

# Manual for SMAC version v2.04.02-master

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July 6, 2013

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# 1 Introduction

This document is the manual for SMAC [2] (an acronym for *Sequential Model-based Algorithm Configuration*). SMAC aims to solve the following *algorithm configuration* problem: Given a binary of a parameterized algorithm  $\mathcal{A}$ , a set of instances  $\mathcal{S}$  of the problem  $\mathcal{A}$  solves, and a performance metric  $m$ , find parameter settings of  $\mathcal{A}$  optimizing  $m$  across  $\mathcal{S}$ .

In slightly more detail, users of SMAC must provide:

- a parametric algorithm  $\mathcal{A}$  (an executable to be called from the command line),
- a description of  $\mathcal{A}$ 's parameters  $\theta_1, \dots, \theta_n$  and their domains  $\Theta_1, \dots, \Theta_n$ ,
- a set of benchmark instances,  $\Pi$ , and
- the objective function with which to measure and aggregate algorithm performance results.

SMAC then executes algorithm  $\mathcal{A}$  with different *parameter configurations* (combinations of parameters  $\langle \theta_1, \dots, \theta_n \rangle \in \Theta_1 \times \dots \times \Theta_n$ , on instances  $\pi \in \Pi$ ), searching for the configuration that yields overall best performance across the benchmark instances under the supplied objective. For more details please see [2]; if you use SMAC in your research, please cite that article. It would also be nice if you sent us an email – we are always interested in additional application domains.

## 1.1 License

SMAC will be released under a dual usage license. Academic & non-commercial usage is permitted free of charge. Please contact us to discuss commercial usage.

## 1.2 System Requirements

SMAC itself requires only Java 6<sup>1</sup> or newer to run. The included scripts are currently only available for Unix-compatible operating systems. The included example scenarios require Ruby.

## 1.3 Version

This version of the manual is for SMAC v2.04.02-master-483.

Project	Version	Commit	Dirty Flag
fastrf	v1.05.01-master-89	37eb5bea2cc01327f8ce7b395e56310b7e0b493a	0
ACLib	v2.04.01-master-429	7cdcd3c32a72c0c0f2af2a951b1f5f293eacf7ea	0
SMAC	v2.04.02-master-483	2636bd0b31ab576d195f0f3822b60c5ca9bee356	0

NOTE: For non-master builds these commits may not contain everything in the build. (*i.e.*, non-master builds can be built with uncommitted changes). If the dirty flag is 0 that means the commit contains this exact copy, 1 means there were some uncommitted changes, and something else means some other error occurred when we tried to generate this.

## 2 Differences Between SMAC and ParamILS

There are a number of differences between SMAC and ParamILS, including the following.

- **Support for continuous parameters:** While ParamILS was limited to categorical parameters, SMAC also natively handles continuous and integer parameters. See Section 4.4.1 for details.
- **Run objectives:** Not all of ParamILS’s run objectives are supported at this time. If you require an unsupported objective please let us know.
- **Order of instances:** In contrast to ParamILS, the order of instances in the instance file does not matter in SMAC.
- **Configuration time budget and runtime overheads:** Both ParamILS and SMAC accept a time budget as an input parameter. ParamILS only keeps track of the CPU time the target algorithm reports and terminates once the sum of these runtimes exceeds the time budget; it does *not* take into account

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<sup>1</sup>Sun Java version 1.6.0\_23 or later recommended

overheads due to e.g. command line calls of the target algorithm. In cases where the reported CPU time of each target algorithm run was very small (e.g. milliseconds), these unaccounted overheads could actually dominate ParamILS’s wall-clock time. SMAC offers a more flexible management of its runtime overheads through the options **--countSMACTimeAsTunerTime** and **--wallClockLimit**. See Section 3.3 for details on the wall clock time limit.

- **Resuming previous runs:** While this was not possible in ParamILS, in SMAC you can resume previous runs from a saved state. Please refer to Section 3.4 for how to use the state restoration feature. Section 5.2 describes the file format for saved states.
- **Feature files:** SMAC accepts as an optional input a feature file providing additional information about the instances in the training set; see Section 4.3.
- **Algorithm wrappers:** The wrapper syntax has been extended in SMAC to support additional results in the “solved” field. Specifically, there is a new result **ABORT** signalling that the configuration process should be aborted (e.g. because the wrapper is in an inconsistent state that should never be reached). A similar behaviour is triggered if option **--abortOnFirstRunCrash** is set and the first run returns **CRASHED**. Additionally, the wrapper can also return additional data to SMAC that is associated with the run <sup>2</sup>. For more information see Section 4.5.2.
- **Instance files vs. instance/seed files:** The **instance\_file** parameter now auto-detects whether the file conforms to ParamILS’s **instance\_file** or **instance\_seed\_file** format. SMAC treats the latter option as an alias for the former. See Section 4.2 for details. While SMAC is backwards compatible with previous (space-separated) files, the preferred format is now `.csv`.

### 3 Commonly Used Options

To get started with an existing configuration scenerio you simply need to execute smac as follows:

```
./smac --scenarioFile <file> --numRun 0
```

This will execute SMAC with the default options on the scenario specified in the file. Some commonly-used non-default options of SMAC are described in this section. The **--numRun** argument controls the seed and names of output files (to support parallel independent runs)

#### 3.1 ROAR Mode

```
./smac --scenarioFile <file> --executionMode ROAR --numRun 0
```

This will execute the ROAR algorithm, a special case of SMAC that uses an empty model and random selection of configurations. See [2] for details on ROAR.

---

<sup>2</sup>This data will be saved in the run and results file (Section 5.2) that is used in state saving

## 3.2 Adaptive Capping

```
./smac --scenarioFile <file> --adaptiveCapping true --numRun 0
```

Adaptive Capping (originally introduced for ParamILS [3], but also applicable in SMAC [1]) will cause SMAC to only schedule algorithm runs for as long as is needed to determine whether they are better than the current incumbent. Without this option, each target algorithm runs up to the runtime specified in the configuration scenario file **--cutoffTime**.

NOTE: Adaptive Capping should only be used when the **--runObj** is **RUNTIME**. Adaptive capping can drastically improve SMAC's performance for scenarios with a large difference between **--cutoffTime** and the runtime of the best-performing configurations. Related configuration options are **--capSlack**, **--capAddSlack**, and **--imputationIterations**.

## 3.3 Wall-Clock Limit

```
./smac --scenarioFile <file> --runtimeLimit <seconds> --numRun 0
```

SMAC offers the option to terminate after using up a given amount of wall-clock time. This option is useful to limit the overheads of starting target algorithm runs, which are otherwise unaccounted for. This option does not override **--tunerTimeout** or other options that limit the duration of the configuration run; whichever termination criterion is reached first triggers termination.

## 3.4 State Restoration

```
./smac --scenarioFile <file> --restoreStateFrom <dir>  
      --restoreIteration <iteration> --numRun 0
```

SMAC will read the files in the specified directory and restore its state to that of the saved SMAC run at the specified iteration. Provided the remaining options (e.g. **--seed**, **--overall\_obj**) are set identically, SMAC should continue along the same trajectory.

This option can also be used to restore runs from SMAC v1.xx (although due to the lossy nature of Matlab files and differences in random calls you will not get the same resulting trajectory). By default the state can be restored to iterations that are powers of 2, as well as the 2 iterations prior to the original SMAC run stopping. If the original run crashed, additional information is saved, often allowing you to replay the crash.

NOTE: When you restore a SMAC state, you are in essence preloading a set of runs and then running the scenario. In certain cases, if the scenario has been changed in the meantime, this may result in undefined behavior. Changing something like **--tunerTimeout** is usually a safe bet, however changing something central (such as **--runObj**) would not be.

To check the available iterations that can be restored from a saved directory, use:

```
./smac-possible-restores <dir>
```

To disable saving any state information to disk, use

```
./smac --scenarioFile <file> --stateSerializer NULL --numRun 0
```

### 3.5 Concurrent Algorithm Execution Requests

```
./smac --scenarioFile <file> --maxConcurrentAlgoExecs <num> --numRun 0
```

In certain circumstances, it may be much faster to allow more than one target algorithm execution at once, (e.g., when multiple cores are available or when actual algorithm execution is I/O bound). To exploit this, you can have SMAC schedule multiple runs at a time. If **--adaptiveCapping** is not set, this will result in the same trajectory as a sequential version (when **--maxConcurrentAlgoExecs** is set to 1). When adaptive capping is enabled, concurrent runs are scheduled with cutoff times as if each were the first of the runs to be scheduled.

