

## The design of the PowerTools engine

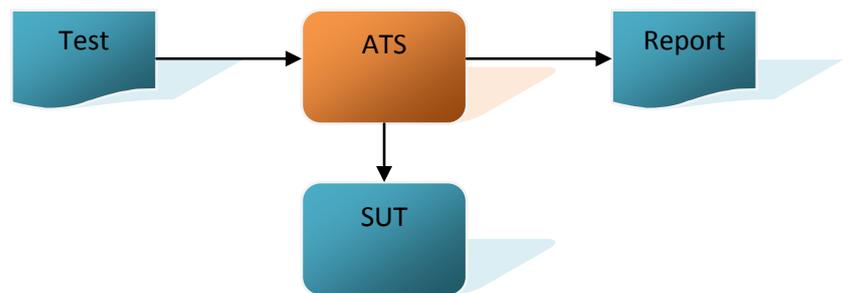
The PowerTools engine is an open source test engine that is written in Java. This document explains the design of the engine, so that it can be adjusted to suit the needs of others. It assumes a basic understanding of automated testing from the reader. The document first explains the basic functionality and some terminology. Then the basic design and the main components are introduced. The remaining sections describe the internals of the main components.

The PowerTools engine is the core of the PowerTools. The PowerTools also include interfacing tools that make available other open source tools like Selenium / WebDriver.

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### The basics

Running an automated test for a System Under Test (SUT) means reading instructions from a test, executing them against the SUT and reporting the results. The complete system that performs these tasks will be called an Automated Test System



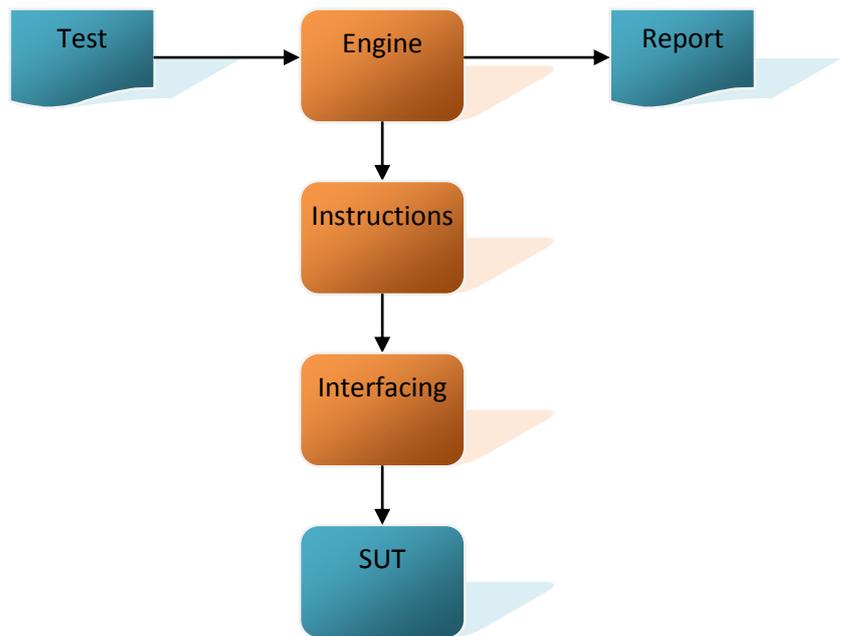
(ATS). An ATS usually consists of several pieces of software, that work together to perform the functions mentioned above. This software can be divided in three parts: The engine, instructions and interfacing. These will be described in a moment.

