GUI Testing

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Agenda

• Introduction
• GUI testing approaches
  – Manual testing
  – Static analysis
  – Automated GUI testing tools
    • Capture/Replay testing tools
    • Random testing
    • Unit testing
    • Model-Based testing
• Spec Explorer extensions for GUI testing
GUI testing raises specific challenges

- GUI test automation is harder than API test automation
  - Documentation; GUIs are slower than APIs

- Observing visible GUI state is difficult

- Observing invisible GUI state is tricky almost impossible

- Controlling GUI actions is difficult
  - Event based
  - Non-solicited events
  - How to simulate user actions?

- State space and test case explosion
  - Multiple ways (mouse, keyboard,...) to achieve the same goal
  - Almost all user actions are enabled most of the time

GUI errors – concrete examples

- Correct functioning
- Missing commands
- Correct window modality
- Mandatory fields
- Incorrect field defaults
- Data validation
- Error handling (messages to the user)
- Wrong values retrieved by queries
- Fill order
- (...)

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Manual testing (V&V) techniques

• Heuristic Methods
  – A group of specialists studies the SW in order to find problems that they can identify

• Guidelines
  – Recommendations about the SW and UI. E.g.,: how to organize the display and the menu structure

• Cognitive walkthrough
  – The developers walk through the SW in the context of core tasks a typical user will need to accomplish. The actions and the feedback of the interface are compared to the user’s goals and knowledge, and discrepancies between user’s expectations and the steps required by the interface are noted

• Usability tests
  – The SW is studied under real-world or controlled conditions (real users), with evaluators gathering data on problems that rise during its use

[JMWU91]
Manual testing

• Advantages
  – More bugs found per test cases executed (good specialist) (not necessarily by time or money invested)
  – Adaptability: bugs found provide hints to find other bugs
  – Can find bugs that are difficult to find with automated tests (the converse is also true)
    • Usability problems
  – Can be supported / made more systematic/repeatable by checklists of standard tests and application specific tests
  – Good for exploratory / initial testing

• Disadvantages
  – Regression testing
  – Effort required
  – Weak coverage
  – Repeatability / reproducibility
  – Good test specialists are difficult to find
  – Depends on the capabilities of the tester

Formal static analysis: Model-checking

Abstraction – System representation is replaced by a simpler one in which irrelevant low level details are removed.

Bounding the state space – the domains of the state variables are bound to a certain number of possible values.

Partial Order Reduction (POR) – POR is based on the fact that the order in which concurrent transitions are executed does not influence the result.

Symbolic model checking – an implicit representation of the states and transitions that model the system.

Binary Decision Diagrams (BDD) – A special case of Symbolic model checking techniques where the implicit representation of the states and transitions is based on Boolean formulas.
Formal static analysis: formal proofs

• Verify if the implementation ($I$) performs the specification ($S$). This can be expressed mathematically either by
  $$I \rightarrow S$$
  or
  $$I \equiv S$$

• The theorem that has to be proved.
  – $S$ and $I$ expressed in the same formal language
  – The formal proof is rigorously constructed as a sequence of steps based on a set of axioms and inference rules, like simplification, rewriting, and induction

Static code analysis

• Lightweight “intellisense”-like checking
  – Check that guidelines are followed, e.g.,
    • Button placement
    • Use only colours which are distinguishable by colour-blind users
  – Check that UI components are used appropriately
    • E.g., button without a Click event handler
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Automated testing approaches

• Capture-Replay tools
  • E.g., WinRunner, Rational Robot, Android

• Random input testing tools
  • E.g., Rational’s TestFactory uses dumb monkey method

• Unit testing frameworks
  • E.g., JUnit, NUnit

• Model-based testing tools
  • E.g., Spec Explorer (extended)
  • E.g., Guitar (for GUI testing)
GUI testing tools

• In the Marketplace:
  – CompuWare TestPartner - www.compuware.com
  – Rational Robot
  – Rational Visual Test - www.rational.com
  – WinRunner
  – LoadRunner - www.mercuryinteractive.com
  – Segue’s SilkTest - www.segue.com

• Open Source
  – Abbot
  – GUITAR
  – Pounder
  – qftestJUI
  – GUI test drivers — (http://www.testingfaqs.org/t-gui.html)

Capture replay tools: how it works?

