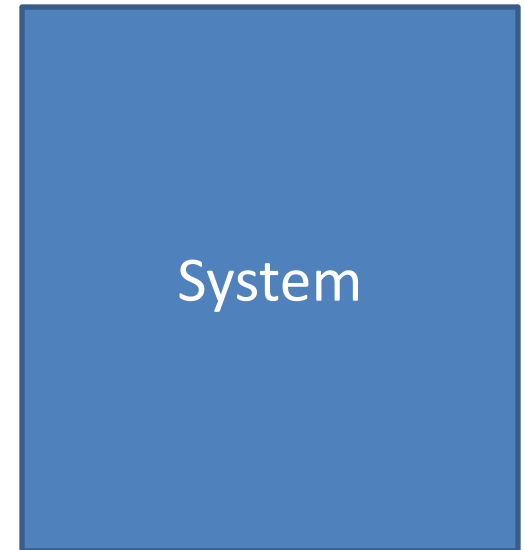
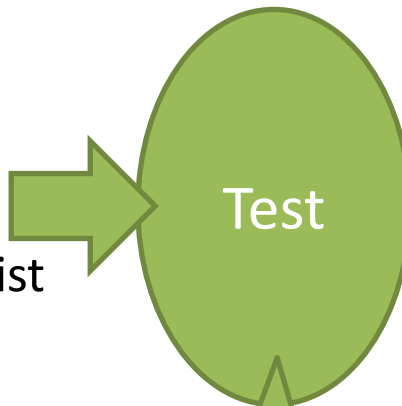
Developer writes code
for each step

System

Connecting Specs to Code

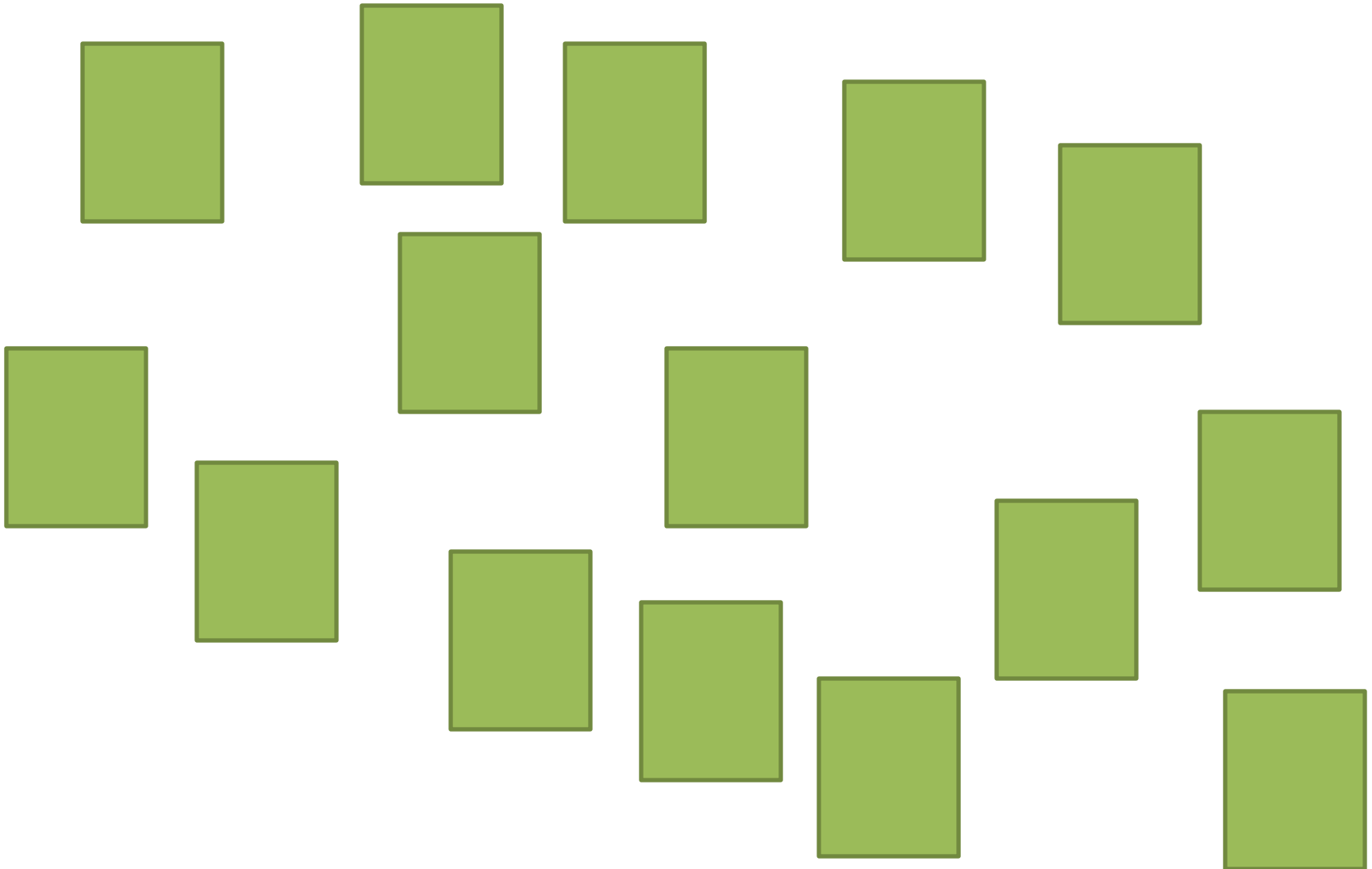
Given I am on the home page
When I log in as a doctor
Then I should see my patient list


Cucumber



Steps form an
executable test

Loads of Disparate Business Specs



Opportunities in Business Specs

- Scenarios are executed separately
- Scenarios are highly repetitive for similar cases

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- Scenarios are highly repetitive for similar cases



Work in progress



This work

Health System

https://www.myhealth.gov.mt



myHealth Login 

e-ID
Number

Password

Login

Register for your e-ID
Forgot your password?

myHealth: the Government of Malta's portal for online access to health records

Patients and the doctors they choose can access health data through this site. The system is being implemented in phases. So far, the following data is accessible:

- 1) Mater Dei Hospital (MDH) Case Summaries (inpatient discharge letters from 2008 onwards),*
- 2) Current Pharmacy of your Choice medicines entitlement*
- 3) Lab results (Haematology, Biochemistry, Immunology, Toxicology) and medical image reports (from 2008 onwards). **For patients to access this data it has to be released to them by the doctor/s they are linked to in myHealth.***
- 4) Appointments at Government Hospitals and Health Centres (polyclinics).*

Cucumber Business Specifications

Scenario: Model definition for myHealth - Doctors Section

Given I am on the "start state"

When I "login as a doctor"

Then I should go to the "doctors landing page"

Given I am on the "doctors landing page"

When I "click on Appointments"

Then I should go to the "appointments page"

Given I am on the "doctors landing page"

When I "click on Case Summaries"

Then I should go to the "case summaries page"

Given I am on the "doctors landing page"

When I "click on Laboratory Results"

Then I should go to the "lab results page"

Given I am on the "doctors landing page"

When I "click on Medical Image Reports"

Then I should go to the "medical image reports page"

Cucumber Business Specifications

Scenario: Model definition for myHealth - Doctors Section

Given I am on the "start state"

When I "login as a doctor"

Then I should go to the "doctors landing page"

States

Given I am on the "doctors landing page"

When I "click on Appointments"

Then I should go to the "appointments page"

Given I am on the "doctors landing page"

When I "click on Case Summaries"

Then I should go to the "case summaries page"

Given I am on the "doctors landing page"

When I "click on Laboratory Results"

Then I should go to the "lab results page"

Cucumber Business Specifications

Scenario: Model definition for myHealth - Doctors Section

Given I am at the "start state"

When "login as doctor"

Then I should go to the "doctors landing page"

States

Given I am on the "doctors landing page"

When I "click on Appointments"

Then I should go to the "appointments page"

Actions

Given I am on the "doctors landing page"

When "click on Case Summaries"

Then I should go to the "case summaries page"

Given I am on the "doctors landing page"

When I "click on Laboratory Results"

Then I should go to the "lab results page"