### 3.6 Named Rungroups

```
./smac --scenarioFile <file> --runGroupName <foldername> --numRun 0
```

All output is written to the folder <foldername>; runs differing in **--numRun** will yield different output files in that folder.

### 3.7 Offline Validation

SMAC includes a tool for the offline assessment of incumbents selected during the configuration process. By default, given a test instance file with  $N$  instances, SMAC performs  $\approx 1\,000$  target algorithm validation runs per configuration (rounded up to the nearest multiple of  $N$ ).

By default, SMAC limits the number of seeds used in validation runs to 1 000 seeds per instance. This number can be changed as in the following example:

```
./smac --scenarioFile <file> --numSeedsPerTestInstance 50
```

(This parameter does not have any effect in the case of instance/seed files.)

#### 3.7.1 Limiting the Number of Instances Used in a Validation Run

To use only some of the instances or instance seeds specified you can limit them with the **--numTestInstances** parameter. When this parameter is specified, SMAC will only use the specified number of lines from the top of the file, and will keep repeating them until enough seeds are used:

```
./smac --scenarioFile <file> --numTestInstances 10
```

For instance files containing seeds, this option will only use the specified number of instance seeds in the file.

#### 3.7.2 Disabling Validation

Validation can be skipped altogether as follows:

```
./smac --scenarioFile <file> --skipValidation
```

### 3.7.3 Standalone Validation

SMAC also includes a method of validating configurations outside of a smac run. You can supply a configuration using the **-configuration** option. All scenario options are applicable to the standalone validator, but check the usage screen to see all the options available NOTE: Some options while present are not applicable for validation but are presented anyway.

Here is an example call:

```
./smac-validate --scenarioFile <file> --numValidationRuns 10000  
--configuration <config string> --maxConcurrentAlgoExecs 8 --numRun 0
```

Usage notes for the offline validation tool:

1. This validates against the test set only; the training instance set is not used.
2. By default this outputs into the current directory; you can change the output directory with the option **--runGroupName**.
3. You can also validate against a trajectory file issued by **--trajectoryFile** option.

## 4 File Format Reference

### 4.1 Option Files

Option Files are a way of saving a different set of values frequently used with SMAC without having to specify them on every execution. The general format for an option file is the name of the configuration option (without the two dashes), an equal sign, and then the value (for booleans it should be true or false, lowercase). Currently options that take multiple arguments are not supported. Additionally you can not use aliases that are single dashed (e.g. to override the Experiment Directory, you must use **--experimentDir** and not **-e**)

When using Option Files it is important that no two files (including the Scenario File), specify the same option, the resulting configuration is undefined, and in general this will not throw an error.

#### 4.1.1 Scenario File

The Scenario Option File, or Scenario File, is the recommended way of configuring SMAC<sup>3</sup>. The Scenario Files used in SMAC are backwards compatible with ParamILS and the name of option names here reflect that<sup>4</sup>. NOTE: **cutoff.length** is not currently supported.

**algo** An algorithm executable or wrapper script around an algorithm that conforms with the input/output format specified in section 4.5. The string here should be invocable via the system shell.

**execdir** Directory to execute <algo> from: (i.e. "cd <execdir>; <algo>")

---

<sup>3</sup>Nothing in general prevents you from specifying non-scenario options in these files, but in general you should restrict your files to these.

<sup>4</sup>Every option name listed here is in fact an alias for an existing option listed in the section 9.4 and it is entirely possible to use SMAC without using Scenario Files.

**deterministic** A boolean that governs whether or not the algorithm should be treated as deterministic. For backwards compatibility with ParamILS, this option also supports using 0 for false, and 1 for true. SMAC will never invoke the target algorithm more than once for any given instance, seed and configuration. If this is set to `true`, SMAC will never invoke the target algorithm more than once for any given instance and configuration.

**run\_obj** Determines how to convert the resulting output line into a scalar quantifying how “good” a single algorithm execution is, (*e.g.* how long it took to execute, how good of a solution it found, etc...). Currently implemented objectives are the following:

Name	Description
<b>RUNTIME</b>	<b>The reported runtime of the algorithm.</b>
<b>QUALITY</b>	<b>The reported quality of the algorithm.</b>

**overall\_obj** While **run\_obj** defines the objective function for a single algorithm run, **overall\_obj** defines how those single objectives are combined to reach a single scalar value to compare two parameter configurations. Implemented examples for this are as follows:

Name	Description
<b>MEAN</b>	<b>The mean of the values</b>
<b>MEAN1000</b>	<b>Unsuccessful runs are counted as <math>1000 \times \text{cutoff\_time}</math></b>
<b>MEAN10</b>	<b>Unsuccessful runs are counted as <math>10 \times \text{cutoff\_time}</math></b>

**cutoff\_time** The CPU time after which a single algorithm execution will be terminated as unsuccessful (and treated as a **TIMEOUT**). This is an important parameter: If chosen too high, lots of time will be wasted with unsuccessful runs. If chosen too low the optimization is biased to perform well on easy instances only.

**tunerTimeout** The limit of the CPU time allowed for configuration (*i.e.* The sum of all algorithm runtimes, and by default the sum of the CPU time of SMAC itself).

**paramfile** Specifies the file with the parameters of the algorithm. The format of this file is covered in Section 4.4.

**outdir** Specifies the directory SMAC should write its results to.

**instance\_file** Specifies the file containing the list of problem instances (and possibly seeds) for SMAC to use during the *Automatic Configuration Phase*. The ParamILS parameter **instance\_seed\_file** aliases this one and the format is auto-detected. The format of these files is covered in section 4.2.

**test\_instance\_file** Specifies the file containing the list of problem instances (and possibly seeds) for SMAC to use during *Validation Phase*. The ParamILS parameter **test\_instance\_seed\_file** aliases this one and the format is auto-detected. The format of these files is covered in section 4.2.

**feature\_file** Specifies the a file with the features for the instances in the **instance\_file** and possibly the **test\_instance\_file**<sup>5</sup>. The format of this file is covered in section 4.3.

---

<sup>5</sup>The Validator will load features into memory for test instances if they exist.



## 4.2 Instance File Format

The files used by the **instance\_file** & **test\_instance\_file** options come in four potential formats, all of which are CSV based<sup>6</sup>. Before specifying the formats it is important to note the three kinds of information that are specified with instances<sup>7</sup>.

**Instance Name** The name of the instance that was selected. This should be meaningful to the target algorithm we are configuring<sup>8</sup>.

**Instance Specific Information** A free form text string (with no spaces or line breaks) that will be passed to the Target Algorithm whenever executed.

**Seed** A specific seed to use when executing the target algorithm.

The possible formats are as follows, and depend on what information you'd like to specify.

1. Each line specifies only a unique **Instance Name**. No **Instance Specific Information** will be used, and **Seed**'s will be automatically generated.
2. Each line specifies a **Seed** followed by the **Instance Name**. Every line must be unique, but for each **Instance Name** additional seeds will be used in order, when that instance is selected.
3. Each line specifies a **Instance Name** followed by the **Instance Specific Information**. Every **Instance Name** must be unique, **Seed**'s will be automatically generated.
4. Each line specifies a **Seed** followed by the **Instance Name** followed by the **Instance Specific Information**. Every line must be unique, and furthermore, for all **Instance Name**'s the **Instance Specific Information** must be the same for all **Seed** values (*i.e.* You cannot specify different instance specific information that is a function of the seed used).

## 4.3 Feature File Format

The **feature\_file** specifies features that are to be used for instances. Feature Files are specified in CSV format, the first column of every row should list an **Instance Name** as it appears in the **instance\_file**. The subsequent columns should list `double` values specifying a computed continuous feature. By convention the value `-512`, and `-1024` are used to signify that a feature value is missing or not applicable. All instances must have the same number of features.

At the top of the file there MUST appear a header row, the cell that appears above the instance names is unimportant, but for each feature a unique and *non-numeric* (*i.e.* it must contain atleast one letter) feature name must be specified.

---

<sup>6</sup>Specifically each cell should be double-quoted (*i.e.*”), and use a comma as a cell delimiter. SMAC also supports the old method of reading files that use space as a cell delimiter and do not enclose values. However these files cannot handle **Instance Name**'s that contain spaces.

