FICO™ Xpress Optimization Suite

Xpress-Tuner

User guide

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Contents

1 Xpress-Tuner purpose

FICO™ Xpress solves MIP problems by applying a number of algorithms and techniques, such as cutting planes, heuristics, branch and bound search, *etc.* The Xpress internal algorithms are user customizable through *control parameters*. Xpress control parameters are designed to control one or more of:

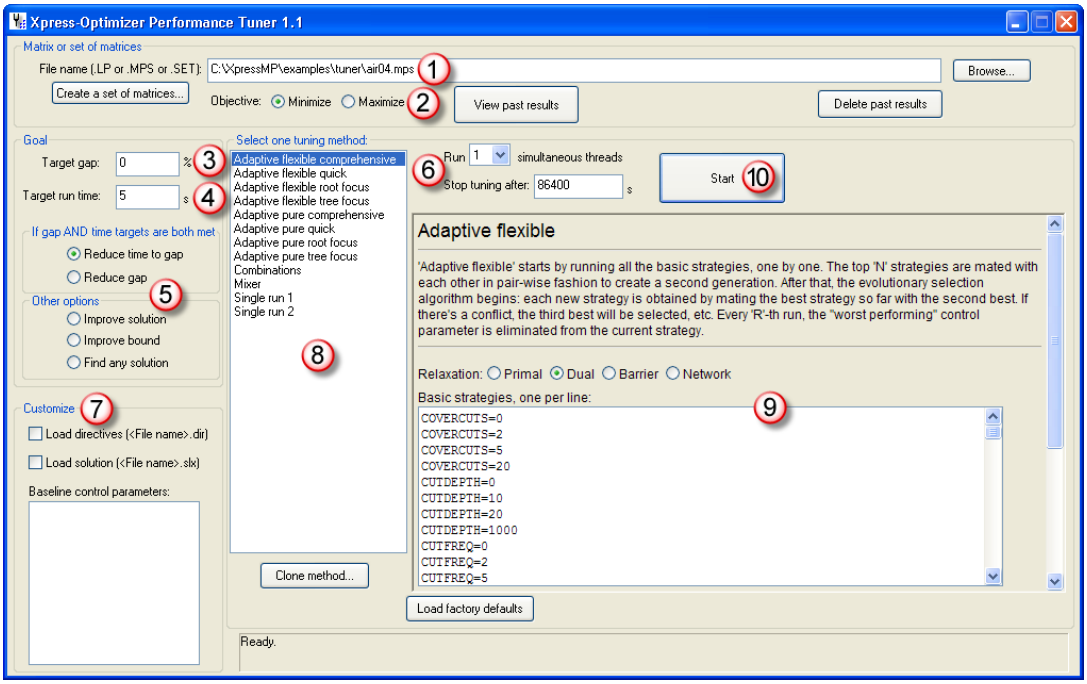
- A choice (*e.g.* breadth-first versus depth-first search)
- A set of choices (*e.g.* pick and choose presolve techniques)
- An amount (*e.g.* number of rounds of knapsack cuts)
- A frequency (*e.g.* apply heuristics every N nodes)

Xpress-Tuner will find a *favorable set of control parameters* that allow the Xpress-Optimizer to solve a particular MIP problem (or a set of problems) faster than by using defaults.

Xpress-Tuner is designed to be easy to use by a non expert, as it always provides a concise winning strategy that can be readily implemented using the Xpress-Optimizer libraries, Xpress-Mosel or Xpress-BCL. At the same time it provides a wealth of information to users familiar with Xpress control parameters, for deeper analysis of the problem behavior with respect to different solution approaches.

2 How to tune a problem

Upon starting Xpress-Tuner, the following application window appears:



The most important user interface elements are:

1. The problem file name: this can be an .MPS or .LP file, a compressed .MPS.GZ or .LP.GZ file, or a .SET file (containing a collection of matrices). It represents the file (or set of files) to be tuned. **Note:** Xpress-Tuner will create a working directory called "\tuner\" in the same directory where the problem file name is located. All tuner runs will be stored in the newly created directory.

