Experiences from Model-Based GUI testing of Smartphone Applications

Mika Katara
Department of Software Systems
Tampere University of Technology, Finland
first.lastname@tut.fi

Special thanks to the former TEMA team at Tampere University of Technology: Henri Heiskanen, Antti Jääskeläinen, Mika Maunumaa, Mika Mäenpää, Antti Nieminen, Tuomas Pajunen, Tommi Takala, and Heikki Virtanen
What are We Looking For?

Bugs that affect smartphone users, i.e. almost everybody
On-line model based testing using models describing what the user can do with the GUI and how the apps interact.
Obstacles and Opportunities for MBT

Practitioners are willing to try out new tools that might help them

Wide variety of open-source testing tools already used (agile unit testing, continuous integration, etc.)

Practitioners are not willing to invest heavily on modeling or specification in general

When quality is not a prime consideration, conventional testing methods seem to work reasonably well

There are areas that are very hard to test using conventional methods (static and linear test cases)

Many applications running concurrently and sharing resources may suggest concurrency problems

Protecting the brand: End users who experience application hang-up/crashing problems etc. may post their bad experiences to the Internet
Since testers don’t want to directly deal with models or test generation algorithms, we have abstracted the algorithms out in our web GUI.

TEMA web GUI is testers’ interface with the test server, used for designing and managing test configurations, running and tracking actual tests, and managing test model packages.

This all boils down to allowing testers to just choose what they want to test and what physical device they want to run their tests on.

Organizational impact:
- Need for test design has diminished, only test configurations (that may involve use cases) have to be created.
- Modeling is imperative.
  - High-level models can be reused, but domain-specific refinements must be created case by case for each domain.
Test Suite Maintenance

A major problem with conventional test automation, especially in the GUI context, is the maintenance of the test suites. In the worst case, you have to modify each test in your suite whenever something changes in the SUT (System Under Test). Using models, test suites are generated automatically, and you only have to change your model or few of the component models.
Keywords and Action Words

Action words describe the user’s actions at a high level of abstraction
Send an SMS, answer a call, add a new contact etc.
Used in high-level models (action machines)

An action word is translated to a sequence of keywords (keystrokes) for menu navigation, text inputting etc.
Some action words can have multiple keyword sequences implementing them
Keywords are used in low-level models (refinement machines)
To achieve a good separation of concerns, we use action words and keywords in separate models at different levels of abstraction. Action machines containing action words are composed with refinement machines containing key words. The resulting composite model is input to the tools executing the model i.e., generating the test cases. To avoid state space explosion, this has been implemented using an on-the-fly algorithm.
Example Test Models

S60 Camera application, action machine

Illustration: Antti Kervinen/TUT
S60 Camera application, refinement machine

Illustration: Antti Kervinen/TUT
Debugging Long Error Traces

Debugging is a major practical problem

This is emphasized in online MBT, since error traces can be very long

Solutions:

1) Test Run Video Synchronization with Log Data

2) Trace Incrementation
Based on the concept of gradually executing a failed test run in subsets
Domains Conquered

We have been primarily focusing on mobile GUI testing, but our approach is also suited to other domains. Our model library presently holds models for the following domains:

- S60
  - Over 100 action machines, almost 1000 action words
  - Estimated number of states if we would compose all the models in parallel: at least $10^{19}$ states
- Mobile Linux
- Android
- Java Swing

Action machines (high-level models) have been reused for different domains.
Conclusions

Modeling typically uncovers more bugs and quirks than test execution itself

Reverse-engineering vs. use of system models
Lack of precise enough GUI specifications
  Agile trend hasn’t made matters easier….

It is possible to find bugs in already well-tested applications
  Mostly minor or cosmetic, but also serious (system errors, etc.)