<sup>7</sup>Features which are required for SMAC but not ParamILS are specified in a seperate file see section 4.3.

<sup>8</sup>Generally **Instance Names** reference specific files on disk.

## 4.4 Algorithm Parameter File

The parameter configuration space of your algorithm need to be defined in a file that is specified by the **paramfile** option. Comments in the file begin with a #, and run to the end of the line.

The file consists of three types of statements:

**Parameter Declaration Clauses** specifies the name of parameters, and their domains.

**Conditional Parameter Clauses** specify when a parameter is active.

**Forbidden Parameter Clauses** specify when a combination of parameter settings is illegal and should be ignored.

### 4.4.1 Parameter Declaration Clauses

SMAC supports two types of parameters, categorical and numeric. The former is specified as follows:

```
name { value1, ..., value_n } [defaultValue]
```

**Example:**

```
timeout { 1, 5, 10, 50, 100, 500, 1000, 5000, 10000 } [500]
```

Here a categorical parameter is declared named `timeout`, its values must be one of the values listed, and it has a default of 500.

Numeric Parameters (both continuous and integral) are specified as follows:

```
name [minValue, maxValue] [defaultValue] (i) (l)
```

**Example 1:**

```
timeout [1, 10000] [500]
```

We have specified `timeout` as numeric with a default value of 500. Any value is legally permitted so long as it's in the Real interval of  $[1, 10000]$ . When drawing a random configuration out of this space they are drawn uniformly.

**Example 2:**

```
timeout [1, 10000] [500]l
```

This example is identical to the previous, except that when drawing random configurations we do so uniformly on a  $\log_{10}$  scale (*e.g.* a value between  $[1, 100]$  is as likely to be selected as between  $[100, 10000]$ ).

**Example 3:**

```
timeout [1, 10000] [500]i
```

In this example the only legal values are integers in the range  $[1, 10000]$ , we select from these integers uniformly.

**Example 4:**

```
timeout [1, 10000] [500]il
```

In this example integers in the range  $[1, 10000]$  are the only values permitted, and when randomly selecting them we do so on a  $\log_{10}$  scale.

#### Restrictions

**Integer** Numeric integral parameters must have all values specified as integers, even though strictly speaking the notation should permit fractional values. Additionally the default value must be an integer.

**Log** Log parameters must have strictly positive lower and upper bounds.

#### 4.4.2 Conditional Parameter Clause

Conditional parameter clauses specify when a parameter is active. A parameter is active when for each clause that lists it as a dependent, the independent variable is active and has a value that satisfies the operation <sup>9</sup>.

Conditional Parameter Clauses have the following syntax:

```
dependentName | independentName operation { value1, ... , value_n }
```

**Example:**

```
sort-algo { quick, insertion, merge, heap, stooge, bogo } [ bogo ]
quick-revert-to-insertion { 1,2,4,8,16,32,64 } [16]
quick-revert-to-insertion | sort-algo in { quick }
```

In the above example the `quick-revert-to-insertion` is conditional on the `sort-algo` parameter being set to `quick`, and will be ignored otherwise.

#### 4.4.3 Forbidden Parameter Clauses

Forbidden Parameters are combinations of parameter settings which should not be treated as valid by SMAC. During the search phase, parameters matching a forbidden parameter configuration, will not be explored <sup>10</sup>.

The Syntax is as follows:

```
{ name1=val1 , name2=val2, ... }
```

**Example**

```
quick-sort { on, off } [on]
bubble-sort { on, off } [off]
{ quick-sort=on, bubble-sort=on }
{ quick-sort=off, bubble-sort=off }
```

The above example implements an exclusive-or <sup>11</sup>. The first forbidden parameter clause prevents both sort techniques from being on at the same time. The second ensures that atleast one of them is on. NOTE: The default parameter setting cannot itself be a forbidden parameter setting.

### 4.5 Algorithm executable / wrapper

The target algorithm as specified by the **algo** parameter must obey the following general contracts. While modifying your own code to directly achieve this is one option there are other methods outlined in section 4.5.3.

#### 4.5.1 Invocation

The algorithm must be invocable via the system command-line using the following command with arguments:

```
<algo_executable> <instance_name> <instance_specific_information> <cutoff_time>
<cutoff_length> <seed> <param> <param> <param>...
```

**algo\_executable** Exactly what is specified in the **algo** argument in the scenario file.

---

<sup>9</sup>The only supported operation presently is `in`.

<sup>10</sup>Specifying a large number of forbidden parameters may degrade SMAC's performance substantially.

<sup>11</sup>Admittedly it could be better modelled with a simple categorical parameter.

**instance\_name** The name of the problem instance we are executing against.

**instance\_specific\_information** An arbitrary string associated with this instance as specified in the **instance\_file**. If no information is present then a “0” is always passed here.

**cutoff\_time** The amount of time in seconds that the target algorithm is permitted to run. It is the responsibility of the callee to ensure that this is obeyed. It is not necessary that the actual algorithm execution time (wall clock time) be below this value (*e.g.* If the algorithm needs to cleanup, or it’s only possible to terminate the algorithm at certain stages).

**cutoff\_length** A domain specific measure of when the algorithm should consider itself done.

**seed** A positive integer that the algorithm should use to seed itself (for reproducibility). “-1” is used when the algorithm is **deterministic**

**param** A setting of an active parameter for the selected configuration as specified in the Algorithm Parameter File. SMAC will only pass parameters that are active. Additionally SMAC is not guaranteed to pass the parameters in any particular order. The exact format for each parameter is:  
-name 'value'

All of the arguments above will always be passed, even if they are inapplicable, in which case a dummy value will be passed.

## 4.5.2 Output

The Target Algorithm is free to output anything, which will be ignored but must at some point output a line (only once) in the following format<sup>12</sup>

```
Result for ParamILS: <solved>, <runtime>, <runlength>, <quality>, <seed>,  
<additional rundata>
```

**solved** Must be one of **SAT** (signifying a successful run that was satisfiable), **UNSAT** (signifying a successful run that was unsatisfiable), **TIMEOUT** if the algorithm didn’t finish within the allotted time, **CRASHED** if something untoward happened during the algorithm run, or **ABORT** if something prevents the target algorithm from successfully executing and it is believed that further attempts would be futile.

SMAC does not differentiate between **SAT** and **UNSAT** responses, and the primary use of these is historical and serves as a check that the algorithm is executing correctly by outputting whether the instance in question is satisfiable or not. See the **--verifySAT** option for information on how to utilize this feature.

SMAC also supports reporting **SATISFIABLE** for **SAT** and **UNSATISFIABLE** for **UNSAT**. NOTE: These are only aliases and SMAC will not preserve which alias was used in the log or state files.

**ABORT** can be useful in cases where the target algorithm cannot find required files, or a permission problem prevents access to them. This will cause SMAC to stop running immediately. Use this option with care, it should only be reported when the algorithm knows for CERTAIN that subsequent

---

<sup>12</sup>ParamILS is not a typo. While other values are possible including SMAC, HAL. ParamILS is probably the most portable. The exact Regex that is used in this version is: `^\s*(Final)?\s*[Rr]esult\s+(?:(for)—(of))\s+(?:(HAL)—(ParamILS)—(SMAC)—(this wrapper))`

results may fail. For things like sporadic network failures, and other cosmic-ray induced failures, one should consider using **CRASHED** in combination with the **--retryTargetAlgorithmRunCount** and **--abortOnCrash** options, to mitigate these.

**runtime** The amount of CPU time used during this algorithm run. SMAC does not measure the CPU time directly, and this is the amount that is used with respect to **tunerTimeout**. You may get unexpected performance degradation when this amount is heavily under reported <sup>13</sup>.

NOTE: The **runtime** should always be strictly less than the requested **cutoff.time** when reporting **SAT** or **UNSAT**.

If an algorithm reports **TIMEOUT** or **CRASHED** the algorithm can report the actual CPU time used, and SMAC will treat it correctly as a timeout for optimization purposes, but count the actual time for **--tunerTimeout** purposes.

**runlength** A domain specific measure of how far the algorithm progressed.

**quality** A domain specific measure of the quality of the solution.

**seed** The seed value that was used in this target algorithm execution. NOTE: This seed **MUST** match the seed that the algorithm was called with. This is used as fail-safe check to ensure that the output we are parsing really matches the call we requested.