2. Optimization direction: minimize or maximize.

3. The desired optimality gap for the problem. Usually 0%, but any number between 0-100% will work (*e.g.* 0.1%)

4. The desired run time for the problem. This should be a realistic expectation based on business requirements. For example, if Xpress takes 5 minutes to find the optimal solution and spends a lot of time branching, input an aggressive target time of 60 seconds. **Note:** Times are always in seconds.

5. *Reduce time to gap* is probably the most desired goal, but other goals are available as well.

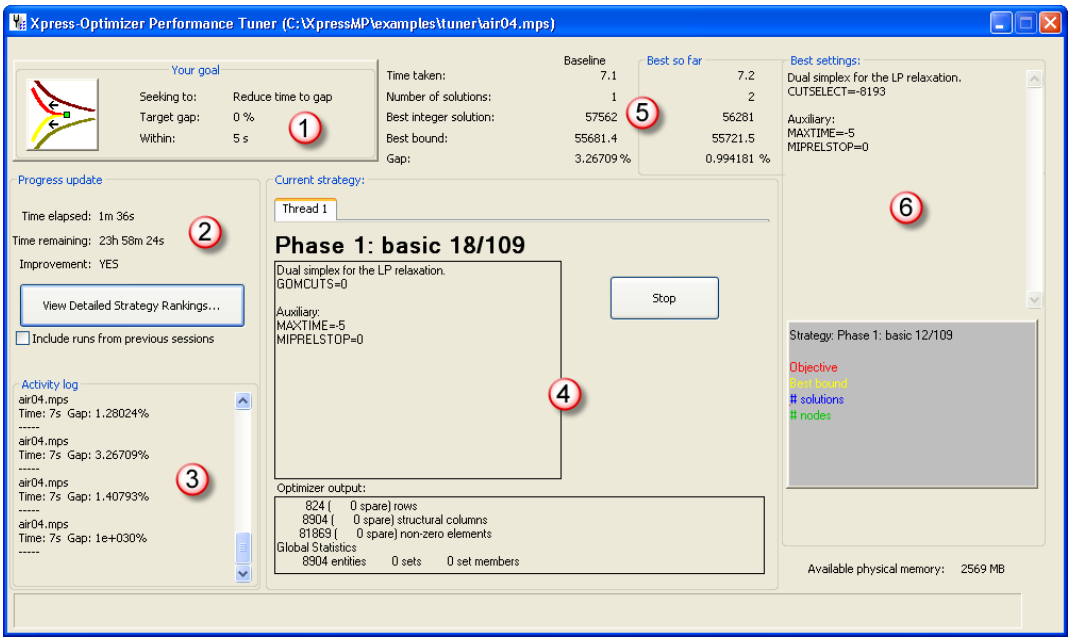
6. Allow Xpress-Tuner to use more than one thread. For best overall performance, use no more than one thread per available CPU/core. Also impose a maximum time limit on all the runs in a tuning session. Note that a generous amount of time may be necessary to obtain a good tuned strategy. Allow a minimum of 200 runs for best results (*e.g.* 60s $\times$ 200 runs = 12,000 s).

7. Optionally, force certain control parameter settings by entering them as baseline parameters. These will override any potential values that may be discovered by the automated tuner. Also check/uncheck the options to load a preexisting solution (.slx file) or a directives file (.dir) for *all* the tuner runs in a session.

8. Select a tuning method. *Adaptive flexible comprehensive* is the most comprehensive tuning method and is usually a good first choice. Other options (*e.g.* focus on root node, focus on branching) may be preferable if the performance shortcoming is better understood.
9. Customize the tuning method as necessary. Instructions are provided by each tuning method.
10. Clicking *Start* will launch the tuner.

