



TESTAR

User Manual

VERSION 1.2

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1 Requirements

The current version of TESTAR runs on Windows 7 64 bit. To ensure that TESTAR runs on your system you need to install the Java Development Kit (JDK) x64 in version 1.8.

2 Installing TESTAR

TESTAR comes in a file called TESTAR.vX.X.win.x64.zip, which contains all files necessary for its execution. Just unzip this file into a directory with write-access. There is no setup routine.

3 Starting TESTAR

Within the main directory you will find several files, which are crucial for the execution of TESTAR. The most important one is testar.bat. Double-click on it and TESTAR will start and display the main screen: If TESTAR was not initiated, it is probable that Java 8 x64 was not correctly identified. You might either run testar.jar by double clicking on it, or try to fix testar.bat to set the correct Java version in your environment.

As shown in the picture 1, the main screen contains four buttons, which start TESTAR into its four main modes:

1. Start in **Spy-Mode**: It will start the System under Test (SUT) and allow you to inspect its GUI. You have different commands available to display different information about the GUI:
 - (a) *Shift + 1* will show the set of actions that TESTAR recognizes, so you can check which ones could be executed during a test. Actions like, for example, left/right clicks, text inputs, drag and drops, etc.
 - (b) *Shift + 2* highlights the widget under cursor. It also displays information about the widget role and an array that represents the path to reach the widget in the widget-tree representing the current displayed GUI.
 - (c) *Shift + 3* displays information about properties of the widget under cursor (see Section 5.2 for further information).
2. Start in **Generation-Mode**: This mode will start the SUT and execute a full test on it. Switching to GenerateManual mode (*Shift + Arrow Left*) you will be able to take the control at any time.
3. Start in **Replay-Mode**: This mode replays a previously recorded sequence. TESTAR will ask you for the sequence to replay.
4. Start in **View-Mode**: The View-Mode allows you to inspect all steps of a previously recorded sequence. Contrary to the Replay-Mode, it will not execute any actions, but only show you the screenshots that were recorded during sequence generation. This is ideal if a sequence turns out not to be reproducible.



Figure 1: TESTAR's main screen

4 Setting up your tests

4.1 General Settings Tab

The Screenshot in picture 2 shows the tab with the general settings for TESTAR.

1. Path to the SUT: Pick the executable of the SUT or insert a custom command line (p.e. `java -jar "suts/calc.jar"`).

For web applications, follow the format

`<Path.to.your.Browser.exe><URL of your SUT>`

in the field Path to the SUT.

*For API related problems, we recommend for now the use of Internet Explorer in order to get the correct identification of widgets. For example:

`"C:\Program Files\Internet Explorer\iexplore.exe" "http://www.youtube.es/"`

You can also put the window title of your SUT in this field following the format `"SUT_WINDOW_TITLE:must_contain_this_text"` However, you will need to have started your SUT before any TESTAR operation.

2. Number of sequences to generate: How many times would you like to test your SUT? A recommended value would be within the range 10 and 100. However, when you have a new SUT it is better to start using a lower value (e.g. 3) in order to be able to check if everything works as expected.
3. Sequence length: How many actions must be performed for each test sequence? After having executed the given amount of actions, TESTAR will stop the SUT and proceed with the next sequence (a value within 15 and 500 is recommended).
4. Force the SUT to the foreground: During test generation, the SUT's windows might get minimized or other processes might block its GUI. If you check this option, TESTAR will force the SUT to the foreground.
5. Stop sequence generation on fault: If TESTAR detects an error, it will immediately stop sequence generation.
6. Logging verbosity: Values 0, 1 (default) or 2. We recommended the value 1. Value 2 will write debugging information, while value 0 will be too brief. The log-files of each sequence run can be found in the output directory and contain information about the actions that were executed, the faults that were found and potential problems that occurred during the test.
7. Edit the TESTAR Protocol: By clicking this button you will open the Protocol Editor. As we will see later on in this Manual, this editor allows you to override and extend the basic functionality in order to implement complex action sets and sophisticated oracles, between others.
8. Load settings file. If you have a specific setup that you saved into a file, you can load it here. This is ideal for switching between different settings for the same SUT or between the settings of different SUTs.
9. Save the current settings to a file. **Remark:** TESTAR automatically saves all setting changes you make. Thus, you do not explicitly have to save your settings to a file every time you make an adjustment.