**additional rundata** A string that will be associated with the run as far as SMAC is concerned. This string will be saved in run and results file (Section 5.2).

Like invocation, all fields are mandatory, when not applicable 0's can be substituted.

### 4.5.3 Wrappers & Native Libraries

In order to optimize an algorithm, SMAC needs a method of invoking it. While modifying the code to manage the timing and input mechanisms manually is possible, this can sometimes be invasive and difficult to manage. There exist three other methods that one could consider using.

**Wrappers** Executable Scripts that manage the resource limits automatically and format the specified string into something usable by the actual target algorithm. This approach is probably the most common, but among its drawbacks are the fact that they often rely on third party scripting languages, and for smaller execution times have a large amount of overhead that may not be accounted for as far as the **tunerTimeout** limit is concerned. Most of the examples included in SMAC use this approach, and the wrappers included can be adapted for your own projects.

NOTE: When writing wrappers it is important not to poll the output stream of the target algorithm, especially if there is lots of output. Doing so often results in lock-contention and significantly modifies the runtime performance of the algorithm enough that the resulting configuration is not well tuned to the real algorithm's performance.

---

<sup>13</sup>This typically happens when targeting very short algorithm runs with large overheads that aren't accounted for.

**Native Libraries Augmentation** Libraries exist (See: **TBD**) for C and Java currently that facilitate adding the required functionality directly to the code. While parsing the arguments into the necessary data structures is still required, they do manage the timing and output requirements in most cases. Unlike the previous approach however, certain crashes may not allow the the values to be outputted (*e.g.* a segmentation fault occurs).

**Target Algorithm Evaluators** This is probably the most powerful, but also the most complicated approach. SMAC is architected in a way that makes it fairly simple to replace the mechanism for execution with something completely custom. This can be done without even recompiling SMAC by creating a new implementation of the `TargetAlgorithmEvaluator` interface, which is responsible for converting run requests (`RunConfig` objects) into run results (`AlgorithmRun` objects). Both the input and output objects are simple *Value Objects* so the coupling between SMAC and the rest of your code is almost zero with this approach. For more information see 6.3

## 5 Interpreting SMAC's Output

SMAC outputs a variety of information to log files, trajectory files, and state files. Most of the files are human readable, and this section describes these files.

NOTE: All output is written to the **outdir** in the **--runGroupName** sub-directory.

### 5.1 Logging Output

SMAC uses `slf4j` (<http://www.slf4j.org/>), a library that allows for abstracting and replacing the logging system with ease, and uses `logback` (<http://logback.qos.ch/>) as the default logging system. While there is limited ability to change logging options via the command line (*e.g.*, **--logLevel**, **--consoleLogLevel**, **--logAllCallStrings**, **--logAllProcessOutput**), one can edit `conf/logback.xml`, to get much more control over the logging of SMAC. For more details of how to edit this file consult the `logback` documentation.

NOTE: If you replace the logger in SMAC or modify the configuration file, the logging command line options may no longer work.

By default SMAC writes the following logging files out to disk (NOTE: The *N* represents the **--numRun** setting):

**log-run*N*.txt** A log file that contains a full dump of all the information logged, and where it was logged from.

**log-warn*N*.txt** Contains the same information as the above file, except only from warning and higher level messages.

**log-err*N*.txt** Contains the same information as the above file, except only from error messages.

**runhashes-run*N*.txt** A file that contains only the Run Hash Codes for a given run see the corresponding entry in the **FAQ**.

#### 5.1.1 Interpreting the Log File

SMAC basically goes through three phases when executing:

- Setup Phase Input files are read, and their arguments validated. Everything necessary to execute the Automatic Configuration Phase is constructed. This phase ends (barring anything that must be lazily loaded), once the message `Automatic Configurator Started` is logged.
- Automatic Configuration Phase: SMAC is now actively configuring the target algorithm. SMAC will spend most of it's time here, and outputs it's progress. The most important output is the Runtime Statistics which will appear like:

```
[INFO ] *****Runtime Statistics*****
Iteration: 35
Incumbent ID: 64 (0x18824F)
Number of Runs for Incumbent: 70
Number of Instances for Incumbent: 70
Number of Configurations Run: 67
Performance of the Incumbent: 1589.1414639125514
Total Number of runs performed: 242
Wallclock time: 18.213 s
Wallclock time remaining: 2.147483628787E9 s
Configuration time budget used: 84056.83939320213 s
Configuration time budget remaining: 2343.160606797872 s
Sum of Target Algorithm Execution Times \
(treating minimum value as 0.1): 84036.36939320213 s
CPU time of Configurator: 20.47 s
User time of Configurator: 19.6 s
Total Reported Algorithm Runtime: 84033.27806288192 s
Sum of Measured Wallclock Runtime: 0.0 s
Max Memory: 3505.8125 MB
Total Java Memory: 1249.0625 MB
Free Java Memory: 719.8940582275391 MB
[INFO ] *****
```

While most of the fields are self-explanatory some deserve special attention:

Incumbent ID

The second ID (0x18824F) is a hex-code that represents the configuration anywhere / everywhere it is logged. The first ID, 64, occurs in context where we know the configuration is intended to be run. This ID will corresponding to the ID in the state files. The second ID will always associate with a unique first ID, but not conversely. The second ID roughly represents the specific configuration in memory <sup>14</sup>.

Performance of the Incumbent

This represents the performance of the incumbent under the given **run\_obj** and **overall\_obj** on the runs so far.

Configuration time budget used

The tuner time that has been used so far.

Sum of Target Algorithm Execution Times

This represents the contribution of the algorithm runs to the Tuner Time (if applicable), in general each run contributes the minimum of 0.1 and it's reported runtime. This parameter differs from Sum of Measurement Wallclock Runtime in that the latter is a direct sum. If you are only running on algorithms with large runtime, this difference may be 0.

---

<sup>14</sup>Specifically every time a configuration is modified, this number is incremented. In cases where the configuration space is small, or we are examining a small part of it, SMAC may end up back at the same configuration again. As far as the behaviour of SMAC is concerned these are identical, the ID is only ever used for logging.

- Validation Phase, depending on the options used this can also take a large fraction of SMAC's runtime. The logic here is actually quite simple, as it largely only requires running many algorithm runs and computing the objectives from them.

At the end of Validation the Runtime Statistics (from the Automatic Configuration Phase) are displayed again, as is the following information

1. The performance of the incumbent on both the training and test set.
2. A sample call of the final incumbent (selected configuration)
3. The complete configuration selected (without inactive conditionals)
4. The complete configuration selected (with inactive conditionals)
5. The Return value of SMAC (generally 0 if successful)

## 5.2 State Files

State files allow you to examine and potentially restore the state of SMAC at a specific point of it's execution. The files are written to the `state-run $N$`  sub-directory, where  $N$  is the value of `--numRun` option.

All files have the following convention as a suffix either `it` or `CRASH` followed by either the iteration number  $M$ , or in some cases `quick` or `quick-bak`.

The state is saved for every iteration  $m$ , where  $m = 2^n$   $n \in \mathbb{N}$ , additionally it is saved when SMAC completes whether successfully or due to crash.

The following files are saved in this state directory (ignoring the suffix):

**java\_obj\_dump** Stores (Java) serialized versions of the the incumbent and the random object state. In general there is no need to look at this file, and it is not human readable.

**paramstrings** Stores a human readable setting of each configuration ran, with a prefix of the numeric id of the configuration (as used in the logs, and other state files).

**uniq\_configurations** Stores the configurations ran in a more concise but effectively un-human readable form. The first column again is the numeric id of the configuration (as used in the logs, and other state files).

**run\_and\_results** Stores the result of every run of the target algorithm that SMAC has done. The first 13 columns (after the header row are designed to be backwards compatible with SMAC versions 1.xx. Each column is labelled with what data it contains, the following columns deserve some description.

**Instance ID** This is the instance used, and is the  $n^{th}$  **Instance Name** specified in the **instance\_file** option.

**Response Value (y)** This is the value determined by the **run\_obj** on the run.

**Censored** Indicates whether the **Cutoff Time Used** field is less than the **cutoff\_time** in the original run. 0 means `false`, 1 means `true`.

