On the Composability of Behavior Driven Acceptance Tests

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After becoming an Assistant Professor at Izmir Institute of Technology, he worked as Chief Information Officer in the university from 2003-2007.

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Outline

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Behavior Driven Development (BDD)

- Information gap between stakeholders and developers to be reduced.
- The scenarios are written in spoken language.
- Acceptance criteria is more understandable by all team members, e.g. Product Owners, Testers, UX Designer, Programmers.
- Comes with a structure: Given - When - Then (Gherkin).

**Given** some initial context (the givens),

**When** an event occurs,

**Then** ensure some outcome.

https://dannorth.net/introducing-bdd/#translations
Behavior Driven Acceptance Tests (BDATs)

- ensure that product is usable.
- ensure that product behaves as expected.
- can be utilized in
  - User Interface Testing (Mobile, Web)
  - Application Programming Interface (API) Testing
Motivation

• By transforming Gherkin clauses written in text to event-based graph models, we can
• Find missing acceptance tests and
• Incorporate advantages of model-based testing.
Advantages of Model-based Testing

- It starts with specifications by reinforcing the idea that QA involvement belongs at the beginning of the discovery stage.
- It forces testability into the product design when talking about the creation of models for a new/modified feature.
- It typically finds design and specification bugs before the code even exists.
- The automatic test suite generation will increase testing thoroughness, test coverage is guaranteed, and there is zero test suite maintenance.

Model-based Testing Process

• Start by modeling the Software Under Test (SUT)
• Derive test cases from the model
• Execute test cases
  • use model as test oracle
  • record coverage
  • trace to model
• Modify model as needed
• Repeat steps

Event-based Modeling

• Event Sequence Graphs (Belli, 2001)

• Event-based formal model
  • inputs and actions are merged as events and assigned to the vertices of an event transition graph.

• They can be used for system modeling and test generation.

Advantages of Event-based Modeling

- Testability is dominated by two practical problems
  - How to provide the test values to the software
  - How to observe the results of test execution
- Controllability
  - How easy it is to provide a program with the needed inputs, in terms of values, operations, and behaviors
- Observability
  - How easy it is to observe the behavior of a program in terms of its outputs, effects on the environment and other hw and sw components

An event sequence graph $\text{ESG} = (V, E, \Xi, \Gamma)$ is a directed graph where

- $V \neq \emptyset$ is a finite set of vertices (nodes),
- $E \subseteq V \times V$ is a finite set of arcs (edges),
- $\Xi, \Gamma \subseteq V$ are finite sets of distinguished vertices
  with $\xi \in \Xi$, and $\gamma \in \Gamma$, called entry nodes and exit nodes.

Event Sequence Graphs (ESGs)

- An ESG with a as entry and b as exit and pseudo vertices [ , ]
- Each edge marked as a legal event pair (EP).

**EPs:**
- a, b
- a, c
- b, c
- c, b
Event Sequence Graphs (ESGs)

- Complete event sequence (CES) represents a walk through the ESG.

CES:
3: [, a, c, b, ],
4: [, a, b, c, b, ],
Event Sequence Graphs (ESGs)

- Faulty (or illegal) event pairs (FEP) are introduced as the edges of the corresponding ESG
  - Faulty CESs (FCESs) constructed using FEPs.

FCES:
- 2: [a, a,
- 3: [a, b, a,
- 3: [a, b, b,
- 3: [a, c, a,
- 3: [a, c, c,
- 1: [b,
- 1: [c,
Event Sequence Graphs (ESGs)

- Refinement of a vertex $v$ and its embedding in the refined ESG

CES:
6: [, x, a, b, c, b, z, ],
5: [, x, a, c, b, z, ],
ESG Test Generation

- **Input:** ESG
- **Output:** Test set with respect to model-based coverage criterion

Two objectives for the test case generation procedure:
- generation of CESs,
- generation FCESs from the complement of ESG.

Test case generation algorithm generates tests that cover both:
- All event pairs in ESG,
- All faulty event pairs of the CESG.
ESG Test Generation Algorithm

Input: an ESG with:
\( n := \) number of the functional units (modules) of the system that fulfill a well-defined task

\( \text{length} := \) required length of the event sequences to be covered

\begin{verbatim}
FOR unit 1 TO n DO
    BEGIN
        Generate appropriate ESG and ESG
        FOR k := 2 TO length DO
            BEGIN
                Cover all ESs of length k by means of CESs subject to
                minimizing the number and total length of the CESs
                END
            Cover all FEPs of unit by means of FCESs subject to
            minimizing the total length of the FCESs
            END
    END

Apply the test set given by the selected CESs and FCESs to the SUT.
Observe the system output to determine whether the system response is in compliance with the expectation.
\end{verbatim}

\( k = 2 \) means edge (EP) coverage

\( k = 3 \) means Edge pair (ET) coverage

\ldots
ESG Tool

http://download.ivknet.de/index.php
State Machines to ESGs

Insert coin: coin inserted → cancelled
Cancel: cancelled → return inserted coins
Print ticket: printing → print ticket

Solution

Full Resolution Approach

Länge: 2
# Nodes: 6
# Edges: 7
# Nodes (CPP): 6
# Edges (CPP): 7

CES:
3: [insert coin, insert coin, print ticket, ],
3: [insert coin, cancel, return inserted coins, ],
No. of CES: 2
No. of Events: 6

FCES:
2: [insert coin, return inserted coins, 
3: [insert coin, cancel, insert coin, 
3: [insert coin, cancel, cancel, cancel, 
3: [insert coin, cancel, print ticket, 
3: [insert coin, print ticket, insert coin, 
3: [insert coin, print ticket, cancel, 
3: [insert coin, print ticket, print ticket, 
3: [insert coin, print ticket, return inserted coins, 
4: [insert coin, cancel, return inserted coins, insert coin, 
4: [insert coin, cancel, return inserted coins, cancel, 
4: [insert coin, cancel, return inserted coins, return inserted coins, 
4: [insert coin, cancel, return inserted coins, return inserted coins, 
1: [cancel, 
1: [print ticket, 
1: [return inserted coins, 
No. of FCES: 15
No. of Events: 42
Proposed Approach

• The proposed approach improves completeness of a BDAT test suite and enables coverage-based test sequence generation.