4.2 Filter Tab

In this tab, picture 3, you will find the following parameters:

1. **Click-filter:** TESTAR will not execute actions on any widget whose title matches the given regular expression in this configuration parameter. Certain actions that TESTAR could execute might be dangerous or undesirable, such as printing out documents, creating, moving or deleting files. To see whether or not your expression works,

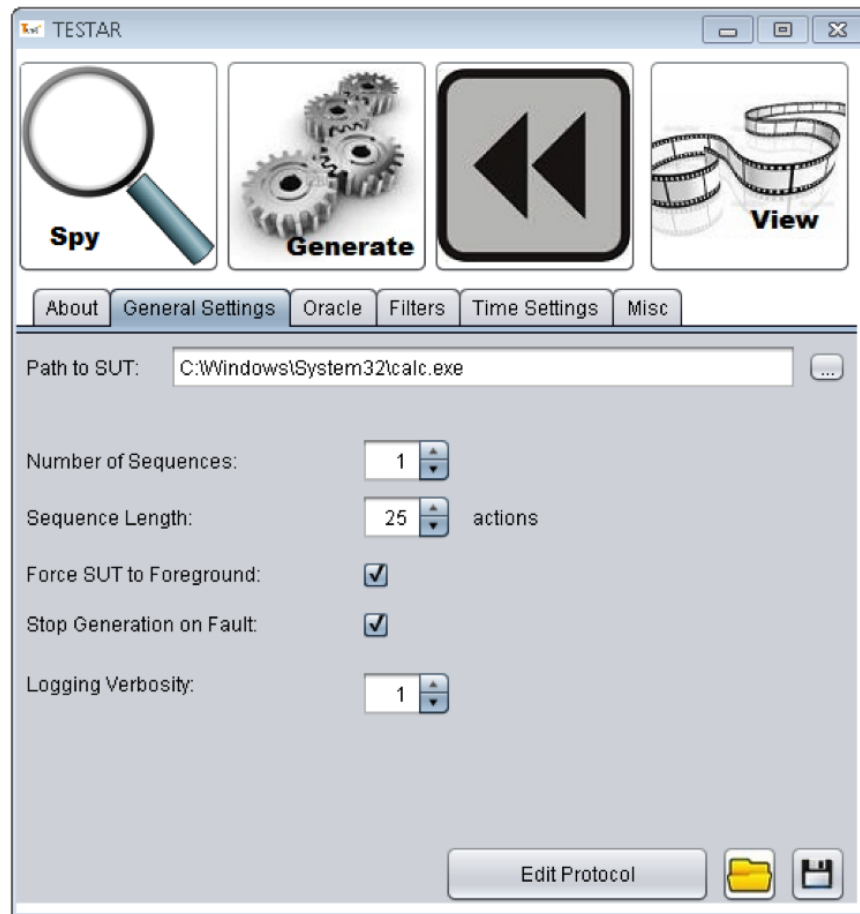


Figure 2: General Settings Tab

simply start TESTAR in Spy-Mode, go to your desired GUI in the SUT and you will be able to check the detected actions.

2. **Processes to kill:** TESTAR will kill any process whose name matches the given regular expression. Some SUTs start other processes during test sequence generation. These might popup in the foreground and block the SUTs GUI. They might also consume excessive memory, etc.

4.3 Specifying simple Oracles

In order to detect faults, you need to tell TESTAR what to look for. In the “Oracle” tab you can specify a simple oracle, which analyzes each state of the GUI and reports errors.

The screenshot in picture 4 shows TESTAR’s oracle settings:



Figure 3: Filters Tab

1. **Suspicious Titles:** In this text box you can enter a regular expression that describes those messages that you consider to be related to possible errors. TESTAR will apply this expression to each title of each widget on the screen. If it matches any widget's title, TESTAR will report an error and save the sequence for later inspection. For example: Imagine you are looking for a critical message box with the title "A NullPointerException Exception has been thrown". You could simply add the expression `.*NullPointerException.*` which will match any title that contains the word "NullPointerException" (the `.*` are placeholders for arbitrary characters). To learn more about Regular Expressions see http://en.wikipedia.org/wiki/Regular_Expression
2. **Freeze Time:** TESTAR is able to detect crashes automatically, because it realizes when the SUT is not running anymore. However, if the SUT does not really crash, but just freezes (is unresponsive) for a long time, then TESTAR does not know whether it is just carrying out heavy computations or hangs. If the SUT is unresponsive for more than the given amount of seconds, TESTAR will consider it to be crashed and mark the current sequence as erroneous (a value within 8 and 30 is recommended, but

it directly depends on the SUT and the related computation operations, as well as the contextual environment performance).