3 Tuning process

While Xpress-Tuner is running, the display changes to:



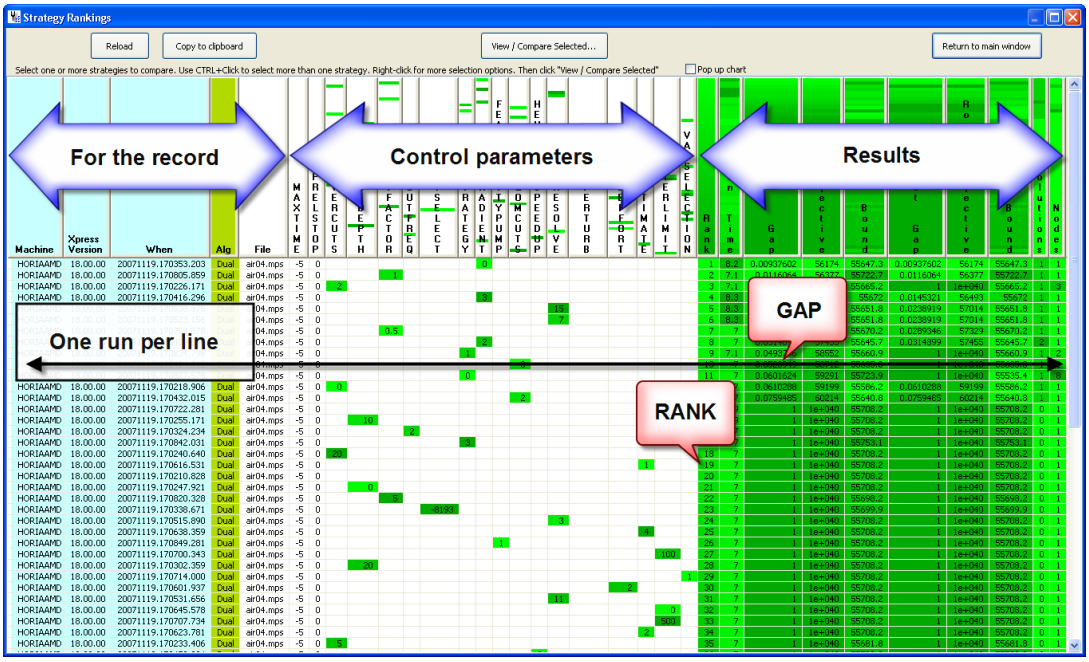
The most important elements/regions are:

1. A summary of the tuning goal, including the target (desired) gap and the time allowed per run.
2. The progress update section shows how much time has passed since the tuning session was started and how much time remains (based on the time limit imposed when starting the Tuner). This section also shows if the Tuner managed to improve on Xpress-Optimizer defaults. Finally, the button *View Detailed Strategy Rankings...* will open a more detailed window (described in section 4 of this Xpress-Tuner user guide). The checkbox *Include runs from previous sessions* controls whether runs from previous tuning sessions of the same problem will be displayed in the detailed window.
3. The activity log shows a very brief summary of a few previously completed strategy runs.
4. This section shows the active control parameter strategy and the output from the active optimization run. The Tuner session can be interrupted by pressing the *Stop* button (all Tuner results are stored on disk so stopping a session is a safe operation; next time, the Tuner will resume where it left off by reading the previous results from disk)
5. Together with number 6, the most important display section of the Xpress-Tuner: the *Baseline* versus *Best so far* comparison shows how the current best tuned strategy compares to the baseline run. In most cases, the Tuner will compare favorably. After every strategy run, this section is updated to show the current winning strategy.
6. The winning strategy settings: a list of control parameters that make up the winning strategy. This list is updated in tandem with the current best strategy and offers constant feedback on how the Tuner is performing.

To compare strategies against each other, click on *View Detailed Strategy Rankings*.