**Run Result Code** This is a mapping from the **Run Result** to an integer for use with previous versions.

**param-file** If `--saveContext` is enabled, a copy of the **paramfile** will be in the state folder

**instances** If `--saveContext` is enabled, a copy of the **instance\_file** will be in the state folder

**instance-features** If `--saveContext` is enabled, and SMAC is running with features, then a copy of the **feature\_file** will be in the state folder.



**scenario** If `--saveContext` is enabled, and SMAC is using a scenario file, then a copy of the `--scenarioFile` will be in the state folder.

### 5.3 Trajectory File

SMAC also outputs a trajectory file into identical files `traj-run-N.txt`<sup>15</sup> and `traj-run-N.csv`. These files outline the incumbent (by id) over the course of execution and it's performance. The first line gives the `--runGroupName`, and then the `--numRun`.

The rest of the file follows the following format:

Column Name	Description
Total Time	Sum of all execution times and CPU time of SMAC
Incumbents Mean Performance	Performance of the Incumbent under the given <code>--runObjective</code> and <code>--overallObjective</code>
Wallclock Time $\sigma$	Time of entry with respect to wallclock time.
Incumbent ID	The ID of the incumbent as listed in the <code>param_strings</code> file 5.2.
acTime	CPU Time of SMAC
Remaining Columns	Give a name value mapping for the configuration value as given by the Incumbent ID column

### 5.4 Validation Output

When Validation is completed four files are outputted, (again *N* is the value of the `--numRun` argument):

1. `rawValidationExecutionResults-runN.csv`:

CSV File containing a list of the configuration, seeds & instance run and the corresponding result and the result of the target algorithm execution. This file is mainly for debugging.

2. `validationInstanceSeedResult-runN.csv`:

CSV File containing a list of seeds & instances and the resulting response value. Again this file is mainly for debugging, but is easier to parse than the previous.

3. `validationResultsMatrix-runN.csv`:

CSV File containing the list of instances on each line, the next column is the aggregation of the remaining columns under the `overall_obj`. Finally there is one additional row that gives the aggregation of all the individual `overall_obj`, aggregated in the same way.

`classicValidationResults-runN.csv`

CSV File containing the result of the validation. The columns are defined as follows:

Column Name	Description
Tuner Time	The tuner time when validation occurred
Emperical Performance	The incumbent's performance on the training set
Test Set Performance	The incumbent's performance on the test set
AC Overhead Time	Total CPU Time Used by the Automatic Configurator

<sup>15</sup>This file is outputted for backwards compatibility with existing scripts.

## 6 Developer Reference

This section is meant as a guide to those who need to modify the SMAC code base for whatever reason.

### 6.1 Design Overview

The SMAC Application is broken up into three distinct projects as follows:

**SMAC** Contains all of the logic that is specific to SMAC, (*e.g.* Validation, the SMAC algorithm, construction of SMAC Objects). In essence it stitches together components of the Automatic Configurator Library. The sources are included in `smac-src.jar`.

**Automatic Configurator Library** Contains all of the primary abstractions/models used by SMAC (*e.g.* Object representations for Instances, Target Algorithm Configurations & methods for executing algorithms,...). 90% of the code that SMAC uses lives in this library. It also contains code for converting the data from these abstractions into input needed to build the model. These are shipped with SMAC in the `aclib-src.jar` file.

**Random Forests** The Random Forest model code. The sources are included in `fastrf-src.jar`.

The scope of this document governs only the first two projects. At the time of writing the **Automatic Configurator Library** code base is in good shape, while the **SMAC** code base suffers from two key problems:

- A sizable portion of the 30 or so classes exist only for the porting process of SMAC from MATLAB to Java, and will be removed in future.
- The bulk of the code necessary to run SMAC lives in three classes `AbstractAlgorithmFramework`, `SequentialModelBasedAlgorithmConfiguration` and finally, `AutomaticConfigurator`. Each of these three classes has problems with poor cohesion (*i.e.* They are all basically doing too much, and could easily be broken up into smaller classes).

As most of the SMAC code is in the **Automatic Configurator Library**, these issues are hardly fatal, and will most likely just be surprising at how disjoint the code bases seem. While the **Automatic Configurator Library** is relatively stable, the **SMAC** portion of the code will be refactored over the coming months to clean up many of its deficiencies.

### 6.2 Class Overview

The most important classes to SMAC are as follows:

Automatic Configurator Library Classes	
Name	Description
AbstractOptions	Base class for creating new options for SMAC. While not important in and of itself, you will generally be implementing or modifying one of it's subtypes to implement options.
AlgorithmRun	Interface that represents the results of a target algorithm run. These are created by a TargetAlgorithmEvaluator. Outside of the TargetAlgorithmEvaluator these classes are generally immutable.
AlgorithmExecutionConfig	Immutable object containing the information required to invoke a target algorithm.
InstanceSeedGenerator	Interface that gets seeds for a ProblemInstance. These objects are constructed by ProblemInstanceHelper
ModelBuilder	Interface whose implementations should result in a constructed model.
OverallObjective	Aggregates many RunObjective values under some statistic (e.g.mean), to produce a value to be optimized.
ParamConfiguration	Class that represents a specific setting of the target algorithm's parameters. This class also implements the Map interface, though does not support all the required operations. The ID associated with is object, is used only for logging and should not be used in the code. Finally although this class is not immutable the general life cycle is that the object is created, given specific values, and then never changed again. In future this may be augmented with the ability to prevent writes. These objects are always constructed via the ParamConfigurationSpace.
ParamConfigurationSpace	(Almost immutable) class that represents the entire configuration space of a target algorithm. This class is constructed with the <b>Algorithm Parameter File</b> described in section 4.4. This class also contains the specifics of each parameter (e.g.domains, defaults, etc...). Currently the Random object used is the only portion that is mutable, and this will change in the future.
ProblemInstance	Immutable class that represents a specific problem instance, constructed by ProblemInstanceHelper.
ProblemInstanceSeedPair	Immutable class that represents a problem instance and seed. Decisions of which seed to use when scheduling a run are made in RunHistory.
RunConfig	Immutable class that represents a problem instance seed pair, and configuration to execute.
RunHistory	Interface that saves all the runs performed, and allows various queries against this information.
RunObjective	Converts an AlgorithmRun into a scalar value for optimization
SanitizedModelData	Converts the run data into a format to use when building the model. Other things such as PCA, and other data filtering are done here. This interface and mechanism will likely be refactored in the future as it is brittle at the moment.
SeedableRandomSingleton	A global random object whose existence is a convincing case that Singleton's are Anti-Patterns. This will, thankfully, go the way of the dodo bird at some point.
StateFactory	Interface that constructs StateSerializer & StateDeserializer to manage saving and restoring state respectively.
TargetAlgorithmEvaluator	Interface whose implementations should be able to run the algorithm (i.e. Implementations should convert RunConfig objects to AlgorithmRun objects). See section 6.3 for more information.

SMAC Library Classes	
Name	Description
AutomaticConfigurator	Constructs all objects necessary to execute SMAC (SMAC entrypoint)
AbstractAlgorithmFramework	<i>Non-abstract</i> class that provides a default Automatic Configurator (ROAR)
SequentialModelBasedAlgorithmConfiguration	Class that subtypes AbstractAlgorithmFramework and implements the methods required for SMAC
Validator	Performs Validation of selected configurations
ValidatorExecutor	Entry point to stand alone validation utility

### 6.3 Target Algorithm Evaluator

The **Target Algorithm Evaluator** subsystem is the part of the code you will be modifying if you would like to change how target algorithms are run. On the next page is a UML class diagram showing most of how this part of the code works.



Once constructed, the `TargetAlgorithmEvaluator` interface is simple, it simply needs to return a new `AlgorithmRun` object, for each `RunConfig` object passed as input, and in the same order, via the `TargetAlgorithmEvaluator.evaluateRun()` method. The construction of these objects is where the complexity lies and so here is a run through of the construction.