Standard Business Specifications

Given I am on the "doctors landing page"
When I "click on Laboratory Results"
Then I should go to the "lab results page"

Given I am on the "lab results page"
When I "search patient data"
Then I should go to the "lab results search results page"
and the result should be "true" when "no data found"
and the result should be "true" when "ok"

Given I am on the "lab results search results"
When I "click on the myHealth logo"
Then I should go to the "doctors landing page"

Given I am on the "lab results search results"
and the result is "ok"
When I "click on view results"
Then I should go to the "view lab results page"

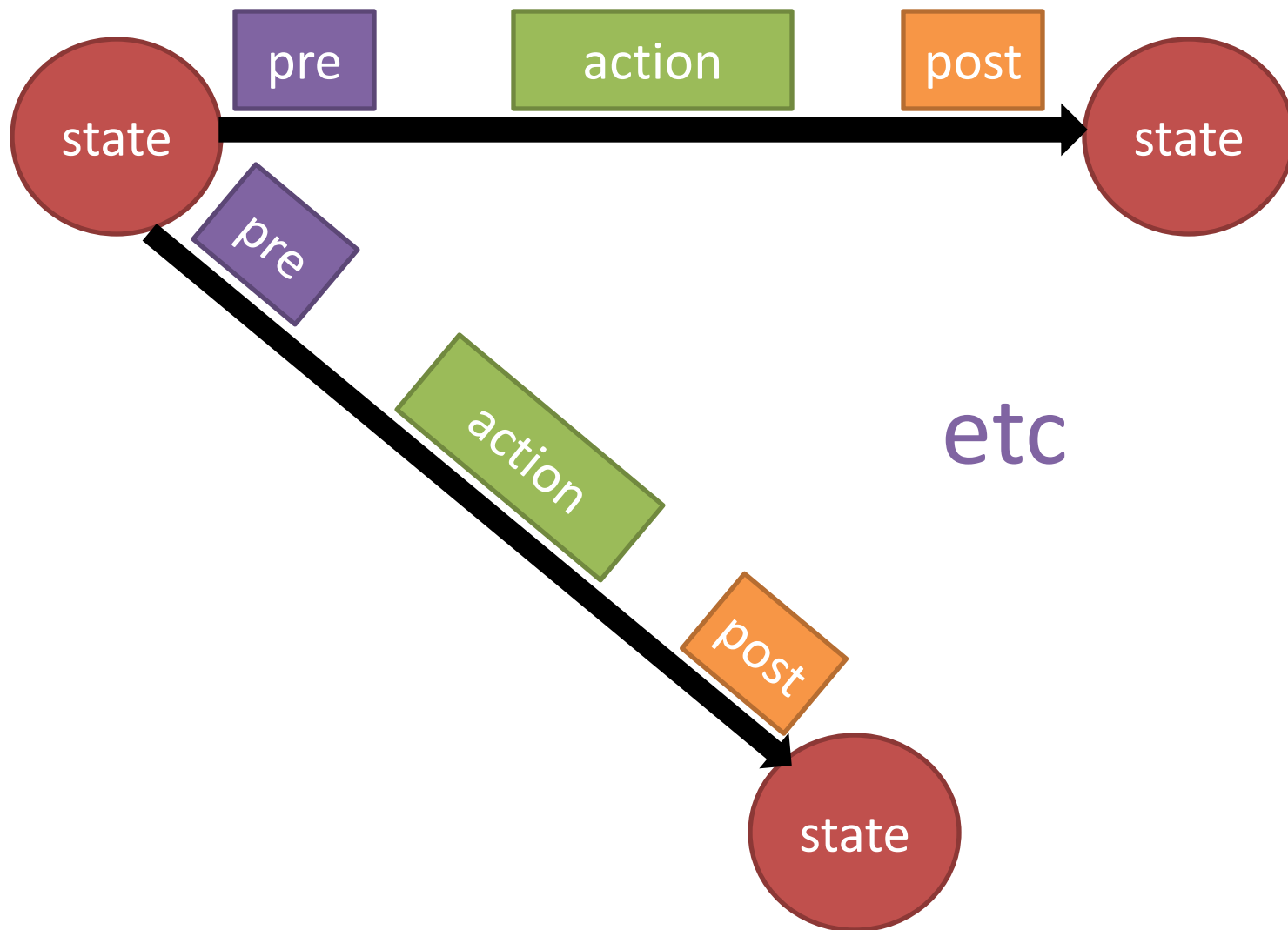
Post
Condition

Pre
Condition

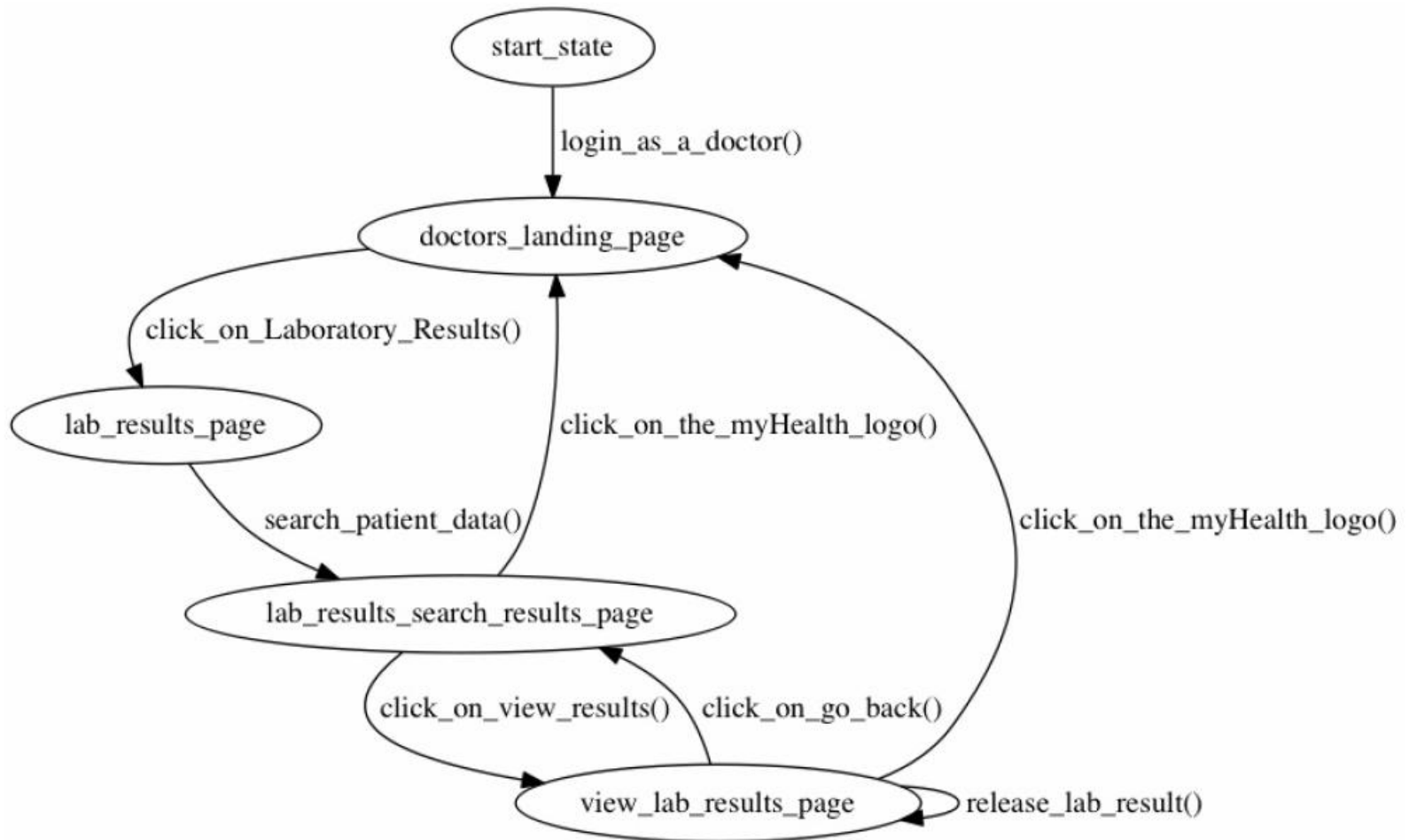
QuickCheck

- Model-based testing
- Haskell & Erlang implementations
- Finite state machines
- Random test generation
- Automated counterexample shrinking

QuickCheck



Automatically Generated QC Model



What were the Results?