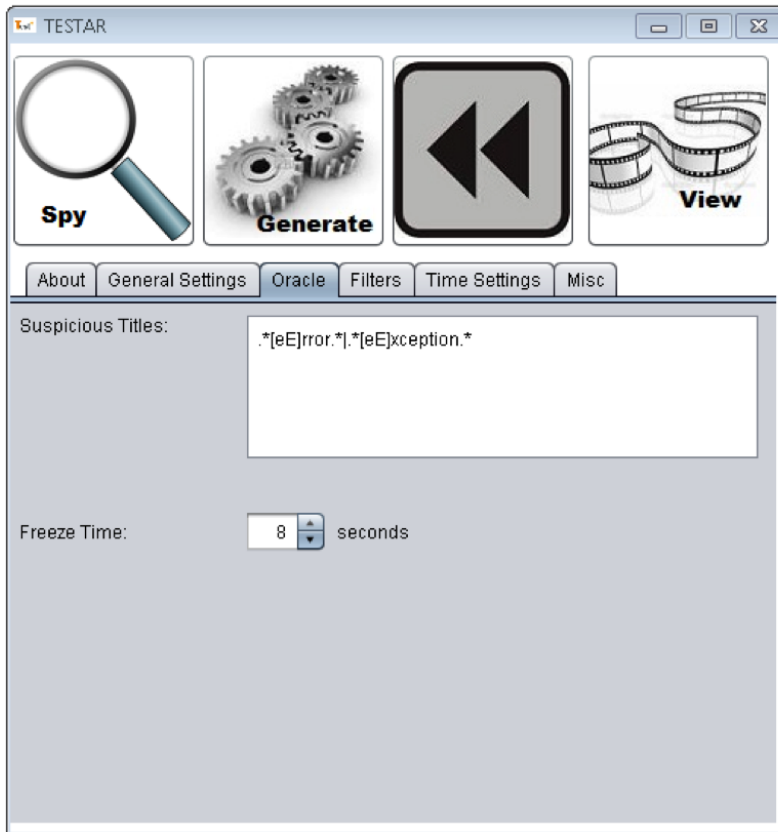


Figure 4: Oracle Tab

4.4 Time Settings Tab

The time Settings tab, picture 5, allows the user to configure the following parameters:

1. **Action Duration:** The higher this value, the longer the execution of actions will take. Mouse movements and typing become slower, so that it is easier to follow what TESTAR is doing. This can be useful during Replay-Mode, in order to replay a recorded sequence with less speed to better understand a fault.
2. **Action Wait Time:** Or time to wait after execution of an action. This is the time that TESTAR pauses after having executed an action in Generation-Mode. Sometimes it can make sense to give the GUI of the SUT more time to react, before executing the next action. If this value is set to a value greater than 0, it can greatly enhance

reproducibility of sequences at the expense of longer testing times (a value within 1 and 10 is recommended).

3. **SUT startup time:** This is the time that TESTAR waits for the SUT to load. Large and complex SUTs might need more time than small ones. Only after this time has expired, TESTAR will start sequence generation. To calculate this value you can start your SUT to find out how long it takes to boot. We recommended closing and re-running the SUT for a more precise startup time identification (due to application catching into memory).
4. **Maximum test time(seconds):** TESTAR will cease to generate any sequences after this time has elapsed. This is useful for specifying a test time out, e.g. “1 hour”, “one day”, “one week”.
5. **Use Recorded Action Timing during Replay:** This option only affects Replay-Mode. If checked, TESTAR will use the action duration and action wait time that was used during sequence generation. If you uncheck the option, you can specify your own values.

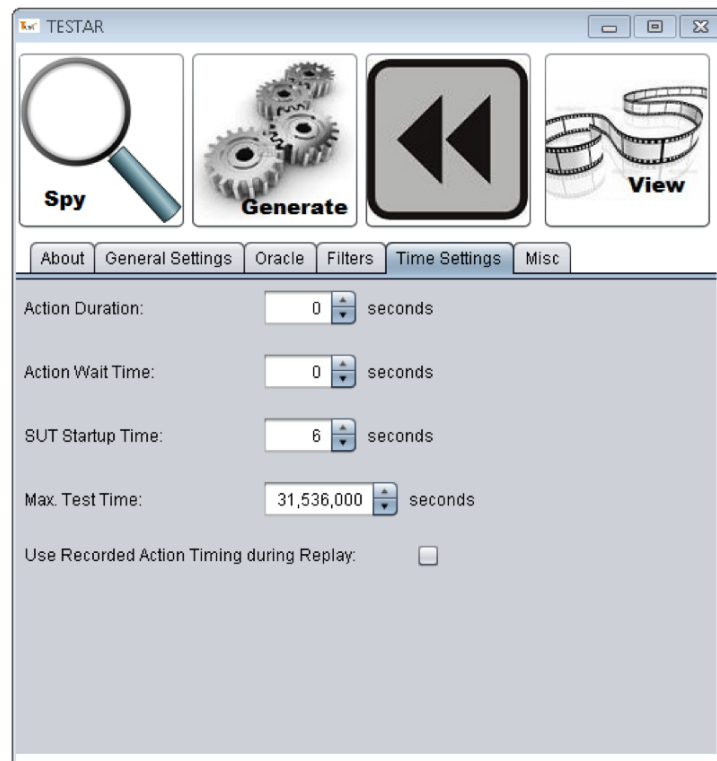


Figure 5: Time Settings Tab

4.5 Miscellaneous Tab

This tab, picture 6, contains some settings that are less frequently used.