4 Detailed results

After clicking on *View Detailed Strategy Rankings*, the following window appears:



Each line in the list represents a run; each run represents a unique strategy tried by the Tuner. The columns in the list are:

Machine	The computer name where the Tuner is running.
Xpress Version	Version of the Xpress-Optimizer.
When	The date and time (+milliseconds) when the run was initiated.
Alg	The algorithm used for the initial LP relaxation.
File	The matrix (or set of files) being tuned.
MAXTIME	The time limit per run (imposed by the user) for the global search.
MIPRELSTOP	The relative gap stopping criterion (imposed by the user).
Control parameters	A varying number of control parameters. No value means default.
Rank	Rank based on the goal specified by the user (*e.g.*, best gap, best solution, *etc.*)
Run time	Actual time elapsed, for the entire solve, including initial LP relaxation.
Gap	The optimality gap. See the definition for MIPRELSTOP.
Objective	The best integer solution of the run.
Bound	The best bound of the run.
Root Gap	The optimality gap after the root node.
Root Objective	The best integer solution after the root node.

Root Bound	The best bound after the root node.
Solutions	Number of integer feasible solutions found.
Nodes	Number of branch and bound nodes explored.

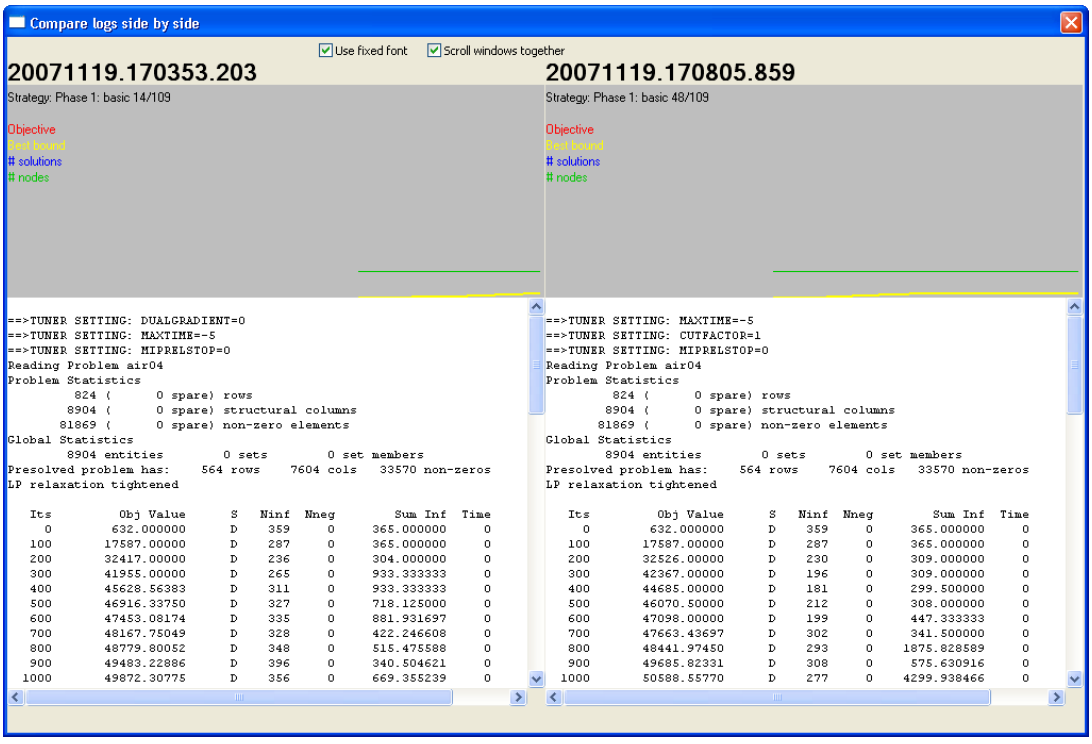
The shade of the color green indicates the relative rank of numbers *within* a column. *Lighter shades* of green indicate *smaller values*; *darker shades* of green indicate *larger values*.
Note: Comparisons between columns are meaningless.