Two important terms that need to be defined now are ‘instruction’ and ‘test line.’ An instruction is a command that the engine knows how to execute. This can be a user defined instruction like ‘create client’ or it can be a built-in instruction of the engine like ‘define constant.’ An instruction can have one or more parameters, for instance the client name or city of residence. A test line is a line in a test that refers to an instruction and provides the arguments – the actual values that the instruction will work with. So a parameter is basically the *name* for what the instruction will work with, and an argument is the *actual value* that the instruction will use. An instruction can look differently for different projects, but the concepts of instruction, test line, parameter and argument apply in each case.

	name	city	email
enter client	John Doe	Amsterdam	john@doe.com

enter client	John Doe	in	Amsterdam	with email	john@doe.com
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A test (execution) engine is a generic piece of software that executes an automated test. It reads the test, invokes the instructions it identifies and reports results. It is generic in the sense that it does not need any information about the system that is being tested. Since it does not directly interact with the SUT, it does not need to know what product is being tested, what this product does, what type(s) of interface it has or what technology was used to build it. All this is taken care of in the instructions and interfacing parts of the ATS. As a result, the same test engine can be used for many different systems or applications, with many kinds of interfaces.



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- It reads instructions from a test line source like a FitNesse table or an Excel sheet.
- It evaluates expressions that appear in instructions.
- It invokes the code that implements the instructions.
- It generates one or more test reports.

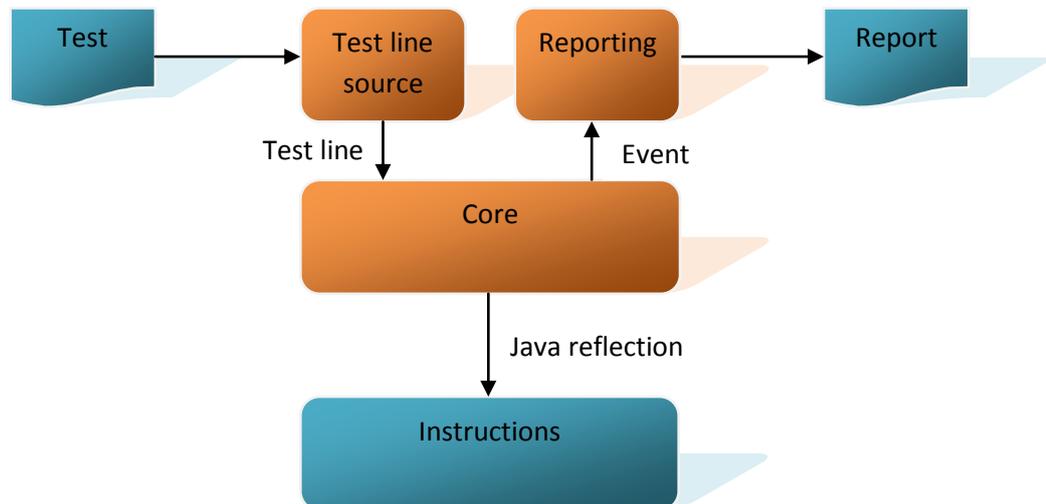
The instructions part of the ATS implements the instructions that can appear in a test. Instructions are invoked by the engine as it encounters them in the test lines that it reads. The engine needs to know which instructions exist and how to invoke them, but that is all. An instruction can do whatever the tester that invented it wants it to do. The instructions do not normally access the SUT directly but use the interfacing part for this.

The interfacing part provides access to the SUT, for both actions towards it and for retrieving information from it. Normally, existing libraries are used that either provide direct access or access a tool that takes care of it.

Please note that a number of instructions is built into the test engine instead of the instructions part. These are generic and relatively basic instructions that indicate the structure of the test or support passing data around.

## The basic design

The basic design of the engine shows the test line sources, core and reports. Test line sources select the test lines in the input document. They deliver them one by one to the core in the form of test line objects. A test line object contains an instruction name and its arguments. The instruction name in the test line is used to identify the Java method that implements the instruction. This method is then invoked using Java reflection, passing it the arguments from the input document. All relevant events are published in one or more reports.



A test line is made available within the engine through the `ITestLine` interface (all packages and files are specified relative to the `org.powerTools.engine` package), which offers four methods:

```
int getNrOfParts()
String getOriginalPart(int partNr)
String getEvaluatedPart(int partNr)
boolean isEmpty()
```

The first part in the test line, part zero, is the instruction name. The remaining parts contain the arguments. Both the original version and the evaluated version of each part are available, in case you want to use the text as it appeared in the test, but the evaluated form is used almost everywhere.

