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

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Business practice

Theory
Agile Development

- Customers operate in a dynamic market
- Constantly changing specs
Agile Development

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• Constantly changing specs
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• Customers operate in a dynamic market
• Constantly changing specs
Connecting Specs to Code
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Given I am on the home page
When I log in as a doctor
Then I should see my patient list

Cucumber
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
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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

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
Opportunities in Business Specs

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• Scenarios are highly repetitive for similar cases

Work in progress

This work
Health System

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"

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 in the "start state"
When "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 "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 page"
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 page"
When I "click on view results"
Then I should go to the "view lab results page"
QuickCheck

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

debugging

state

pre

action

post

state

pre

action

post

state

etc
Automatically Generated QC Model
What were the Results?
## Manual Testing

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

- 43 function points
- 204 manual test cases
Business Specifications

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

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

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

Cucumber
Whole Process

Cucumber

Compiles to

QuickCheck Model

Generates

Test cases

System
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)

- Cucumber steps implementation: 4 days
- Cucumber Specifications: 2 days
- Test Case Generation: 1 day
Recurrent: Time Taken (days)

- Test Case Generation (automatic)
- Test Case Execution (automatic)
- Test Case Execution (manual)
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

Language Structure

Flexible  Rigid
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:

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

Again, how much should we restrict the languages?
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 ]
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

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

pre
action
post

pre
action
post

etc
Event Listeners

pre

event ?

post

pre

event ?

post

etc
Monitor at Runtime

System

Observations

Monitor

pre

post

event?
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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• A number of issues to consider
  – How much to restrict the language
  – Application to other domains
  – Loops
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• A number of issues to consider
  – How much to restrict the language
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• Lots of exciting stuff ahead
  – Aspects
  – Runtime monitoring
Thank you