Manual Testing

Doctor - Release Medical Image Reports		
Test Description	Values	Results
Partially Releasing a Report	Click on the Release button next to any Result Category header	<p>A <i>Released by self</i> label is displayed instead of the Release button.</p> <p>A Partially Released icon will be displayed next to the result in the following pages: Landing Page, Search Patient Data, and Search Medical Image Reports</p>
Releasing a full Report	Click on the Release All button next to the Episode Details header	<p>A <i>Released by self</i> label is displayed instead of the Release buttons next to each Result Category header</p>
Releasing an Updated Report	Click on the Release button next to any Result Category header having an "exclamation mark" icon in the right corner	<p>A <i>Released by self</i> label is displayed instead of the Release button.</p> <p>The owner of the result (i.e. a Citizen) will be shown an "exclamation mark" icon next to the result in the following pages: Landing Page, Search Patient Data, and Search Medical Image Reports</p>

Stats

- 43 function points
- 204 manual test cases

Business Specifications

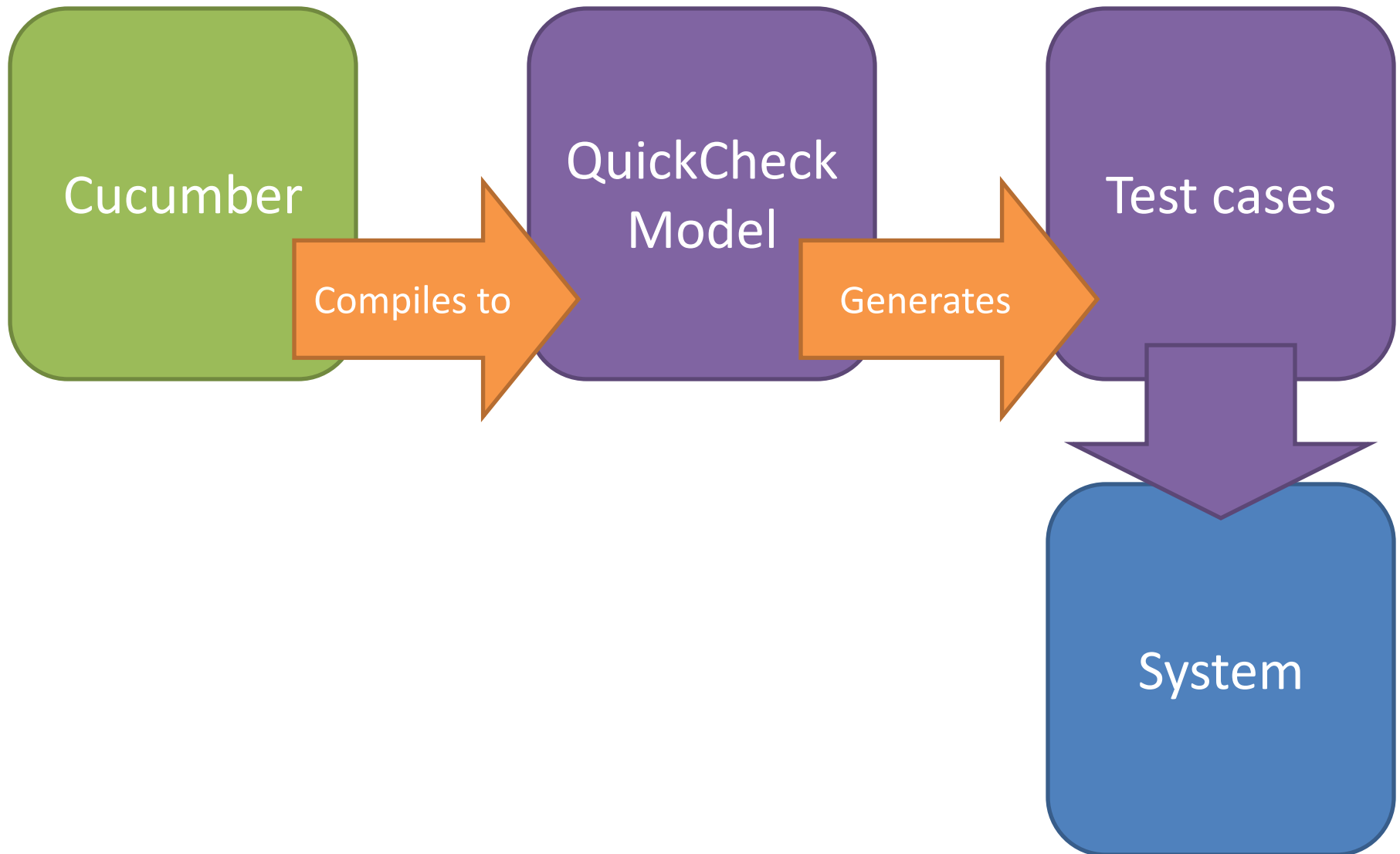
Given: ...
When: ...
Then: ...
And: ...

Given: ...
When: ...
Then: ...
And: ...

Given: ...
When: ...
Then: ...
And: ...