1. **Output directory:** This determines the directory where TESTAR outputs recorded sequences, log-files and state snapshots. We do not recommend changing this.
2. **Temporary Directory:** TESTAR will use this directory to store temporary files during the execution of sequences.
3. **Files to copy before SUT start:** When you start the SUT, sometimes it can be useful to restore certain configuration files to their default, so that the SUT always starts in the same state. Therefore you can define pairs of paths (copy from / to). TESTAR will copy each specified file from the given source location to the given destination. Simply click the text-area and a file dialog will pop up.
4. **Files to delete before SUT start:** Certain SUTs generate configuration files, temporary files and files that save the system's state. This might be problematic during sequence replay, when you want a system to always start in the same state. Therefore, you can specify these files, to be deleted before the SUT gets started. If you click the text-area, a file dialog will pop up which allows selecting files and directories to be deleted.

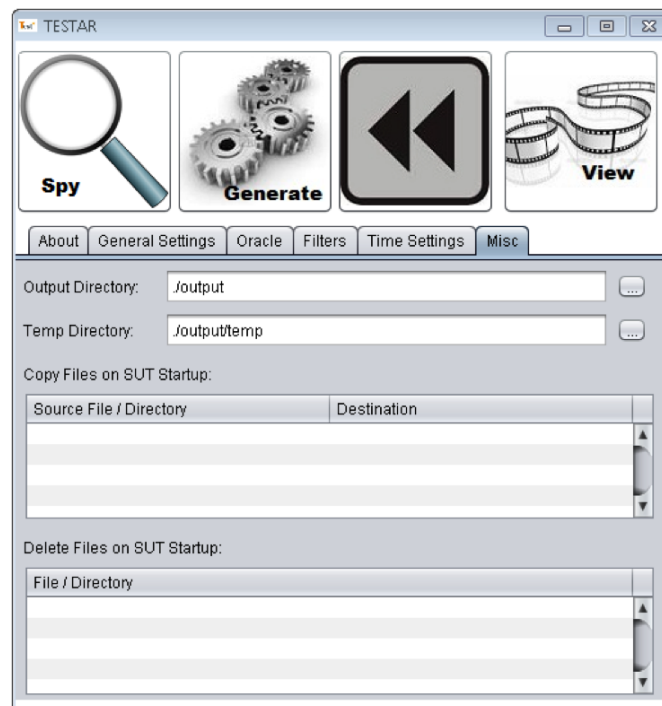


Figure 6: Misc Tab

4.6 Specifying Advanced Oracles

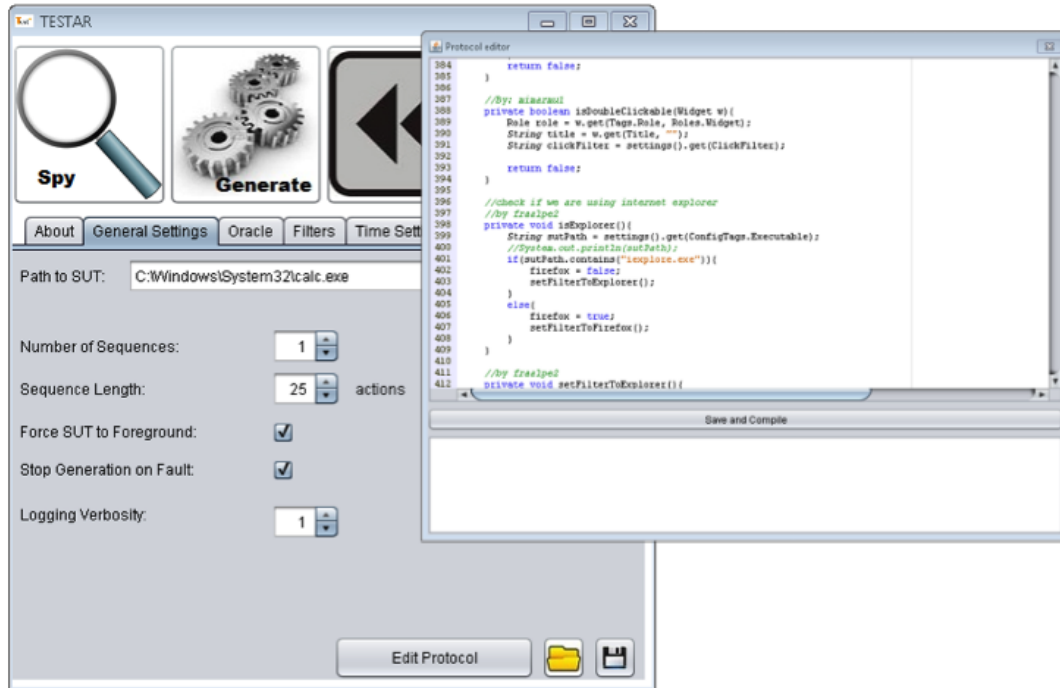


Figure 7: TESTAR’s protocol editor

All the settings presented so far help you to setup tests for automated testing to discover crashes, freezes and undesired output. However, at some point you might need to implement more complex actions or setup for more sophisticated oracles that can also test specific functionality. TESTAR allows you to edit its protocol, i.e. the source code that determines its behavior. The screenshot in picture 7 shows the Protocol Editor, which you can enter by navigating to the “General Settings” tab and clicking the “Edit Protocol” button. It shows:

1. The Source Code of the Protocol.
2. The “Save and Compile” Button, which compiles the protocol and saves it to be used during the next test.
3. The Error Console, which informs you about potential errors during compilation.

The source code used in the protocol is plain Java. The methods in the class each correspond to the way TESTAR works and give you the possibility to adapt the default behavior. The figure in picture 8 explains the basic workflow of TESTAR and in Listing 1 you can find the corresponding Java methods.

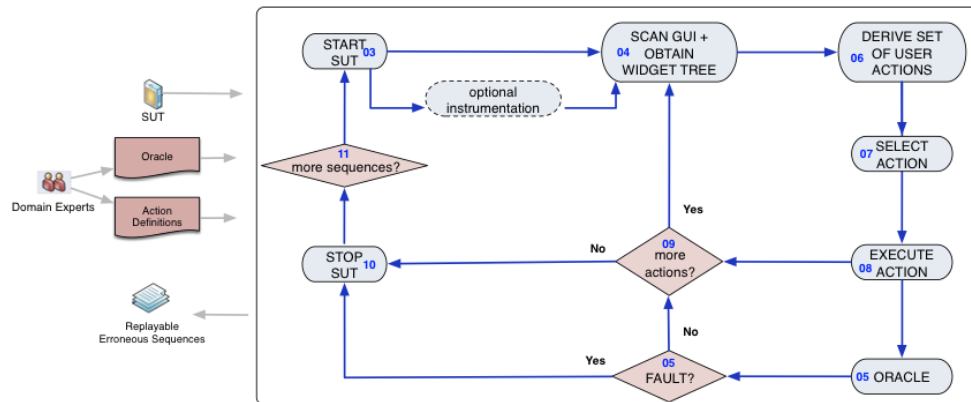


Figure 8: TESTAR's workflow

As an example you can edit the method **SUT startSystem()** of the protocol when login is required to test your system. That way TESTAR will do it automatically each time a test sequence is started.

```

SUT sut = super.startSystem();
new CompoundAction.Builder()
.add(new Type("user"),0.1) //assume keyboard focus is on the user field
.add(new KeyDown(KBKeys.VK_TAB),0.5) //assume next focusable field is pass
.add(new Type("pass"),0.1)
.add(new KeyDown(KBKeys.VK_ENTER),0.5).build() //assume login performed by ENTER
.run(sut, null, 0.1);
return sut;

```

Listing 1: The Java Methods that can be customized

```

// initial setup before starting SUT test
01. void initialize(Settings settings)

// clean-up tasks for new test runs
02. void beginSequence()

// any action to be taken during SUT execution
03. SUT startSystem()

// step-by-step STATE of the SUT, with an attached ORACLE
04. State getState(SUT system)

// determines the STATE ORACLE verdict
05. Verdict getVerdict(State state)

// the set of available ACTIONS from a SUT's STATE
06. Set<Action> deriveActions(SUT system, State state)

```

```

// which ACTION should be PERFORMED next (i.e. random, Search-Based)
07. Action selectAction(State state, Set<Action> actions)

// runs an ACTION from a SUT STATE, with return code (success?)
08. boolean executeAction(SUT system, State state, Action action)

// determines the stopping criteria
09. boolean moreActions(State state)

// finishing tasks for an ending test run
10. void finishSequence(File recordedSequence)

// determines whether to continue SUT testing (additional runs)
11. boolean moreSequences()

```

5 Running the tool

5.1 Action Visualization in Spy-Mode

When in Spy-Mode, TESTAR displays the detected actions (Shift + 1 to toggle visualization). Each action type has a specific appearance, as described in the following table:

Green dot	Left click
Yellow circle	Right click
Red circle	Left double click
Blue Arrow	Drag & Drop Operation
Blue Text	Click into text field and type some text
Gold circle	Left click and right arrow

Table 1: Visualization in Spy-Mode

5.2 Widget tree visualization

As shown in picture 9 you can see several properties of the widget selected (Shift + 3 when in Spy mode).