• Two different interacting modes
  • **Capture**: The user/tester interacts with the tool
    The tools saves user actions and output
  • **Replay**: Saved user actions are reproduced
    The output obtained is compared with the one expected

• Three different execution modes:
  – Position based; Object based; Mixed

• Output verification
  – Property/content comparison; Bitmap comparison; Optical character recognition (OCR)

• Scripts
  – Saved from user actions; From scratch; Mixed

• A higher level of abstraction is needed to reach independence of GUI updates
Capture replay tools

• Advantages
  – Test case recording (capture) (similar to macro recording in Excel)
  – Recorded test scripts can be made more generic by programming
    • E.g., use logical names in test script and map logical names to physical objects in a separate file
  – Automatic test case execution (replay)
  – Output checking

• Disadvantages
  – Can be used only when the SW application is working correctly
  – (good for regression testing but) Sensitivity to physical details
  – Do not support automatic generation of test cases.
Random testing tools

- Do you know that a monkey using a piano keyboard could play a Vivaldi opera? Could the same monkey, using your application, discovery defects?

- Actions performed randomly without knowledge of how humans use the application

- Microsoft says that 10 to 20% of the bugs in Microsoft projects are found by these tools

- Two kinds of tools
  - **Dumb monkeys** – low IQ; they can’t recognize an error when they see one
  - **Smart monkeys** – generate inputs with some knowledge to reflect expected usage; get knowledge from state table or model of the AUT.

Random input testing tools

- **Advantages**
  - Good for finding system crashes
  - No effort in generating test cases
  - Independent of GUI updates
  - Increase confidence on the SW when running several hours without finding errors
  - “Easy” to implement

- **Disadvantages**
  - Not good for finding other kinds of errors
  - Difficult to reproduce the errors
  - Unpredictable
Unit testing frameworks

- E.g., JUnit, NUnit
- Advantages
  - Flexibility
  - Automatic test execution
  - Support TDD (Test Driven Development)
  - Used in combination with appropriate GUI test libraries (e.g., Jemmy and Abbot) can be used for GUI testing (essentially reduce GUI to API testing)
- Disadvantages
  - Test cases are programmed manually
  - Usually more lines of testing code than application code

Model-based GUI testing

- Advantages
  - Higher degree of automation (test case generation)
  - Allows more exhaustive testing
  - Good for correctness/functional testing
  - Model can be easily adapted to changes
- Disadvantages
  - Requires a formal specification/model
  - Test case explosion
  - Test case generation has to be controlled appropriately to generate a test case of manageable size
  - Small changes to the model can result in a totally different test suite
GUI model

- Abstract models. Ex.: PIE and RED-PIE.
- Grammars. Ex.: BNF.
- State-based. Ex.: FSM, Petri nets.
- Model-based. Ex.: VDM, Z.
- Property-based
  - Algebraic. Ex.: OBJ.
- Behavior-based:
  - Process Algebras. Ex.: CSP
- Hybrid approaches. Ex.: VDM and CSP.

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System Testing with model programs

Microsoft Research (FSE) : Colin Campbell, Wolfgang Grieskamp, Yuri Gurevich, Lev Nachmanson, Wolfram Schulte, Nikolai Tillmann, Margus Veanes

GUI testing process
GUI modelling with Spec#

- One module (sub-model) for each window/dialog

- State variables inside modules to model the state of the window

- Methods annotated as actions to model the possible user actions on that window

- Probe methods (with Get as name's prefix) to observe the state of the GUI

- Actions inside each module has at least one pre-condition: the corresponding window is enabled (one window is enabled when it is open and doesn't have a child modal window on top)

```csharp
namespace MyNotepad
{
    // State variables
    string text="", selText="";
    bool dirty=false;
    int posCursor=0;

    // Start and close the Notepad application
    [Action] void LaunchNotepad()
    { requires IsOpen("Notepad"); { AddWindow("Notepad","",false);
        // ... state variables initialization ...
    }

    [Action] void SaveChangesBeforeClose(string option)
    { requires Enabled("MsgClose"); {
        switch (option) {
            case "No": RemoveWindow("Notepad"); return;
            case "Yes": AddWindow("Save"); return;
            case "Cancel": return;
            default: return;
        }
    }

    // Change and query the content of the main window
    [Action] id=Probe] string GetText()
    { requires IsOpened("Notepad"); {
        return text;
    }
```
Window manager

- **AddWindow**(windowName, parentWindowName, isModal)
- **RemoveWindow**(windowName)
- **IsEnabled**(windowName)
- **IsOpen**(windowName)

- The state keeps information about the hierarchical active windows’ structure.

- When a method open/closes a window, such window must be added/removed to/from the window manager.

- When a window is closed, all its child windows are closed.

- One window is enabled when it is open and there isn’t a modal window on top.