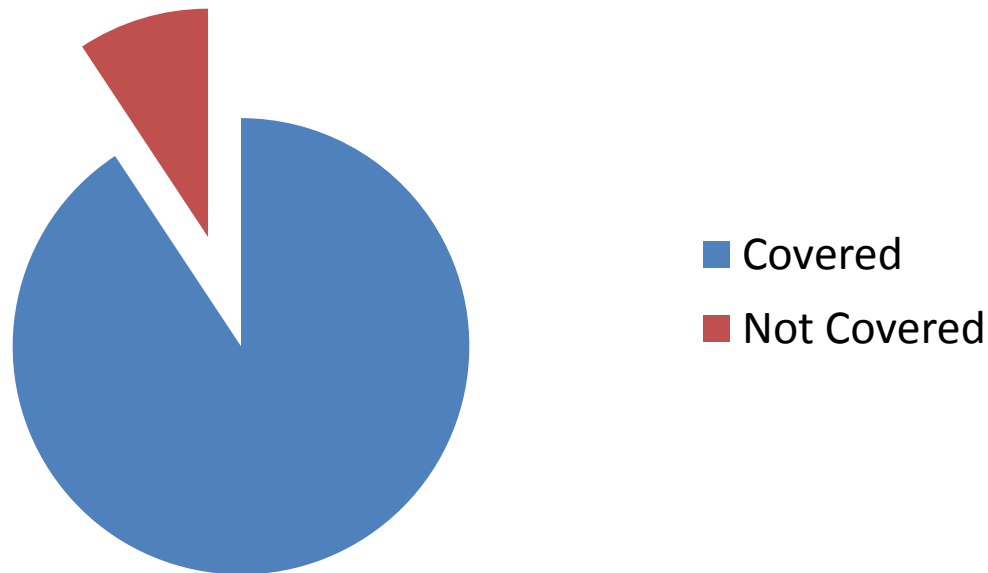


Whole Process



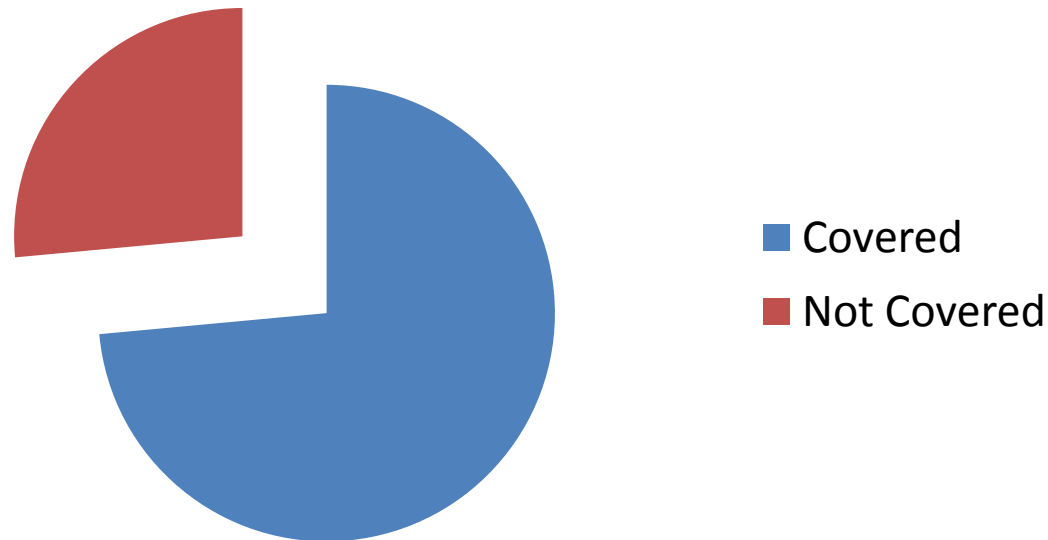
Results: Functionality Covered

- Out of 43 function points, 39 were covered
 - Eg: checking a PDF



Results: Test Cases

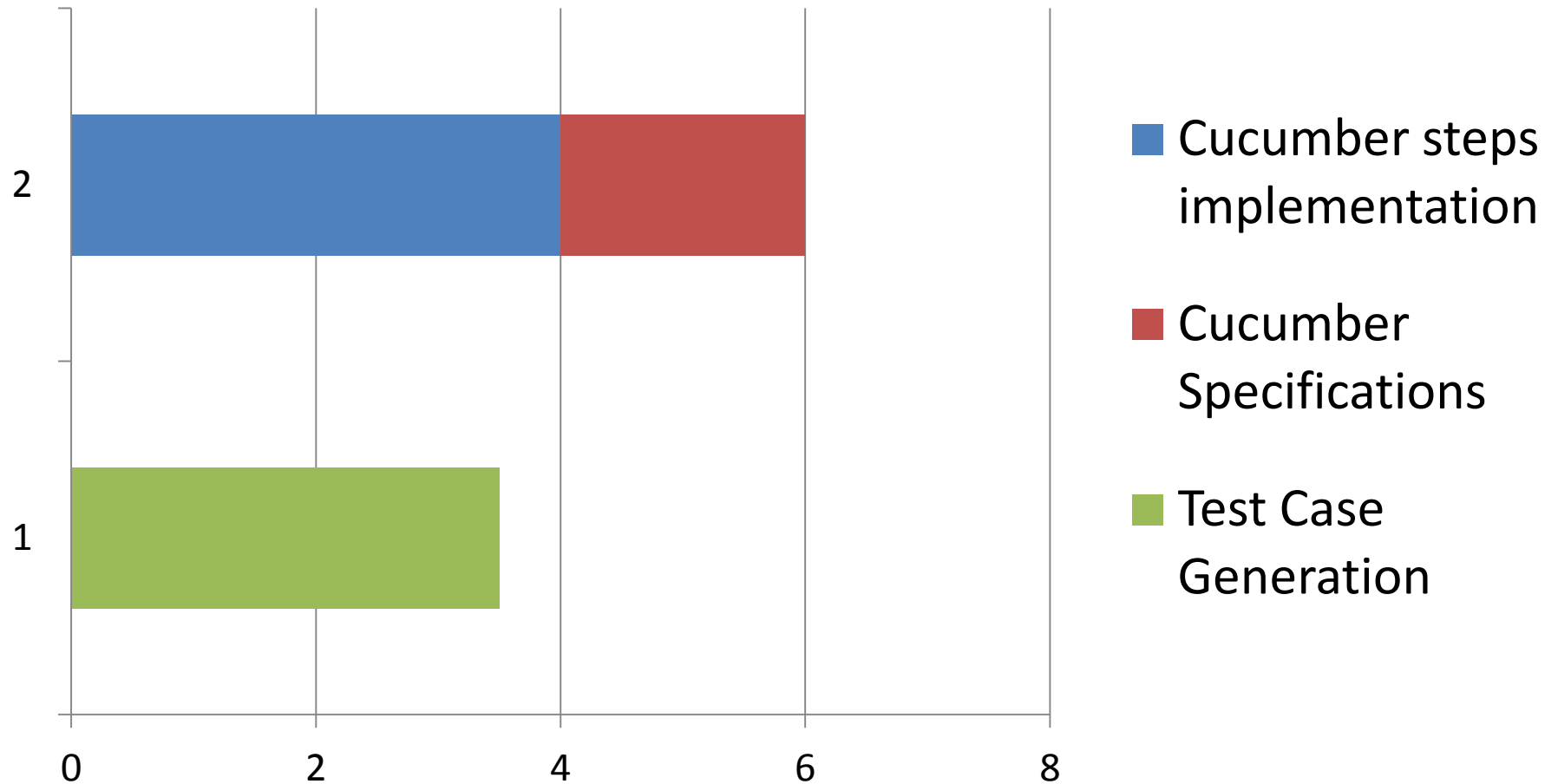
- 204 manual test cases
- 150 out of 204 created automatically
 - Remaining 54 could not be created due to non-covered functionality



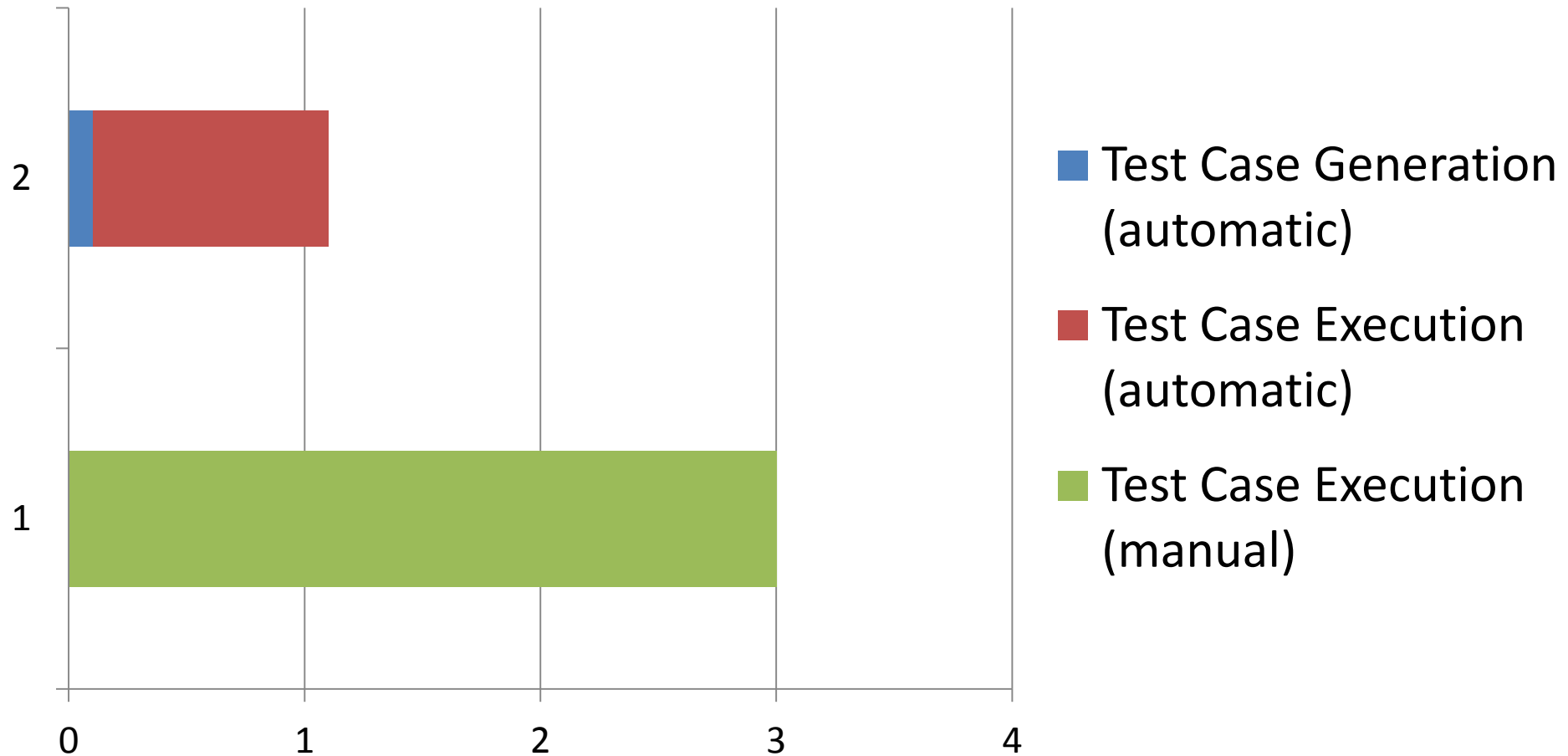
Time taken

- Setup time
- Recurrent time

Setup: Time Taken (days)