• With the assumption that Gherkin clauses can be represented by events, the proposed approach suggests use of event sequence graphs (ESGs) for modeling BDATs.

• To model a BDAT as an ESG, ESGs are extended with tags.
Tagged ESG

A tagged ESG is an ESG, where a vertex may contain a tag instead of an event.

Scenario: cart02 - Adding a product to cart
Given I am on a product detail page \#productPage
When I select the amount
And I click the add to cart button
Then the product is added to my shopping cart \#shoppingCart

A tagged ESG is used to represent a BDAT.
Tagged ESG

Scenario: check01 - Successful checkout
Given I have added an item to my shopping bag #shoppingCart
When I proceed to the check out
And I enter valid delivery details
And I select a payment method
And I confirm the order
Then I am redirected to the thank you page #orderConfirmed

#shoppingCart tag is used as a connection point and then eliminated.
Combining two BDATs on tagged ESG
Finding missing BDATs

• **Elimination by Combination** for finding missing BDATs

• Once two BDATs are combined using a tag, that tag is eliminated.

• Therefore, all possible tagged scenarios or their graphical representations, i.e., tagged ESGs, are combined.

• A combined tagged ESG may be combined with another simple or combined tagged ESG.

• The goal is to reach an ESG without any tags.
Finding missing BDATs

- **Elimination by Combination** for finding missing BDATs
- After all possible combinations are completed, a tag remained on a tagged ESG indicates that there is a missing BDAT.
- More than one tag remaining may mean more missing BDATs.
Finding missing BDATs

This BDAT is the only Gherkin scenario that has the tag `#orderDetail`. Since there is no match, it indicates that a BDAT that starts with `#orderDetail` tag is missing. Complete this missing BDAT as follows:

Scenario: acc03 - Check orders
  Given I am logged in on the site `#atHome`
  When I navigate to my orders
  Then I see a list of my orders
  And I can open an order to see the order details `#orderDetail`

Scenario: acc10 - Back to order list page
  Given `#orderDetail`
  When I press OK button
  Then order list page is displayed `#orderList`
Evaluation

- Proposed approach is applied to an existing test suite for an e-commerce software. [https://github.com/spriteCloud/ecommerce-cucumber-web-test-automation-suite](https://github.com/spriteCloud/ecommerce-cucumber-web-test-automation-suite)

- Existing test suite has **15 BDATs**, or scenarios, with **64 Gherkin clauses**. Clause per scenario ratio is **4.26**.

- After applying the proposed approach, we end up with **24 BDATs** and **85 Gherkin clauses**. There are 9 new scenarios but only 5 of them are missing scenarios. The other 4 scenarios are introduced to simplify and standardize some original scenarios. So, clause per scenario ratio is descended to **3.54**.
Test Sequence by TSD Tool

- No. of Nodes: 50
- No. of Edges: 70
- CES with 111 events:
  
  [ login page is displayed, enter username, enter password, click login button, home page is displayed, go to order list page, order list page is displayed, click on an order, order details are displayed, press OK button, order list page is displayed, click home icon, home page is displayed, click shopping cart button, shopping cart page is displayed, click check out button, check out page is displayed, enter new address, enter new invalid payment, confirm invalid order, "invalid payment" is displayed, press OK button, check out page is displayed, enter new address, enter new invalid payment, click cancel button, check out page is displayed, enter new address, enter new valid payment, click cancel button, check out page is displayed, select existing payment, click cancel button, check out page is displayed, enter new address, enter new valid payment, confirm valid order, "order taken" is displayed, press OK button, order list page is displayed, click home icon, home page is displayed, enter multiple keyword, click search button, product list page is displayed, select a filter, click filter button, filtered product list page is displayed, click on a product, product details are displayed, select amount, add to cart, shopping cart page is displayed, click home icon, home page is displayed, enter single keyword, click search button, product list page is displayed, click on a product, product details are displayed, click home icon, home page is displayed, select a product list page, product list page is displayed, select a product, product list page is displayed, click home icon, home page is displayed, click account button, account page is displayed, update payment, "payment updated" is displayed, press OK button, account page is displayed, update address, "address updated" is displayed, press OK button, account page is displayed, update payment, "payment updated" is displayed, click home icon, home page is displayed, click shopping cart button, shopping cart page is displayed, click check out button, check out page is displayed, select existing address, select existing payment, confirm valid order, "order taken" is displayed, press OK button, order list page is displayed, click home icon, home page is displayed, select a product list page, product list page is displayed, select a filter, click filter button, filtered product list page is displayed, click home icon, home page is displayed, click shopping cart button, shopping cart page is displayed, click check out button, check out page is displayed, click home icon, home page is displayed, click logout button, login page is displayed, enter username, enter password, click login button, home page is displayed, click logout button, ]
Conclusion

• This paper proposes an approach to represent BDATs using ESGs.

• With the proposed approach, the test designer not only finds and completes missing BDATs but also combines them to know which BDAT can be executed after which BDAT.

• When the final composition is supplied to the TSD tool, it automatically generates a test sequence that covers all BDATs.

• So, the proposed approach improves testability of BDATs.