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Extensions to Spec Explorer

[Diagram of GUI testing process]

- **Test case generation**
- **GUI model** (Spec# or AsmL)
- **GUI mapping definition**
- **GUI tool**
- **GUI application under test** (binary executable)
- **Test execution**
- **Test results**
Test case generation (extensions)

FSM generation by bounded exploration

Test case generation

FSM Reduced

GUI model (Spec# or AsmL)

Bounds

HFSM

Coverage criteria

Spec Explorer

Test suite

FSM reduction: example

Independent dialogs
**HFSM: top level**

\[ \text{Navigation map} (\text{FSM}) = \{ (\pi_{\text{GetWindowWithFocus}} (s), a, \pi_{\text{GetWindowWithFocus}} (s')) \mid (s, a, s') \in T \} \]

**HFSM: middle level**

** FSM of Open dialog **

\[ \text{FSM}_{\text{Open dialog}} = (\pi_{\text{ManipulateVariables}} ("\text{Dia log}"), (s), a, \pi_{\text{ManipulateVariables}} ("\text{Dia log}"), (s')) \mid (s, a, s') \in T \land s', s \in \pi_{\text{Enabled}} ("\text{Dia log}"), s' \]
**HFSM: bottom level**

**FSM original:**
70 states and 399 transitions
Test suite with 673 steps

**FSM reduction (preserving top level)**

**FSM original:**
70 states and 399 transitions
Test suite with 673 steps

Garbage

**FSM reduced:**
20 states and 95 transitions
Test suite with 147 steps
GUI mapping tool architecture

1: select model action
2: make GUI object visible/enable
3: use to point out GUI object

GUI model (Spec# or AsmL)
GUI Mapping Code Generator
GUI object mapping (XML)
GUI action mapping code

GUI Spy tool
Front-end
GUI Application Under Test (bin. exec.)

Test execution and the GUI test library

GUI object mapping (XML)
GUI mapping code
GUI test library
GUI application under test (bin. exec.)

Execute
Compare
Spec Explorer
Test suite
e.g. Close()
Expected result

e.g. Click(…)
e.g. SendMessage(…)
Actual result

GUI model (Spec# or AsmL)
e.g. Close()

Expected result
Test result
Generated code

#region automatically generated code
{
    // ...
    public static string MyNotepad_GetText()
    {
        return UserEvents.Event_GetText("MyNotepad.Text");
    }

    public static void MyNotepad_InsText(string p0)
    {
        UserEvents.Event_SendText("MyNotepad.Text", p0);
    }

    public static void MyNotepad_Close()
    {
        UserEvents.Event_SelectOption("MyNotepad.Close");
    }

    public static void MyNotepad_AcknMsgCannotFind()
    {
        UserEvents.Event_MessageBox("MyNotepad.AcknMsgCannotFind",""");
    }

    public static void ReplaceDialog_Cancel()
    {
        UserEvents.Event_Click("ReplaceDialog.RCancel");
    }
    // ...
}
#endregion
XML files

Logical to physical object mapping

```xml
<obj diffgr:id="obj2" msdata:rowOrder="1"
    diffgr:hasChanges="inserted">
    <LogicalName>MyNotepad.Text</LogicalName>
    <ClassName>Edit</ClassName>
    <ControlID>15</ControlID>
    <Caption>-</Caption>
    <SubOption>-</SubOption>
    <ParentClassName>Notepad</ParentClassName>
    <ParentCaption>Untitled - Notepad</ParentCaption>
    <SubOpClassName>-</SubOpClassName>
    <FullPath>-</FullPath>
</obj>
```

GUI test library

```csharp
// To act upon GUI objects
void Click(string GUIObjName);
void SendText(string GUIObjName, string txt);
void SelectText(string GUIObjName, int start, int end);
void SelectSubOption(string GUIObjName, string option);
void SelectCheckBox(string GUIObjName, bool check);
void SelectMsgBoxOp(string GUIObjName, string option);

// To observe properties of GUI objects
string GetText(string GUIObjName);
string GetSelectedText(string GUIObjName);
int GetInsertionPoint(string GUIObjName);
bool GetCheckBox(string GUIObjName);

// To map logical object names to physical objects
void LoadXMLObjMapping(string XMLFileName);
```
GUI Errors

Pre-condition mismatch:
- a test case is trying to act on a control that is not enabled or cannot be found; or
- a test case is trying to act on a window that is not reachable or is not opened (e.g., a modal dialog is open and the window we want to reach is behind that dialog);

Post-condition mismatch:
- the expected result was not displayed (e.g., a text box does not display the expected content);

Demo
References

Main references

Other references
• [UTF-site] For Unit testing frameworks visit sites – www.nunit.org; www.junit.org

SpecExplorer and Spec# references
• [FSE-site] Visit FSE web site for more information: research.microsoft.com/foundations
• [SE-site] Visit Spec Explorer site for download: research.microsoft.com/SpecExplorer/

Additional reading
• Model-Based Testing papers – www.geocities.com/model_based_testing/online_papers.htm