Recurrent: Time Taken (days)



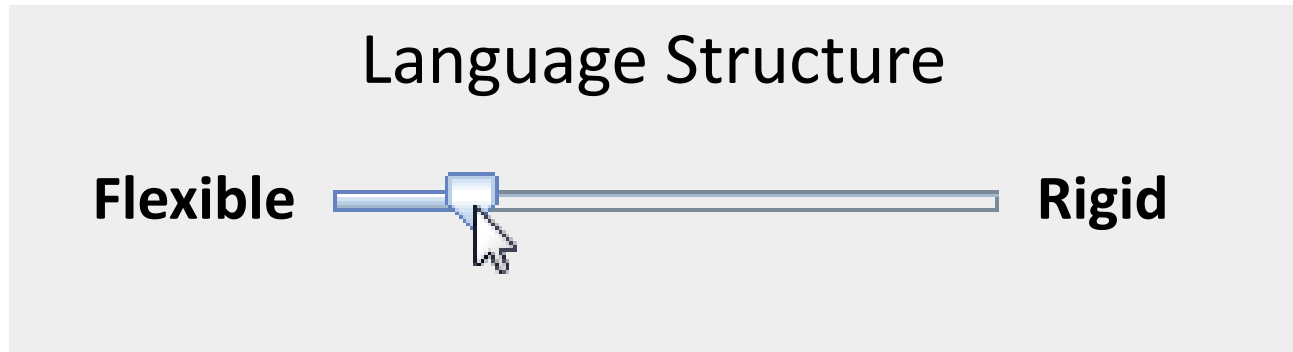
Limitation 1

- Conventions
 - Given I “start” on the home page
 - Given I am ... in a state
 - And some precondition
 - When I do some action
 - Then I should reach some state
 - And some postcondition

Case study experience

- We wrote the specs with the conventions in mind
- Next step: applying the approach where Cucumber specs already in place

Underlying Issue



Limitation 2

- Only applied to **web applications**
 - Concept of a page = FSM state
 - Interaction with page = transition

Other domains

- GUI-based desktop application
 - What is a **state**?
 - A tab
 - Or a single state for a system with no tabs
 - What is an **action**?
 - Input
 - Mouse clicks

Limitation 3

- Loops
 - Connecting test cases creates loops
 - Test case assertions might not be generic enough!
 - Eg:
 - When login
 - Then one user should appear online