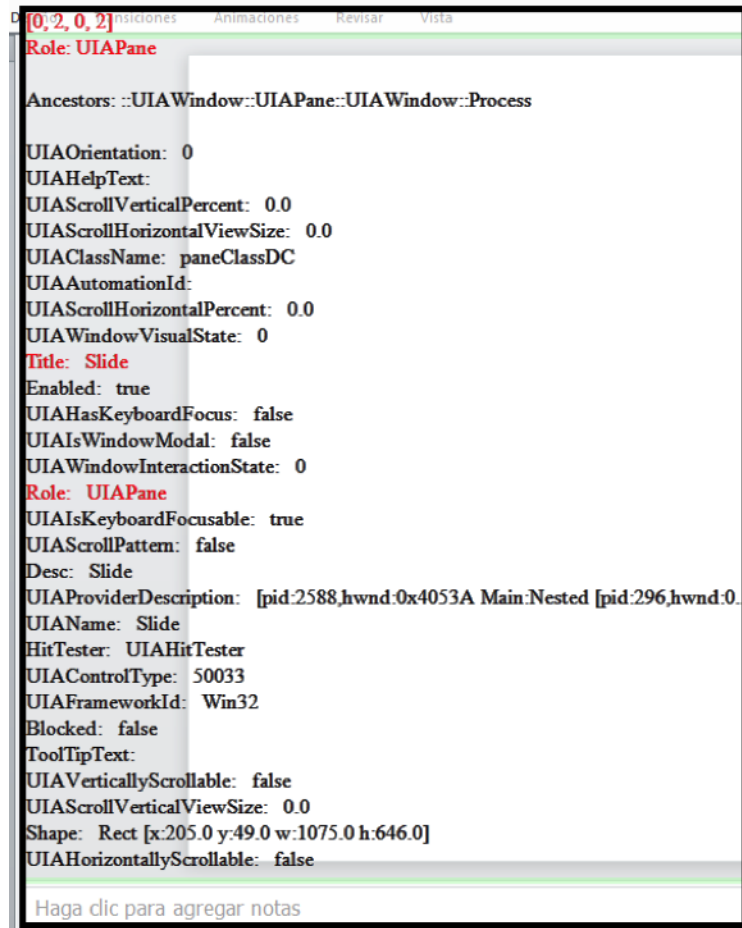


Figure 9: Widget's properties

Note: This set of properties could be adapted to future needs.

In addition, TESTAR allows you to display the hierarchical relationships between widgets (picture 10). By means of different colored rectangles, TESTAR frames the analyzed widget (green color) with their ancestors and predecessors. This will be useful when you wish to filter one widget and all the contents within it, among other cases. To enable this feature you will need to press the "Alt" key (check keyboard shortcuts).

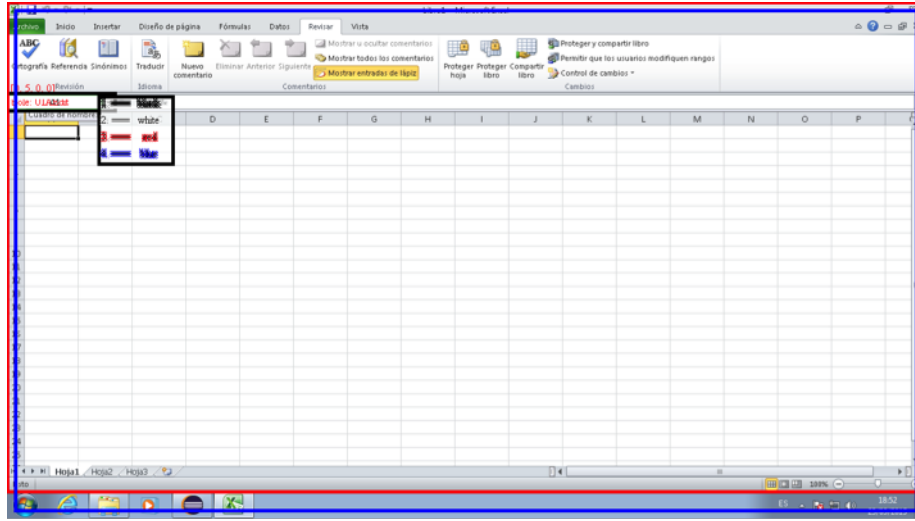


Figure 10: Hierarchical relationship between widgets

5.3 Test sequence generation and execution

Before running a complete test in the 'Generate'-Mode you have to pay attention to a few things:

1. **Actions definition** Define the set of actions that you want TESTAR to execute on your SUT: Although you may like to setup a thorough test that fully stresses your SUT, you might want to spare out certain actions, such as printing documents, terminating the SUT (which might be detected as a crash by the oracle) or minimizing it, etc. You might also want to only test a specific subset of all actions because you suspect that faults in specific dialogs of the GUI are more likely to be triggered. You can use the *ClickFilter* in the *Filters* tab to exclude actions on particular widgets (see section 4.2 for further details). You may also want to more precisely define the actions in the protocol editor, particularly the method named "deriveActions".
2. **Timing settings** Define startup time, action duration or wait time after actions. Those time settings might be important for your test, since they influence the reproducibility of sequences. If you start sequence generation too early (before the SUT has been fully loaded) or execute actions too fast / do not give the GUI enough time to react, your generated sequences will still find faults. However, these faults might be more exotic (a human user might not be able to trigger them at all) and are usually very hard to reproduce since the timing aspect plays an important factor. (See section 4.4 to learn how to set these settings)
3. **SUT starting point** Make sure that the SUT always starts in the same initial state. This is very important to guarantee reproducibility. The large majority of SUTs remembers specific settings or saves the position of its windows as they have been during the last session. If you do not restore the SUT's settings to their defaults, a previously recorded sequence might not be replayed properly, simply because the SUT

starts in a different state during sequence generation and sequence replay (e.g. starts already with the last edited document opened). You can use the settings in the *misc* tab to delete or restore the SUT's settings files. Alternatively, you may want to edit TESTAR protocol, through its protocol editor, to programmatically perform suitable tasks.

4. **Making SUT ready for testing** In some cases it is necessary to perform certain actions soon after starting the SUT (e.g. when you need to login). To do this, you can edit the method "startSystem" of TESTAR protocol (see section 7 to find an example of this).
5. **Oracles definition** Define your oracle: TESTAR automatically detects certain faults, such as crashes. However, you might want to look for critical error messages or low responsiveness. Sections 4.3 and 4.6 describe how to set up oracles that help you find certain types of faults.
6. **Stopping criteria** Depending on how long you want TESTAR to run, you have to adjust your stopping criteria. You might want to run it for 5 hours (then you can use the Maximum Time setting in the *General Settings* tab) or have it generate 1000 sequences, etc. (See section 4.1 to learn how to set these settings)
7. **Foresee tests** It can be difficult to verify whether TESTAR will do what you told it to and thus you have to test your settings. Therefore you may use TESTAR inspection features in order to inspect the set of actions that TESTAR will execute later on (hit Shift + 1 to see the generated actions) or you can switch to the "Generate-Debug" mode using Shift + Left Arrow / Right Arrow.
8. **Take the testing control** You can also generate the sequence manually by switching to Generate-Manual (Shift + Left Arrow) mode. This way you can force TESTAR to select certain actions that you might find interesting. Notice that you will have to wait ActionWaitTime seconds between actions, if not some actions will be missed in the recorded test sequence.

Generally, it will take some time until you have everything set up for a full test. Make sure that you experiment with your settings in the Spy Mode and look for potential problems that might arise. Take a look at the appendix, which lists helpful keyboard shortcuts (e.g. stopping test generation etc.) that you can use once a test is running.

6 Viewing and replaying the results

During test generation in the *Generate Mode*, TESTAR will save all the sequences into the output directory as you can see in picture 11 (See appendix for further information)

Once TESTAR has finished a test, you might want to inspect those generated sequences to better understand faults or problems. There are basically four ways to do that:

1. **Replay the sequence:** Of course this is the preferred way, since it shows you directly what TESTAR has generated. When you start TESTAR you can click on the *Replay Mode Button* and TESTAR will ask you for the file to replay. Just select a sequence file of your choice and hit ok and TESTAR will try to replay it. You can even slow down the sequence in case it was recorded at a high speed (just increase the value for action

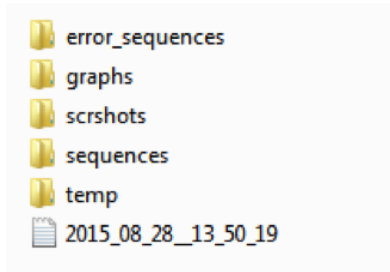


Figure 11: Output directory

duration). However, certain sequences might not be reproducible, because the SUT is not in the correct starting state (have you considered deleting / restoring settings files?) or the sequence was recorded too fast (increase the value of action duration and action wait time during sequence generation). In that case you can follow the steps shown on point 2.

2. View Screenshots of the Generated Sequence: Just hit the button for the *View Mode*. Again TESTAR will ask you for a file of a recorded sequence. Browse to the location of the file and hit ok. Now you will enter the *View Mode*, which will show you screenshots of each state that the SUT has been in during sequence generation. Just keep hitting “Next” to proceed to the next step, also you can go back to the previous action by pressing “Back”. There are two additional buttons that allows us go to the end (“End”) or the beginning (“Begin”) of the sequence. *The View Mode* will always work and it allows you to see what happened on the screen during sequence generation, which can be very helpful in case you are unable to replay a previously recorded sequence.
3. Graph: Three different test sequence graphs are generated in order to let you see which UI States were traversed and which actions were executed. Each one offers you a different level of information.
 - (a) Minimal: Contains the number of times that each state and action have been visited or executed.
 - (b) Tiny: This graph adds states/actions identificators to the minimal graph.
 - (c) Screenshoted: Contains the same information as the ones above plus screenshots of each state/action.