1. When the code starts up, SMAC requests a specific Target Algorithm Evaluator (using some globally unique String as a key), from `TargetAlgorithmEvaluatorBuilder.getTargetAlgorithmEvaluator()`
2. This invokes the similarly named method in `TargetAlgorithmEvaluatorLoader`, which uses SPI (see 6.4 for more information on SPI) to find the `TargetAlgorithmEvaluatorFactory` whose `getName()` method returns the matching string. The name MUST NOT have any white space. For reference, the `CommandLineTargetAlgorithmEvaluatorFactory` returns `CLI`.
3. When an match is found, a no argument constructor (in the diagram this is shown under the `CommandLineTargetAlgorithmEvaluator` class) is invoked.
4. Next the `getTargetAlgorithmEvaluator()` method is invoked which in the above diagram would return a `CommandLineTargetAlgorithmEvaluator`
5. With this new instance in hand, the `TargetAlgorithmEvaluatorBuilder` then wraps this object with various decorators (e.g. `RetryCrashedRunTargetAlgorithmEvaluator`) depending on the options supplied (not-shown).

The use of SPI allows new implementations to be created without modifying the existing SMAC code, and requires less maintenance to update to newer versions of SMAC. Unfortunately at the time of writing there are two limitations to keep in mind with this approach.

1. You cannot supply options to the user to configure your `TargetAlgorithmEvaluator`.
2. You cannot use this method to add new decorators.

Neither of these seems significant at the current time. If a new decorator is needed, you can hard code the base implementation and return a wrapped instance of it (i.e. Create a new `TargetAlgorithmEvaluatorFactory` that returns a wrapped instance of an existing `TargetAlgorithmEvaluator`). Configuration of the `TargetAlgorithmEvaluator` can be done via files at this point.

When using the SPI approach you are strongly encouraged to also implement **Plugin Versioning**; see Section 6.4.

## 6.4 Plugin Versioning

Any plug-ins or changes to SMAC should contain an implementation of `VersionInfo`, and the implementor should be labelled as a provider of `VersionInfo` via SPI<sup>16</sup>.

In essence this interface simply has two getter methods `getProductName()` and `getVersion()`. If everything is done correctly when SMAC starts up you should see the product name and version printed in the logs.

**Example:**

---

<sup>16</sup>SPI is the Service Provider Interface, see SPI on Wikipedia ([http://en.wikipedia.org/wiki/Service\\_provider\\_interface](http://en.wikipedia.org/wiki/Service_provider_interface)) as well as this utility which simplifies the process drastically (<http://code.google.com/p/spi/>)

```
[INFO ] Version of Automatic Configurator Library is v1.00.04dev-307
[INFO ] Version of Random Forest Library is v1.04.01dev-50
[INFO ] Version of SMAC is v2.00.01dev-318
[INFO ] Version of Surrogate is v1.01dev-227
```

This can make debugging and managing reproducibility much easier.

## 6.5 Run Hash Codes

A Run Hash Code is a sequence of hashes that represent which runs were scheduled by SMAC. When calling SMAC using

```
./smac --scenarioFile <file> --runHashCodeFile <logfile>,
```

SMAC logs all Run Hash Codes to <logfile>. This option allows reading of that log file for subsequent runs to ensure that the exact same set of runs is scheduled. This is primarily of use for developers.

## 7 Acknowledgements

We are indebted to Jonathan Shen for porting our random forest code from C to Java in preparation for a Java port of all of SMAC. We thank Marius Schneider for many valuable bug reports and suggestions for improvements. Thanks also to Chris Thornton for being a secondary beta tester.

## 8 References

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- [2] Hutter, F., Hoos, H. H., and Leyton-Brown, K. (2011b). Sequential model-based optimization for general algorithm configuration. In *Proc. of LION-5, LNCS*, pages 507–523.
- [3] Hutter, F., Hoos, H. H., Leyton-Brown, K., and Stützle, T. (2009). ParamILS: an automatic algorithm configuration framework. *Journal of Artificial Intelligence Research*, 36:267–306.

## 9 Appendix

### 9.1 Return Codes

NOTE: All error conditions besides 255 are fixed. However in future some exceptions that previously reported 255 may be changed to a non 255 value as needed / requested

Value	Error Name	Description
0	<b>Success</b>	Everything completed successfully
1	<b>Parameter Error</b>	There was a problem with the input arguments or files
2	<b>Trajectory Divergence</b>	For some reason SMAC has taken a unexpected path ( <i>e.g.</i> SMAC executes a run that does not match a run in the <b>--runHashCodeFile</b> )
3	<b>Serialization Exception</b>	A problem occurred when saving or restoring state
255	<b>Other Exceptions</b>	Some other error occurred

## 9.2 Version History of Java SMAC

**Version 2.00 (Aug-2012)** First Internal Release of Java SMAC (this is a port and extension of the original Matlab version).

**Version 2.02 (Oct-2012)** First Public Release of SMAC v2 and contained many fixes from the previous release.

**Version 2.04 (Dec-2012)** Second Release of Java SMAC including the following improvements:

1. Validation file output times consistent with Tuner Times
2. Some **INFO** log statements have been moved to **DEBUG** and some **DEBUG** to **TRACE**
3. Added support for verifying whether responses of SAT and UNSAT are consistent with Instance Specific Information see **--verifySAT** option for more information
4. Added support for the SMAC\_MEMORY environment variable to control how much RAM (in MB) SMAC will use when executed via the supplied shell scripts.
5. Context is now added to the state folders to make it easier to debug issues later, to disable consult the **--saveContext** option.
6. Greatly improved memory usage in State Serialization code, and now we free the existing model prior to building a new one, so for some JVMs this may improve memory usage.

**Version 2.04.01 (Feb-2013)** Minor Bug Fix of Java SMAC

1. Added option to validate over training set instances
2. Can now use <DEFAULT> as a configuration to validate against
3. Fixed bug where **TIMEOUT** runs below our requested cutoff time are not counted properly when considering incumbent changes
4. Can now specify the initial incumbent with the **--initialIncumbent** option.
5. Wallclock time is now saved in the trajectory file instead of -1
6. FAQ Improvements
7. Git commit hash is now documented in Manual, FAQ, and Version strings
8. **(BETA)** Support for bash auto-completion of arguments for `smac` and `smac-validate`. You can load the file by running:

```
. ./util/bash_autocomplete.sh
```



## Version 2.04.02 (Jul-2013) Minor Bug Fix of Java SMAC

1. Incumbent Performance now displayed when validation is turned off.
2. **--runtimeLimit** option is no longer just for show.

### 9.3 Known Issues

1. When using the **--initialIncumbent** option you **MUST** specify ALL parameters (even non-active ones), failure to do so may result in the model suffering poor performance or crashing.
2. Parameter files with values containing quotation marks, cannot be read by smac-validate.
3. SMAC may crash with a `ConvergenceException` when **--adaptiveCapping** is `true`, this has happened only once out of thousands of Runs, but we have no fix at this time other than trying a different seed. NOTE: The cause of this has been found and it will be fixed in version 2.06.
4. Trajectory file does not output standard deviation. NOTE: This column is now the wallclock time, and not standard deviation.
5. Using any alias for **--showHiddenParameters**, **--help**, or **--version** as values to other arguments (*e.g.* Setting `--runGroupName --help`) does not parse correctly (This is unlikely to be fixed until someone complains).
6. Using large parameter values in continuous integral parameters, may cause loss of precision, and or crashes if the values are too big.
7. On older versions of Java (<1.6.0\_23), SMAC may get an `IOException` with Out Of Memory when trying to execute the target algorithms