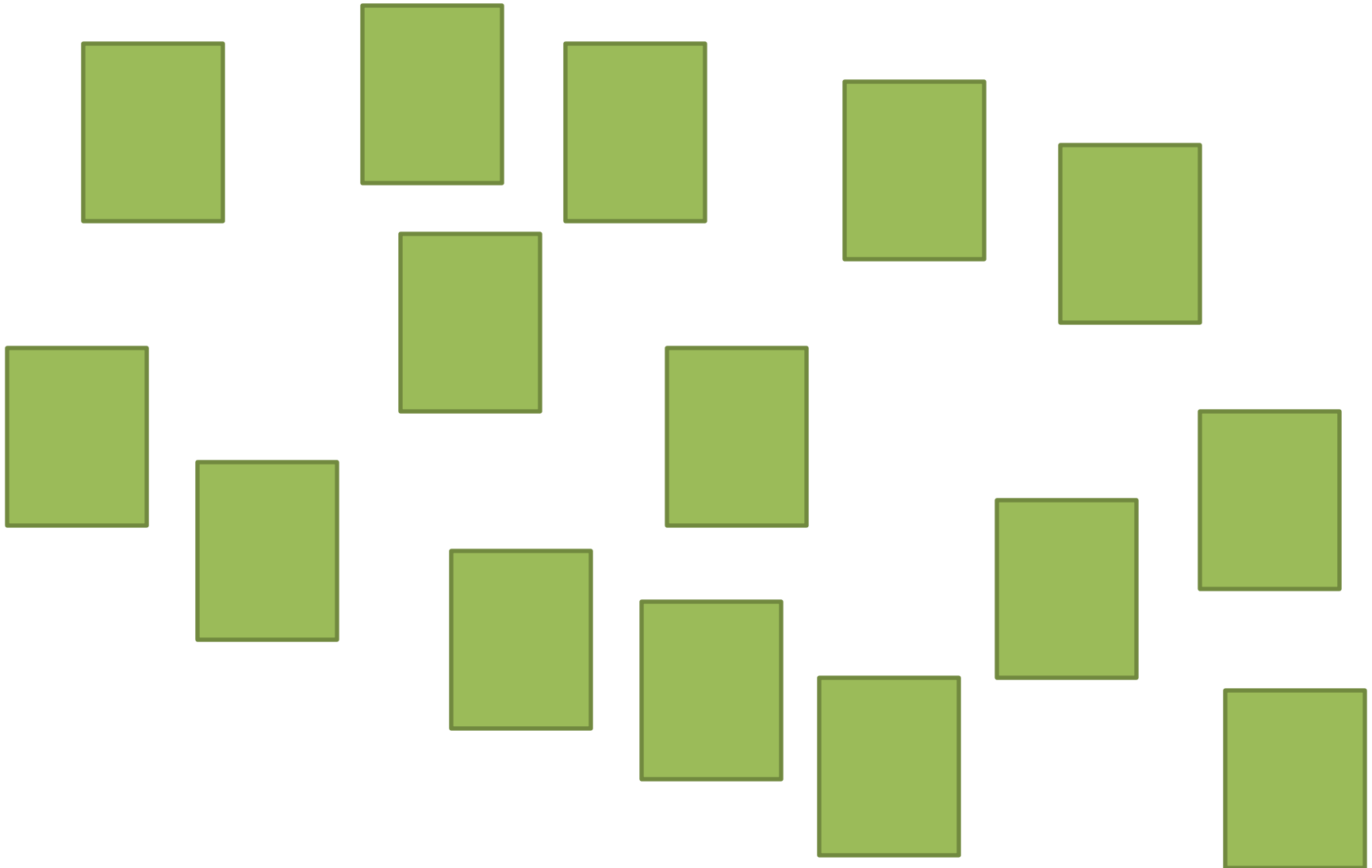
Loops

- Warning the developer
- Responsibility on the developers

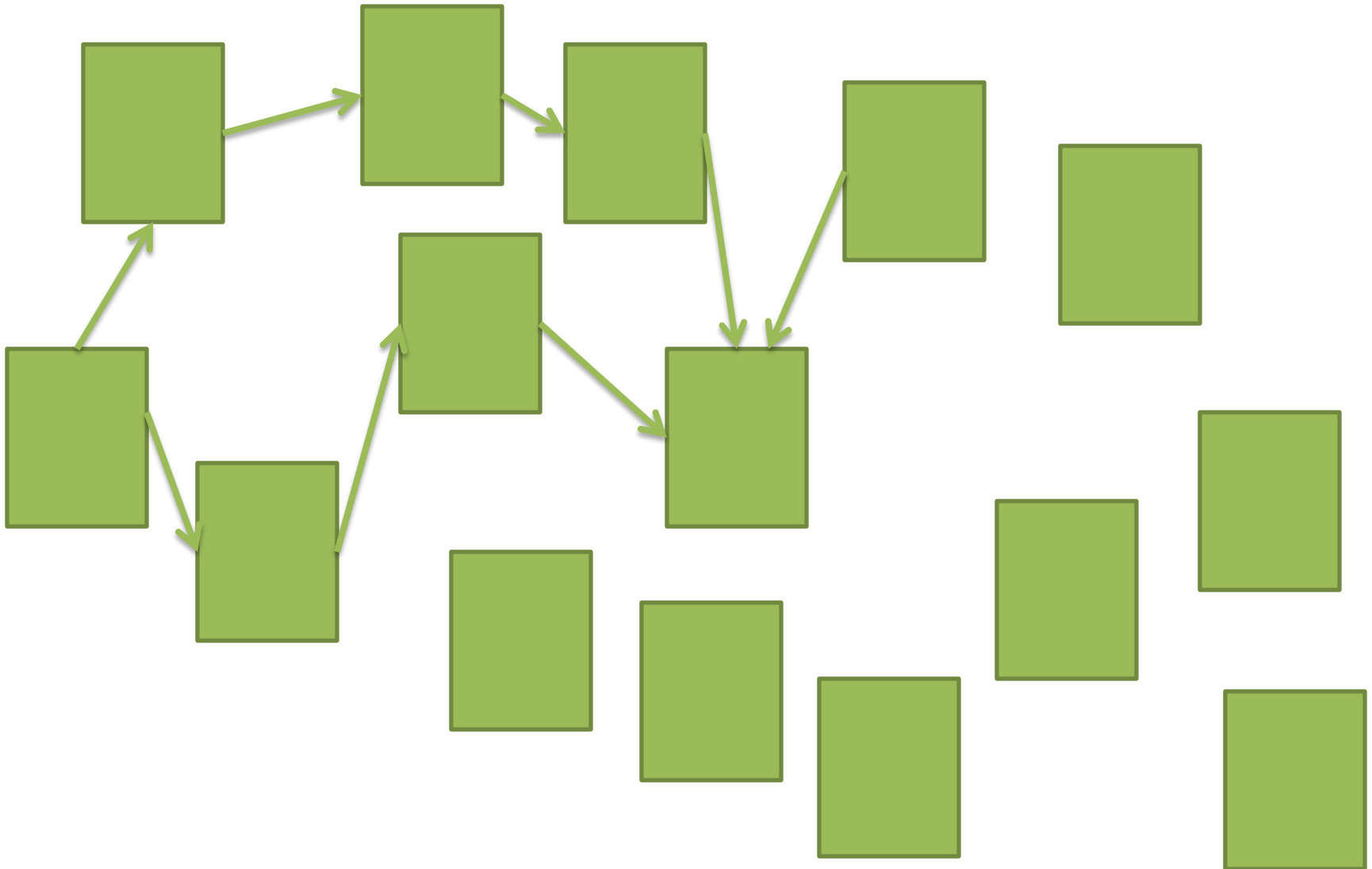




Loads of Disparate Business Specs



Loads of Disparate Business Specs



Repetition

Scenario: Register new user for account close test

Given a setup for site **www.site.fr**

When the device is **Mobile**

And the user fills in and submits the registration form

Then the registration should be completed successfully

Scenario: Register new user for account close test

Given a setup for site **www.site.en**

When the device is **Mobile**

And the user fills in and submits the registration form

Then the registration should be completed successfully

Scenario: Register new user for account close test

Given a setup for site **www.site.fr**

When the device is **PC**

And the user fills in and submits the registration form

Then the registration should be completed successfully

Sets

Definitions:

AllSites = {www.site.fr, www.site.en}

Devices = {Mobile, PC}

Scenario: Register new user for account close test

Given a setup for site **<Site> from AllSites**

When the device is **<Device> from Devices**

And the user fills in and submits the registration form

Then the registration should be completed successfully

Sets Operators

Definitions:

AllSites = {www.site.fr, www.site.en}

Devices = {Mobile, PC}

Scenario: Register new user for account close test

Given a setup for site **<Site> from AllSites**

When the device is **<Device> from Devices – {Mobile}**

And the user fills in and submits the registration form

Then the registration should be completed successfully

Sets Operators

Definitions:

AllSites = {www.site.fr, www.site.en}

Devices = {Mobile, PC}

Again, how much should we restrict the languages?

Scenario: Register new user for account close test

Given a setup for site **<Site> from AllSites**

When the device is **<Device> from Devices – {Mobile}**

And the user fills in and submits the registration form

Then the registration should be completed successfully

Default operations

...

When the user quits the application

Then the cache is cleared

Removing Duplication using Aspects

Matching: "And the user quits the application"

[

Then the cache is cleared

]

Duplication

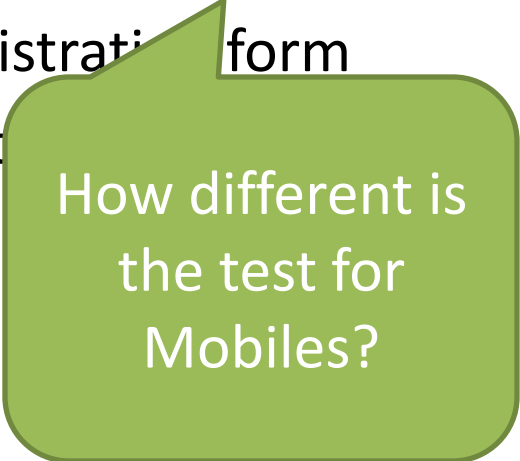
Scenario: Register new user for account close test

Given a setup for site **<Site> from AllSites**

When the device is **<Device> from Devices – {Mobile}**

And the user fills in and submits the registration form

Then the registration should be completed



How different is
the test for
Mobiles?

Aspects for Testing

Scenario: Register new user for account close test

Given a setup for site **<Site> from AllSites**

When the device is **<Device> from Devices** **{Mobile}**

And the user fills in and submits the registration form

Then the registration should be completed successfully

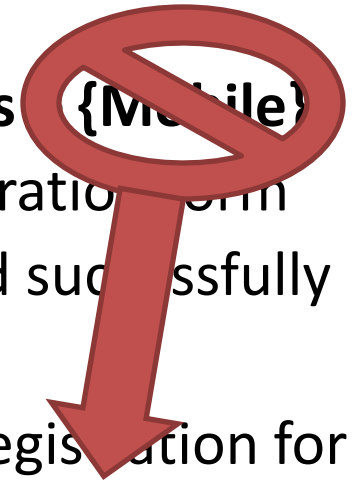
Matching: "And the user fills in and submits the registration form"

And the device is **<Device> from Devices-{Mobile}**

[

Then the front cache is cleared

]