The events to report are communicated to the reporting component through the `reports.TestRunResultPublisher` class. Most events are reported by the engine itself rather than from instruction implementations.

A method that implements an instruction is a regular Java method. But in order for the engine to find it, the method must satisfy two conditions: The class that defines it must be registered with the engine and the method name must be a CamelCase version of the instruction name. When looking for an instruction, the engine will first create a proper method name from the instruction name by CamelCase-ing it: An instruction 'enter client address' must be implemented using a method called `EnterClientAddress(...)`. If a registered class has a method of this exact name, the engine will find it and invoke it. The method can have any number of parameters. It will receive the test line arguments in its parameters.

## Test line sources

The common functionality for test line sources is part of the `sources` package. Test lines may be read from any kind of document, including plain text, XML or Excel. The document types that are currently supported are Microsoft Excel (both `.xls` and `.xlsx`) and FitNesse Wiki pages, but you can use any document as a test line source if you implement a class that will parse the file and return its test lines. A test line source must extend the abstract class `TestSource` and implement two abstract methods: `void initialize()` and `TestLine getTestLine()`. The `initialize()` method is useful for some test line sources and left empty for the rest. It avoids having the constructor of a test line source throwing exceptions in case of errors.

The `XlsTestSource` class uses the API provided by the Apache POI project (<http://poi.apache.org>) to parse sheets in `.xls` files. The `getTestLine()` method iterates over the rows, skipping empty lines and lines with an empty first column. It also takes care to discard any trailing empty columns, to avoid accidentally passing too many arguments to an instruction.

Documents can define procedures, or scripted instructions, if the test line source supports this feature. It must then recognize an instruction that starts the definition of a procedure, collect the instructions that make up the procedure and create a `Procedure` object for it. This object requires the parameters and the instructions added to it. A parameter can be an output parameter, meaning that a symbol (like a variable) can be passed as an argument and assigned to from within the procedure. After registering the procedure, it will automatically be invoked when it is encountered in a test. A `ProcedureTestSource` object will be created and used to get the next test lines from.

## Evaluating expressions

The last step in preparing a test line is evaluating any expressions. An expression starts with a question mark and can contain literal constants, names of symbols and operators. This evaluation functionality is common between all test line sources and is implemented in their base class, `TestSource`. All other relevant code is in the `expression` package.

The evaluation of an expression is performed in two stages. The parsers for both stages are generated using the ANTLR parser generator ([www.antlr.org](http://www.antlr.org)). The first stage is taken care of by a lexer and parser that are generated from the grammar in `Expression.g`. They check the expression for lexical or syntactical errors and throw an exception if they find one. If the expression is syntactically correct, the parser returns an abstract syntax tree (AST) for it, a data structure that represents the whole expression.

The second stage of parsing is the actual evaluation. It uses the tree walker grammar in `ExpressionTreeWalker.g` to 'parse' the AST. The value of any symbols (constants, variables, etc.) is retrieved from the current scope. The operators are given a default implementation that throws an exception with a meaningful error message in abstract base class `Value`. The derived classes provide the proper implementations.

If evaluation of any expression fails, the test line is skipped. So any test line that is passed to the core component has all expressions already evaluated.

## Reporting

The reporting component is found in the `reports` package. The `TestRunResultPublisher` class publishes the events it receives to all registered report objects. The events have been grouped in four interfaces:

<i>Interface name</i>	<i>Type of events</i>
<code>ITestSubscriber</code>	Test run
<code>ITestCaseSubscriber</code>	Test case
<code>ITestLineSubscriber</code>	Test line
<code>ITestResultSubscriber</code>	Test line result

A report that is interested in the events in a particular interface can implement that interface and register itself with the publisher. This allows a separate report with only the error messages, a log with all details, or any other combination of events.