### 9.4 Options Reference

#### 9.4.1 SMAC Options

General Options for Running SMAC

**--adaptiveCapping** Use Adaptive Capping

**Aliases:** `--adaptiveCapping`

**Default Value:** Defaults to true when `--intraInstanceObjective` is `RUNTIME`, false otherwise

**Domain:**  $\{true, false\}$

**--capAddSlack** amount to increase computed adaptive capping value of challengers by (post scaling)

**Aliases:** `--capAddSlack`

**Default Value:** 1.0

**Domain:**  $(0, \infty)$

**--capSlack** amount to scale computed adaptive capping value of challengers by

**Aliases:** --capSlack

**Default Value:** 1.3

**Domain:**  $(0, \infty)$

**--cleanOldStateOnSuccess** will clean up much of the useless state files if smac completes successfully

**Aliases:** --cleanOldStateOnSuccess

**Default Value:** true

**Domain:**  $\{true, false\}$

**--consoleLogLevel** default log level of console output (this cannot be more verbose than the logLevel)

**Aliases:** --consoleLogLevel

**Default Value:** INFO

**Domain:**  $\{TRACE, DEBUG, INFO, WARN, ERROR, OFF\}$

**--countSMACTimeAsTunerTime** include the CPU Time of SMAC as part of the tunerTimeout

**Aliases:** --countSMACTimeAsTunerTime

**Default Value:** true

**Domain:**  $\{true, false\}$

**--doValidation** perform validation when SMAC completes

**Aliases:** --doValidation, --validation

**Default Value:** true

**Domain:**  $\{true, false\}$

**--executionMode** execution mode of the automatic configurator

**Aliases:** --executionMode

**Default Value:** SMAC

**Domain:**  $\{SMAC, ROAR\}$

**--expectedImprovementFunction** expected improvement function to use during local search

**Aliases:** --expectedImprovementFunction

**Default Value:** EXPONENTIAL

**Domain:**  $\{EXPONENTIAL, SIMPLE\}$

**--experimentDir** root directory for experiments Folder

**Aliases:** --experimentDir, -e

**Default Value:** <current working directory>

**--help** show help

**Aliases:** --help, -?, /?, -h

**--imputationIterations** amount of times to impute censored data when building model

**Aliases:** --imputationIterations

**Default Value:** 2

**Domain:** [0, 2147483647]

**--initialIncumbent** Initial Incumbent to use for configuration (you can use RANDOM, or DEFAULT as a special string to get a RANDOM or the DEFAULT configuration as needed). Other configurations are specified as: -(name) 'value' -(name) 'value' ...

**Aliases:** --initialIncumbent

**Default Value:** DEFAULT

**--initialIncumbentRuns** initial amount of runs to schedule against for the default configuration

**Aliases:** --initialIncumbentRuns, --defaultConfigRuns

**Default Value:** 1

**Domain:** (0, 2147483647]

**--initialN** initial amount of runs to request when intensifying on a challenger

**Aliases:** --initialN, --initialChallenge

**Default Value:** 1

**Domain:** (0, 2147483647]

**--intensificationPercentage** percent of time to spend intensifying versus model learning

**Aliases:** --intensificationPercentage, --frac\_rawruntime

**Default Value:** 0.5

**Domain:** (0, 1)

**--logLevel** Log Level for SMAC

**Aliases:** --logLevel

**Default Value:** DEBUG

**Domain:** {*TRACE, DEBUG, INFO, WARN, ERROR, OFF*}

**--maskInactiveConditionalParametersAsDefaultValue** build the model treating inactive conditional values as the default value

**Aliases:** --maskInactiveConditionalParametersAsDefaultValue

**Default Value:** true

**Domain:** {true, false}

**--maxIncumbentRuns** maximum number of incumbent runs allowed

**Aliases:** --maxIncumbentRuns, --maxRunsForIncumbent

**Default Value:** 2000

**Domain:** (0, 2147483647]

**--numChallengers** number of challengers needed for local search

**Aliases:** --numChallengers, --numberOfChallengers

**Default Value:** 10

**Domain:** (0, 2147483647]

**--numEIRandomConfigs** number of random configurations to evaluate during EI search

**Aliases:** --numEIRandomConfigs, --numberOfRandomConfigsInEI, --numRandomConfigsInEI, --numberOfEIRandomConfigs

**Default Value:** 10000

**Domain:** [0, 2147483647]

**--numIterations** limits the number of iterations allowed during automatic configuration phase

**Aliases:** --numIterations, --numberOfIterations

**Default Value:** 2147483647

**Domain:** (0, 2147483647]

**--numPCA** number of principal components features to use when building the model

**Aliases:** --numPCA

**Default Value:** 7

**Domain:** (0, 2147483647]

**--numRun** number of this run (and seed)

#### **REQUIRED**

**Aliases:** --numRun, --seed

**Default Value:** 0

**Domain:** [0, 2147483647]

**--optionFile** read options from file

**Aliases:** --optionFile

**--optionFile2** read options from file

**Aliases:** --optionFile2, --secondaryOptionsFile

**--restoreStateFrom** location of state to restore

**Aliases:** --restoreStateFrom

**Default Value:** N/A (No state is being restored)

**--restoreStateIteration** iteration of the state to restore

**Aliases:** --restoreStateIteration, --restoreIteration

**Default Value:** N/A (No state is being restored)

**--runGroupName** name of subfolder of outputdir to save all the output files of this run to

**Aliases:** --runGroupName

**Default Value:** RunGroup-<current date and time>

**--runtimeLimit** limits the total wall-clock time allowed during the automatic configuration phase

**Aliases:** --runtimeLimit, --wallClockLimit

**Default Value:** 2147483647

**Domain:** (0, 2147483647]

**--saveContext** saves some context with the state folder so that the data is mostly self-describing (Scenario, Instance File, Feature File, Param File are saved)

**Aliases:** --saveContext, --saveContextWithState

**Default Value:** true

**Domain:** {*true*, *false*}

**--seedOffset** offset of numRun to use from seed (this plus --numRun should be less than LONG\_MAX)

**Aliases:** --seedOffset

**Default Value:** 0

**--showHiddenParameters** show hidden parameters that no one has use for, and probably just break SMAC (no-arguments)

**Aliases:** --showHiddenParameters

**--stateDeserializer** determines the format of the files that store the saved state to restore

**Aliases:** `--stateDeserializer`

**Default Value:** `LEGACY`

**Domain:** `{NULL, LEGACY}`

**--stateSerializer** determines the format of the files to save the state in

**Aliases:** `--stateSerializer`

**Default Value:** `LEGACY`

**Domain:** `{NULL, LEGACY}`

**--totalNumRunsLimit** limits the total number of target algorithm runs allowed during the automatic configuration phase

**Aliases:** `--totalNumRunsLimit, --numRunsLimit, --numberOfRunsLimit`

**Default Value:** `9223372036854775807`

**Domain:** `(0, 9223372036854775807]`

**--treatCensoredDataAsUncensored** builds the model as-if the response values observed for cap values, were the correct ones [NOT RECOMMENDED]

**Aliases:** `--treatCensoredDataAsUncensored`

**Default Value:** `false`

**Domain:** `{true, false}`

**-v** print version and exit

**Aliases:** `-v, --version`

## 9.4.2 Scenario Options

Standard Scenario Options for use with SMAC. In general consider using the `--scenarioFile` directive to specify these parameters and Algorithm Execution Options

**--checkInstanceFilesExist** check if instances files exist on disk

**Aliases:** `--checkInstanceFilesExist`

**Default Value:** `false`

**Domain:** `{true, false}`

**--cutoffTime** CPU time limit for an individual target algorithm run

### REQUIRED

**Aliases:** `--cutoffTime, --cutoff_time`

**Default Value:** `0.0`

**Domain:**  $(0, \infty)$

**--instanceFeatureFile** file that contains the all the instances features

**Aliases:** --instanceFeatureFile, --feature\_file

**--instanceFile** file containing a list of instances to use during the automatic configuration phase (see Instance File Format section of the manual)

**REQUIRED**

**Aliases:** --instanceFile, -i, --instance\_file, --instance\_seed\_file

**Default Value:** null

**--interInstanceObj** objective function used to aggregate over multiple instances (that have already been aggregated under the Intra-Instance Objective)

**Aliases:** --interInstanceObj, --inter\_instance\_obj

**Default Value:** MEAN

**Domain:**  $\{MEAN, MEAN1000, MEAN10\}$

**--intraInstanceObj** objective function used to aggregate multiple runs for a single instance

**REQUIRED**

**Aliases:** --intraInstanceObj, --overallObj, --overall\_obj, --intra\_instance\_obj

**Default Value:** null

**Domain:**  $\{MEAN, MEAN1000, MEAN10\}$

**--outputDirectory** Output Directory

**Aliases:** --outputDirectory, --outdir

**Default Value:** <current working directory>/smac-output

**--runObj** per target algorithm run objective type that we are optimizing for

**REQUIRED**

**Aliases:** --runObj, --run\_obj

**Default Value:** null

**Domain:**  $\{RUNTIME, QUALITY\}$

**--scenarioFile** scenario file

**Aliases:** --scenarioFile

**--testInstanceFile** file containing a list of instances to use during the validation phase (see Instance File Format section of the manual)

## REQUIRED

**Aliases:** --testInstanceFile, --test\_instance\_file, --test\_instance\_seed\_file

**Default Value:** null

**--tunerTimeout** limits the total cpu time allowed between SMAC and the target algorithm runs during the automatic configuration phase

**Aliases:** --tunerTimeout

**Default Value:** 2147483647

**Domain:** [0, 2147483647]

**-p** File containing algorithm parameter space information (see Algorithm Parameter File in the Manual)

## REQUIRED

**Aliases:** -p, --paramFile, --paramfile

**Default Value:** null

### 9.4.3 Algorithm Execution Options

Options related to running the target algorithm

**--abortOnCrash** treat algorithm crashes as an ABORT (Useful if algorithm should never CRASH). NOTE: This only aborts if all retries fail.