A talented student was able to create the first version of the S60 model library in 2 months (+1 month for debugging & maintenance)

Automatic GUI testing requires mature test automation support from the domain
Case: S60 (Project Starting Point)

Built-in applications in S60 smartphones, such as Gallery, Music Player, Flash Player, Notes, Voice Recorder, Contacts and Messaging

Keyword execution using proprietary and commercial test automation tools

Optical character recognition was used for verifications, which caused some reliability and maintenance issues

21 defects of different severities and priorities were found

Some of these defects existed in more than one smartphone model

The most severe of the defects caused the phone to hang with “System error” message on the display

About two thirds of the defects were discovered while modeling (reverse engineering), and the remaining third by execution (dynamic testing)

Most of the defects had already been previously found in traditional testing (both manual and automatic test execution), but they had not been fixed for some reason

However, there were also some that were totally new

Many of the defects were related to concurrency issues: performing some multimedia-related functionality in one application and then switching to another application caused unexpected behavior in some circumstances

In addition to defects found in applications, some were found in test automation tools, which was considered rather surprising, as these tools were quite mature
Case: Mobile Linux

Media player application by Ixonos

New modeling challenge: real-time requirements
- Playing videos, fast-forwarding, rewinding, pausing…
- Although it was difficult, real-time support was eventually accomplished at model level

Keyword execution using Linux accessibility features
- API access to GUI components
- Easier and more reliable than in S60 case

Some minor bugs were found (both during modeling and execution)
Case: Android Phone

Messaging, Contacts and Calendar applications
Action machines created for S60 were reused
Calendar was modeled with ATS4 AppModel and converted to TEMA models with an automatic converter
Keyword execution was based on A-Tool by Symbio
Optical character recognition was implemented with MS Office Imaging, which could have been more reliable
Some bugs were found (both during modeling and execution)
Case: Android Revisited

BBC News application
RSS reader optimized for BBC news feeds
Self-made test automation for the emulator
Based on API access -> improved reliability
Modeling the BBC News (16 state machines) took a few days time
With usability improvements in the modeling tool this could be made even faster
During the case, the application was updated thrice and the platform once (2.1 → 2.2)
Maintaining the models was fast – no need to update a huge set of test cases
Random mode was used in the test generation
Setting up the test run takes practically no time at all
240 separate test runs lasting over 115 hours in total
27 000 action words – 50 000 keywords
The longest run lasted over three hours
Average duration was 30 minutes
Emulator lost Internet connection in every couple of hours
## Bugs Found

14 bugs found in total
8 during modeling
6 in random test execution from the model

Two of the bugs caused the application to crash

Even quite small inconsistencies were found – easily missed by a manual tester

<table>
<thead>
<tr>
<th>#</th>
<th>Description</th>
<th>Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A button gets stuck on a disabled state</td>
<td></td>
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<tr>
<td>2</td>
<td>When the main feed is changed, the feed header is not updated</td>
<td>modeling</td>
</tr>
<tr>
<td>3</td>
<td>OK and Cancel buttons do not save/restore values in preferences</td>
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<tr>
<td>4</td>
<td>When the widget feed is changed, the feed view is not updated</td>
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<tr>
<td>5*</td>
<td>Application sometimes crashes when refreshing feeds after modifying the preferences,</td>
<td></td>
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<tr>
<td>6</td>
<td>Max headline value zero not handled properly in preferences</td>
<td></td>
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<tr>
<td>7</td>
<td>Inconsistency when switching between multiple widget feeds</td>
<td></td>
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<tr>
<td>8</td>
<td>News item count not updated properly in the feeds view</td>
<td></td>
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<tr>
<td>9</td>
<td>Preferences shows ”Select default feed” although the application was started from a widget.</td>
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<tr>
<td>10</td>
<td>Extra whitespaces in news titles</td>
<td></td>
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<tr>
<td>11</td>
<td>Refresh inconsistency when marking news read</td>
<td></td>
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<tr>
<td>12</td>
<td>Widget forgets its state when set to the foreground</td>
<td></td>
</tr>
<tr>
<td>13*</td>
<td>Update frequency value zero not handled properly</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Widget launches the main app if the widget feed is unavailable</td>
<td></td>
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Keyword Execution with a Robot

Solution for the automated testing of touch display devices
Simulates real human user interaction with SUT
The applications are tested in actual devices
Different sets of robot fingers for device actuation
Visual verification of the results with a camera and OCV (Optical Character Verification)
Easy integration with TEMA Toolset

For more information, visit http://www.optofidelity.com
Thank You!

Acknowledgements for financiers:
Tekes, Nokia, Ixenos, Symbio, Cybercom Plenware, F-Secure,
Qentinel, Prove Expertise, Academy of Finland (grant #121012)