## The core

The core component receives test lines from the test line source component, invokes the code that implements the instructions in the test lines, and passes various events to the reporting component. It also provides a runtime API to instructions code.

Since every project has its own combination of instructions, test document format and reporting wishes, you have to indicate how you want your engine to work. By subclassing the abstract class `Engine`, you get to select these. One or more test document formats can be supported by creating one or more `run()` methods that select the desired test line source. New types can be added if necessary. The report format(s) can be selected in the constructor by adding the reports to the publisher. Here also, new types can be added if necessary. The classes that implement instructions are specified to the `InstructionExecutors` object so that it can find instruction methods.

Several built-in instructions are provided in the `BuiltinInstructions` class, but these instructions are not made available by default. A specific set of these instructions can be supported by creating a new class with basic instructions (that reuse the existing functionality) and registering it.

If it is important that state is retained between calls to the `run()` methods, the engine class should be a singleton class.

When a test is run, the `run()` method of the engine will keep requesting and executing test lines from the specified test line source until they run out. Since the test line source will only return a valid test line with expressions already evaluated, the `execute()` method can look up the method to invoke without further checking of the test line. The `Executor` object it receives contains all relevant information for invoking that method. It also converts the arguments to the types that the method expects (if these are basic types like `int` and `float`), so parsing of (numerical) parameters by the instruction itself is not needed.

## Exchanging data

One way to pass data around between instructions is to let an instruction save it in a place that is accessible to other instructions, for instance data members of the instruction class. While such mechanisms can obviously work just fine, it has the disadvantages that 1) it would have to be implemented again and again for many situations and 2) it is not always clear in the test case how data is passed around, which increases the maintenance effort. The engine offers a simple but powerful mechanism that supports the data exchange needs of many situations by offering 'symbols.'

A symbol is a logical name for a value. It is the same concept as that of variables in a programming language, but made available in tests as well as in the code that implements instructions. Some of the built-in instructions that are normally made available in test cases are 'define constant,' 'define variable' and 'set.' These allow a tester to give a logical name to a value that will be used in a test. The value of a symbol is available in expressions. A simple use of this mechanism is making configuration items like URLs available anywhere in the test. A more powerful use of it is returning results from instructions back to the test, as in the simple example below.

define variable	accountNr		
create account	John Doe	john@doe.com	accountNr
send welcome email	?accountNr		

The 'create account' instruction receives a variable name to store the generated account number in. The 'send welcome email' instruction receives the account number as it was stored in the accountNr variable.

This mechanism works for structured data as well as for single data values. Unlike constants and variables, structures can hold many data items, as in the below example.

define variable	accountNr		
define structure	person		
set	person.firstName	John	
set	person.lastName	Doe	
set	person.email	John@doe.com	
create account	person	accountNr	
send welcome email	?accountNr		

This functionality is not only available from a test, but also from instruction code. The runtime allows creating a symbol and setting and retrieving the value of a symbol. One place where this is needed is the 'create account' instruction that will need to set the variable that should receive the generated account number.

## The runtime

The core provides internal classes and instruction classes access to some of its basic features using a runtime object. Any instructions class with a constructor with an `IRunTime` interface will receive the runtime object upon creation (using reflection). The instruction methods can use it to report errors, warnings and debug info. But the runtime also provides access to the stack of test lines sources and the associated symbols like constants and variables.

Since a test line source can invoke another one, including procedures, a stack of test line sources can be active at any moment. A test sheet could refer to another sheet, which calls a procedure, which calls another procedure. Each of these can define 'symbols' like constants and variables, some only at the global scope and others with a limited scope. A variable that is defined in an Excel sheet will have global scope for example; it will be visible at any point during the test run after the point where it is defined. A parameter of a procedure will only exist while the procedure is being executed, and the same for a variable that is defined inside the procedure. These symbols can be accessed using the API of the `TestSourceStack`. It includes creating variables and constants, setting and retrieving the value of a symbol.