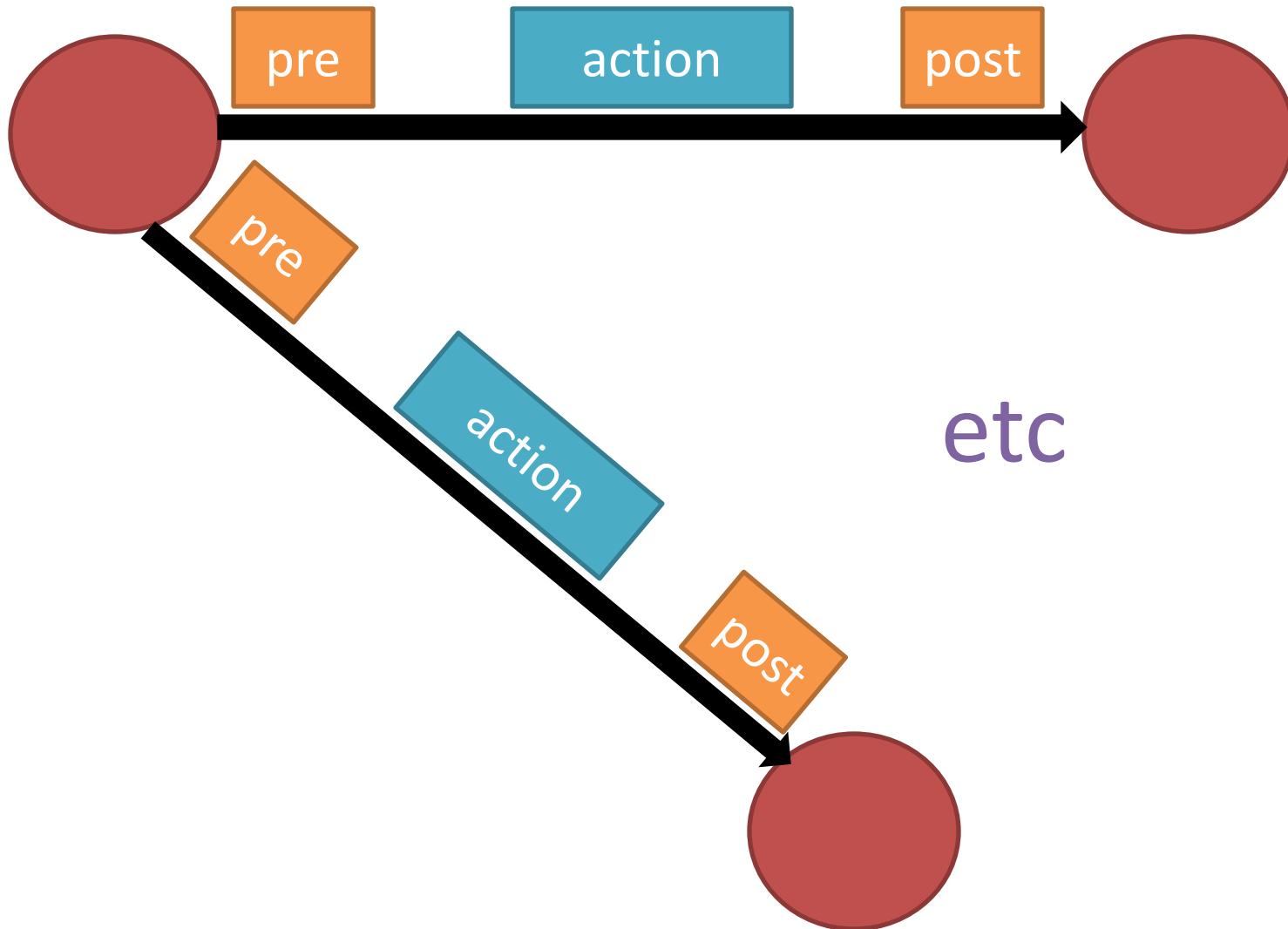
Future Work

- Testing will not cover all possibilities
- Use test checks during runtime

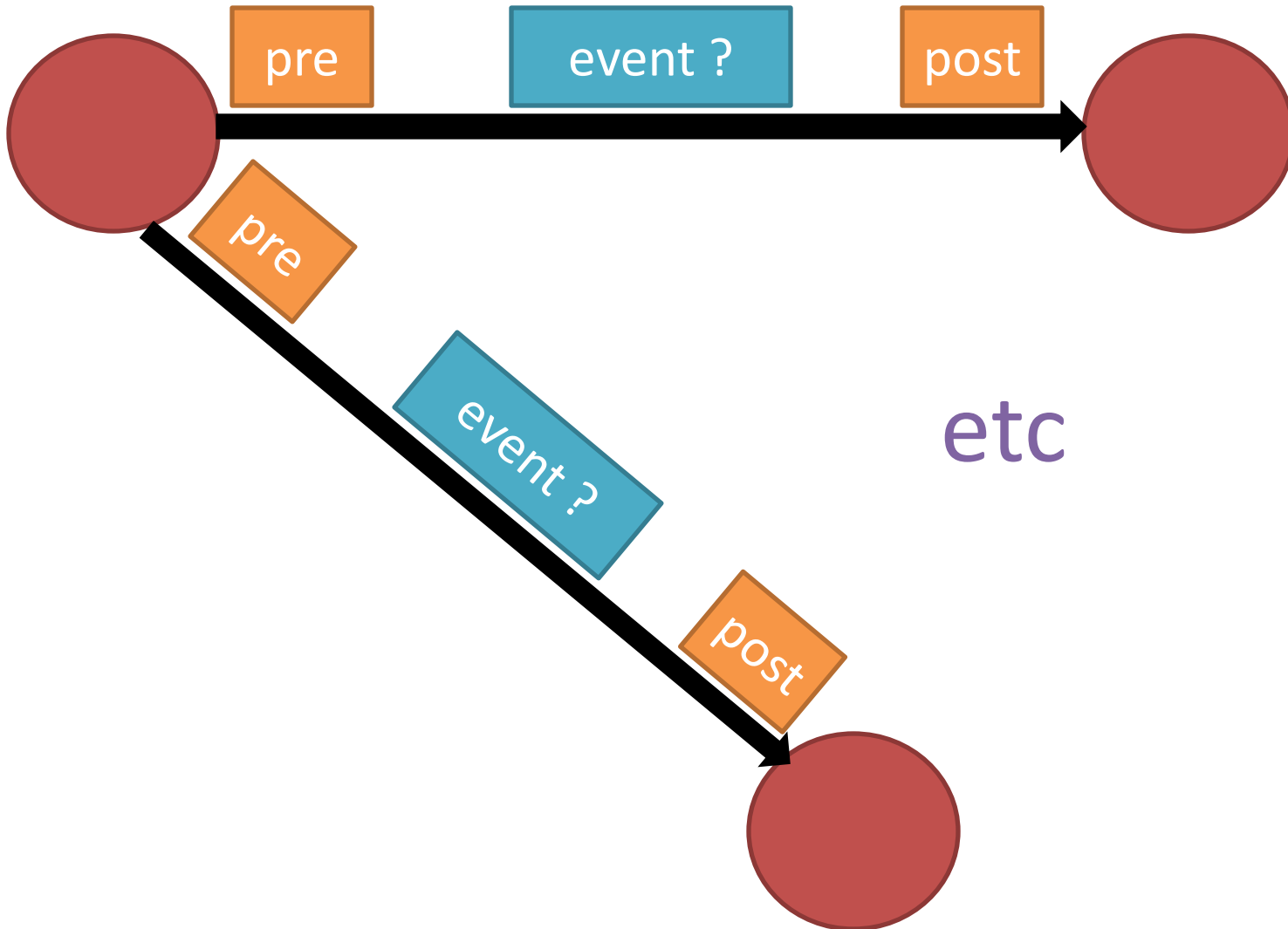
Future Work

- Testing will not cover all possibilities
- Use test checks during runtime
- QuickCheck specifications can easily be used for runtime verification