Additionally, these three graph versions are provided in abstracted versions: An abstract graph groups similar states and actions for a more simplistic representation. It helps to inspect too big graphs.

4. Log-files: TESTAR saves valuable information of each run on the log-file with the format `yyyy_mm_dd.hour_min_sec`. (See section 4.1: Login Verbosity for further details).

7 Further documentation

For more information we have a FAQs page here:

<http://webtestar.dsic.upv.es/index.php/faq/>

Moreover, the most recent overview paper explaining TESTAR and how it has been used in practice can be downloaded here:

http://webtestar.dsic.upv.es/wp-content/uploads/2015/06/testar_pub_ijismd2015.pdf

8 Experimental features

TESTAR development is still ongoing. Currently we are working on various extensions.

1. AdhocTest mode: This mode allows sending commands to TESTAR through a client. It activates a server to listen to test sequences (listening port: 47357). To send an order use the format `<action_type(parameters*)>\r\n` (i.e. `LC(500,420)` would indicate to TESTAR that it should left click at position 500,420).
2. ClickFilterLayerProtocol: Under Spy mode it enables you to add or remove a widget to a taboo list. When a widget is within that list, TESTAR will not be able to perform any action on it. On the other hand, we can add or remove a widget to a white list. This will permit TESTAR to interact with that widget even though other general rules should not allow it. Requirements: ClickFilterLayerProtocol and Spy mode, also you will need `<Shift+2 deactivated; Shift+1 activated>`. Shortcuts: Shift + Ctrl switch widget under cursor to White list. Ctrl switch widget under cursor to Black/Tabu list. Press the same button to return it to its previous state.
3. Actions prioritisation: Set priority to some actions to enable forms filling (text-input fields and slides). I.e. new database user creation: name/surname, phone, direction, etc.
4. QLearning: It is an alternative algorithm to random. This algorithm has different criteria to choose which should be the following action to be executed (e.g. Max reward, discount...). It needs further investigation to see if it provides improvements. To learn more about QLearning see <https://en.wikipedia.org/wiki/Q-learning>.

9 Known issues

When using Java 8, an exception takes place when we open the protocol editor provided by TESTAR. This error will be solved in further versions, however it does not affect the editor, so you will be able to use it without problems.

TESTAR might consume too much memory in long tests, so you could get an Out-OfMemory error with long sequences (e.g. more than 5000 actions). To solve this problem you can modify the file `testar.bat` by increasing the value of the argument `"-Xmx"` (e.g. `-Xmx2g`).

10 Acknowledgements

Besides the current TESTAR developers, we want to mention Sebastian Bauersfeld who worked on the initial versions of the tool due to financing under the FITTEST project ICT-2009.1.2 no 257574. The current TESTAR team is being funded by different initiatives that we will mention here. The SHIP project (SMEs and HEIs in Innovation Partnerships) (reference: EACEA/A2/UHB/CL 554187), whose objective is to transfer technologies from university to companies. The PERTEST project (TIN2013-46928-C3-1-R) on software testing. A proof of concept project financed by the Universidad Politecnica de Valencia (Programa de Prueba de Concepto 2014, SP20141402).

11 Appendix

11.1 Keyboard shortcuts

Within the various modes, TESTAR accepts several shortcuts:

Shortcut	Effect	Modes
Shift + Arrow Down	Quit TESTAR	Spy, GenerateManual, Generate, Replay
Shift + Arrow Up	Save snapshot of current state to output directory	Spy, GenerateManual, Generate, Replay Text
Shift + Arrow Left/Arrow Right	Switch Mode	Spy, GenerateManual, Generate, GenerateDebug, Replay
Shift + 1	Toggle Action Visualization	Spy
Shift + 2	Toggle visualization of Widget under Cursor	Spy
Shift + 3	Toggle widget information	Spy
Shift + Enter	Activates a server to listen to test sequences (port 47357)	GenerateManual,Generate, GenerateDebug,Spy
Alt	Show hierarchical relationship	Spy
Ctrl	Add/remove widget title from a filter list	Spy (requirement: ClickFilterLayerProtocol)
Shift + Ctrl	Add/Remove widget title from a white list	Spy (requirement: ClickFilterLayerProtocol)

Table 2: Shortcuts

11.2 Directories

./temp	Temporary files such as the currently recorded sequence
./output	TESTAR outputs log files, state snapshots and generated sequences into this directory
./output/error_sequences	Sequences on which TESTAR has found an error
./output/graphs	TESTAR generate different graphs for each sequence
./output/srcshots	Screenshots of each sequence showing every state and the widgets that have been selected
./output/sequences	Generated sequences
./resources	If you have files for your SUT that need to be restored through copying, you can put them in here

Table 3: Directories