**Aliases:** --abortOnCrash

**Default Value:** false

**Domain:** {*true*, *false*}

**--abortOnFirstRunCrash** if the first run of the algorithm CRASHED treat it as an ABORT, otherwise allow crashes.

**Aliases:** --abortOnFirstRunCrash

**Default Value:** true

**Domain:** {*true*, *false*}

**--algoExec** command string to execute algorithm with

## REQUIRED

**Aliases:** --algoExec, --algo

**Default Value:** null

**--deterministic** treat the target algorithm as deterministic

**Aliases:** --deterministic



**Default Value:** false

**Domain:**  $\{true, false\}$

**--execDir** working directory to execute algorithm in

**REQUIRED**

**Aliases:** --execDir, --execdir

**Default Value:** null

**--logAllCallStrings** log every call string

**Aliases:** --logAllCallStrings

**Default Value:** false

**Domain:**  $\{true, false\}$

**--logAllProcessOutput** log all process output

**Aliases:** --logAllProcessOutput

**Default Value:** false

**Domain:**  $\{true, false\}$

**--numConcurrentAlgoExecs** maximum number of concurrent target algorithm executions

**Aliases:** --numConcurrentAlgoExecs, --maxConcurrentAlgoExecs, --numberOfConcurrentAlgoExecs

**Default Value:** 1

**--retryTargetAlgorithmRunCount** number of times to retry an algorithm run before eporting crashed (NOTE: The original crashes DO NOT count towards any time limits, they are in effect lost). Additionally this only retries CRASHED runs, not ABORT runs, this is by design as ABORT is only for cases when we shouldn't bother further runs

**Aliases:** --retryTargetAlgorithmRunCount

**Default Value:** 0

**Domain:** [0, 2147483647]

**--runHashCodeFile** file containing a list of run hashes one per line: Each line should be: "Run Hash Codes: (Hash Code) After (n) runs". The number of runs in this file need not match the number of runs that we execute, this file only ensures that the sequences never diverge. Note the n is completely ignored so the order they are specified in is the order we expect the hash codes in this version. Finally note you can simply point this at a previous log and other lines will be disregarded

**Aliases:** --runHashCodeFile

**--targetAlgorithmEvaluator** Target Algorithm Evaluator to use when making target algorithm calls

**Aliases:** --targetAlgorithmEvaluator, --tae

**Default Value:** CLI

**--targetAlgorithmEvaluatorSearchPath** location to look for other target algorithm evaluators [ See manual but generally you can ignore this ]

**Aliases:** --targetAlgorithmEvaluatorSearchPath, --taeSP

**Default Value:** <current working directory>/plugins/ among others

**--verifySAT** Check SAT/UNSAT/UNKNOWN responses against Instance specific information (if null then performs check if every instance has specific information in the following domain SAT, UNSAT, UNKNOWN, SATISFIABLE, UNSATISFIABLE)

**Aliases:** --verifySAT

**Default Value:** null

**Domain:** {*true*, *false*}

#### 9.4.4 Random Forest Options

Options used when building the Random Forests

**--freeMemoryPercentageToSubsample** when free memory percentage drops below this percent we will apply the subsample percentage

**Aliases:** --freeMemoryPercentageToSubsample

**Default Value:** 0.25

**Domain:** (0, 1]

**--fullTreeBootstrap** bootstrap all data points into trees

**Aliases:** --fullTreeBootstrap

**Default Value:** false

**Domain:** {*true*, *false*}

**--ignoreConditionality** ignore conditionality for building the model

**Aliases:** --ignoreConditionality

**Default Value:** false

**Domain:** {*true*, *false*}

**--logModel** store response values in log-normal form

**Aliases:** --logModel

**Default Value:** true

**Domain:**  $\{true, false\}$

**--minVariance** minimum allowed variance

**Aliases:** --minVariance

**Default Value:** 1.0E-14

**Domain:**  $(0, \infty)$

**--numTrees** number of trees to create in random forest

**Aliases:** --numTrees, --nTrees, --numberOfTrees

**Default Value:** 10

**Domain:**  $(0, 2147483647]$

**--penalizeImputedValues** treat imputed values that fall above the cutoff time, and below the penalized max time, as the penalized max time

**Aliases:** --penalizeImputedValues

**Default Value:** false

**Domain:**  $\{true, false\}$

**--preprocessMarginal** build random forest with preprocessed marginal

**Aliases:** --preprocessMarginal

**Default Value:** true

**Domain:**  $\{true, false\}$

**--ratioFeatures** ratio of the number of features to consider when splitting a node

**Aliases:** --ratioFeatures

**Default Value:** 0.8333333333333334

**Domain:**  $(0, 1]$

**--shuffleImputedValues** shuffle imputed value predictions between trees

**Aliases:** --shuffleImputedValues

**Default Value:** false

**Domain:**  $\{true, false\}$

**--splitMin** minimum number of elements needed to split a node

**Aliases:** --splitMin

**Default Value:** 10

**Domain:**  $[0, 2147483647]$

**--storeDataInLeaves** store full data in leaves of trees

**Aliases:** --storeDataInLeaves

**Default Value:** false

**Domain:**  $\{true, false\}$

**--subsamplePercentage** multiply the number of points used when building model by this value

**Aliases:** --subsamplePercentage

**Default Value:** 0.9

**Domain:** (0, 1]

**--subsampleValuesWhenLowOnMemory** subsample model input values when the amount of memory available drops below a certain threshold (see --subsampleValuesWhenLowMemory)

**Aliases:** --subsampleValuesWhenLowOnMemory, --subsampleValuesWhenLowMemory

**Default Value:** false

**Domain:**  $\{true, false\}$

#### 9.4.5 Validation Options

Options that control validation

**--maxTimestamp** maximum relative timestamp in the trajectory file to configure against. -1 means auto-detect

**Aliases:** --maxTimestamp

**Default Value:** Auto Detect

**Domain:**  $[0, \infty) \cup \{-1\}$

**--minTimestamp** minimum relative timestamp in the trajectory file to configure against.

**Aliases:** --minTimestamp

**Default Value:** 0.0

**Domain:**  $[0, \infty)$

**--multFactor** base of the geometric progression of timestamps to validate (timestamps selected are:  $\maxTime \times \text{multFactor}^{-n}$  where  $n$  is  $\{1, 2, 3, 4, \dots\}$  while  $\text{timestamp} \geq \text{minTimestamp}$  )

**Aliases:** --multFactor

**Default Value:** 2.0

**Domain:**  $(0, \infty)$

**--numSeedsPerTestInstance** number of test seeds to use per instance during validation

**Aliases:** --numSeedsPerTestInstance, --numberOfSeedsPerTestInstance

**Default Value:** 1000

**Domain:** (0, 2147483647]

**--numTestInstances** number of instances to test against (will execute min of this, and number of instances in test instance file). To disable validation in SMAC see the --doValidation option

**Aliases:** --numTestInstances, --numberOfTestInstances

**Default Value:** 2147483647

**Domain:** (0, 2147483647]

**--numValidationRuns** approximate number of validation runs to do

**Aliases:** --numValidationRuns, --numberOfValidationRuns

**Default Value:** 1000

**Domain:** (0, 2147483647]

**--outputFileSuffix** Suffix to add to validation run files (for grouping)

**Aliases:** --outputFileSuffix

**--validateOnlyLastIncumbent** validate only the last incumbent found

**Aliases:** --validateOnlyLastIncumbent

**Default Value:** true

**Domain:** {*true*, *false*}

**--validationHeaders** put headers on output CSV files for validation

**Aliases:** --validationHeaders

**Default Value:** true

**Domain:** {*true*, *false*}

**--validationRoundingMode** selects whether to round the number of validation (to next multiple of numTestInstances)

**Aliases:** --validationRoundingMode

**Default Value:** UP

**Domain:** {*UP*, *NONE*}