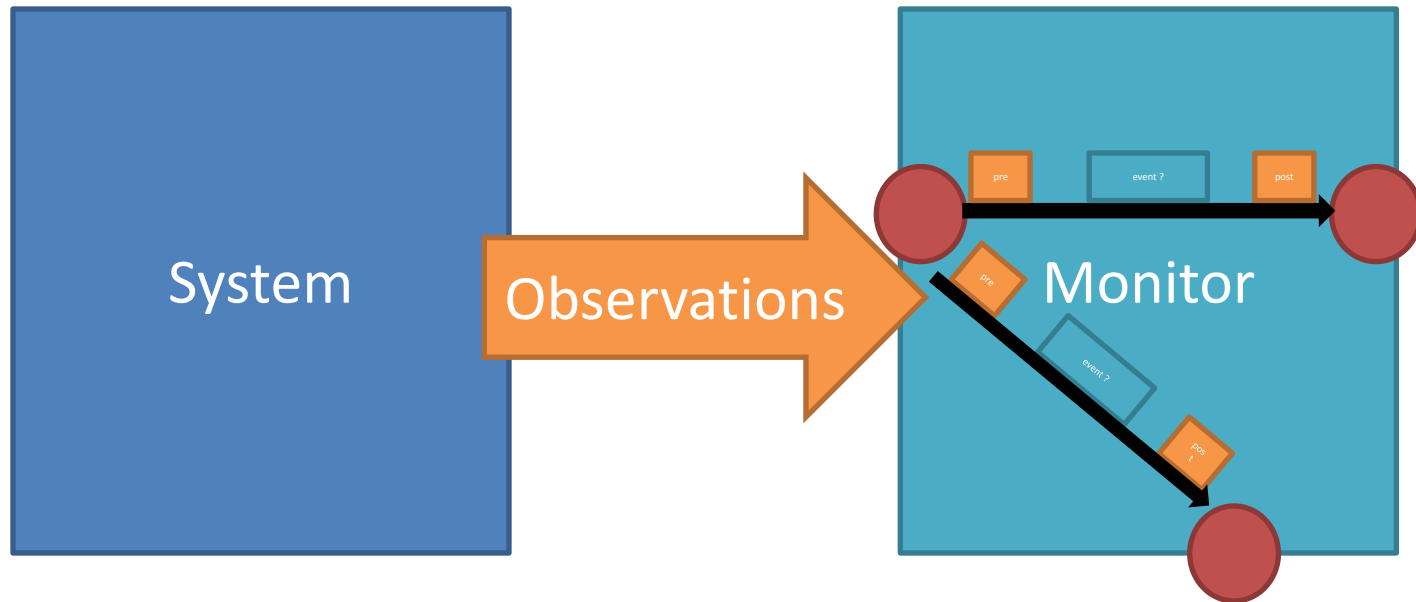
QuickCheck – Action Generation



Event Listeners



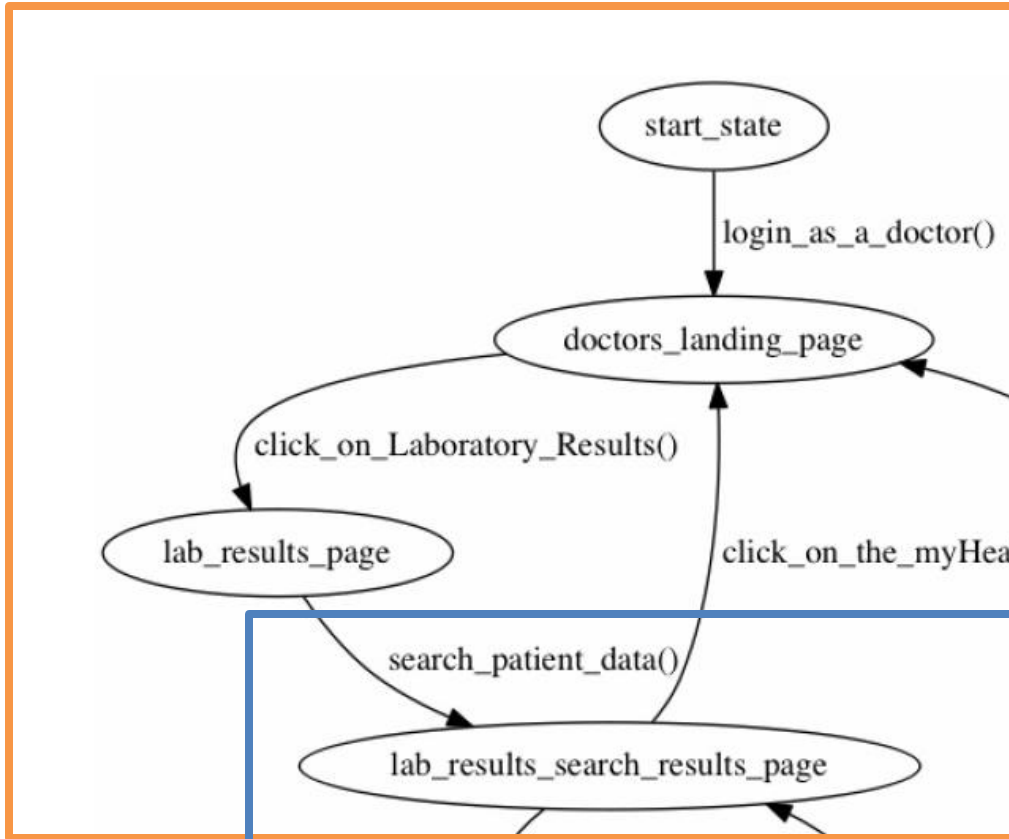
Monitor at Runtime



Alert! Overheads

- Checking at runtime uses up resources
- Area of runtime verification
 - Sampling
 - Log now and check later

Optimisation



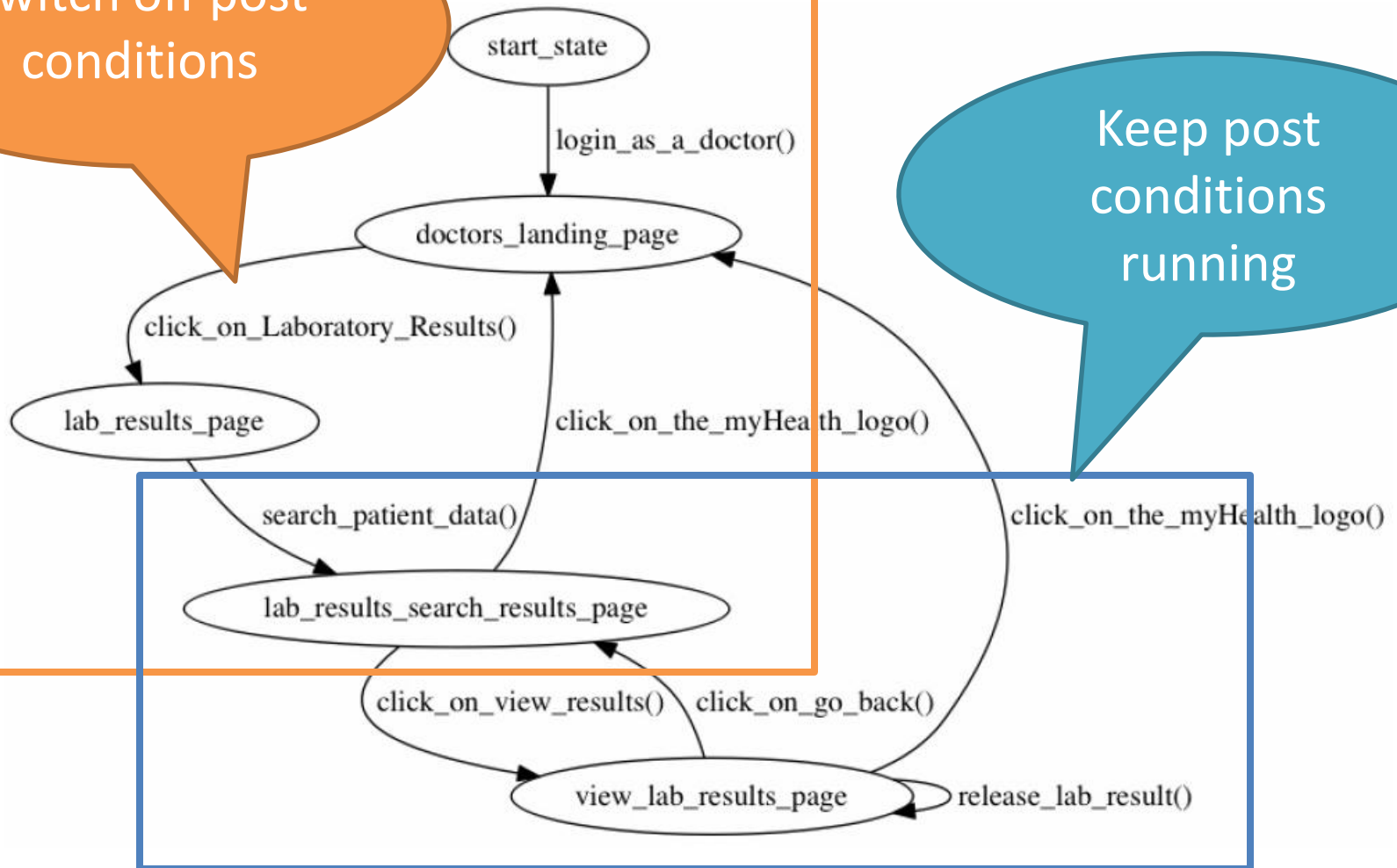
Well tested...
Do not runtime
verify

Keep verifying at
runtime

Optimisation

Switch off post conditions

Keep post conditions running



Challenges

- Similar to the problem with loops
 - Assertions may be too specific

Conclusions

- Leveraging business specs for MBT
 - Spec & Automation code already available

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- Leveraging business specs for MBT
 - Spec & Automation code already available
- A number of issues to consider
 - How much to restrict the language
 - Application to other domains
 - Loops

Conclusions

- Leveraging business specs for MBT
 - Spec & Automation code already available
- A number of issues to consider
 - How much to restrict the language
 - Application to other domains
 - Loops
- Lots of exciting stuff ahead
 - Aspects
 - Runtime monitoring

Thank you