In some cases, such as for the *Gap* column, lighter shades of green are better and will correlate with lower (better) *Rank* values. In other case, such as for the *Bound* column for a minimization problem, larger values (highlighted with dark shades of green) are better.

The results in the table can be sorted by clicking on any column header. The sorting is stable, which means that several criteria can be applied in series (*e.g.* sort by gap, then by objective, then by number of nodes).

The results in the table can be copied to the clipboard (*Copy to clipboard*) and then pasted in Excel, *etc.*

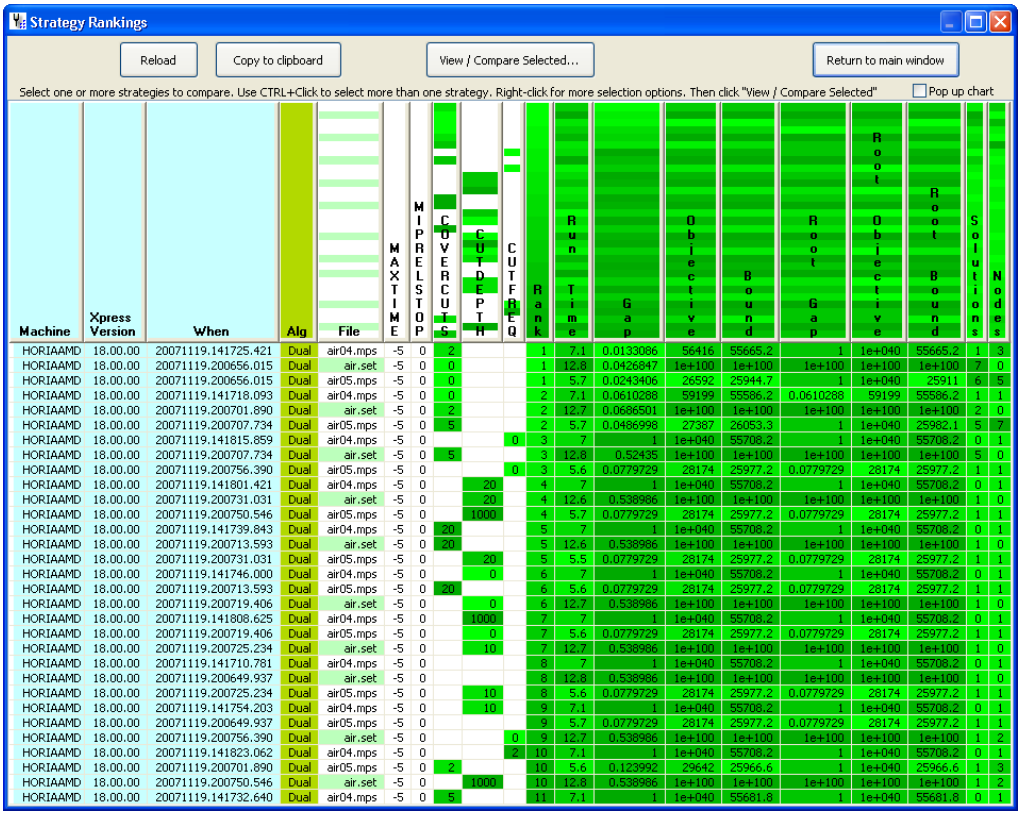
By right clicking in the results list, various options for manipulating the current selection will become available, such as selecting all the runs whose values in the current column are equal to the value currently under the mouse cursor. When one or more runs are selected, click on the button *View / Compare Selected...* to analyze the 2+ more runs side by side:



5 Tuning a set of problems

To ensure that the control parameter settings obtained using the Tuner are robust enough for an entire category of problems, it's a good idea to select a varied set of inputs to a mathematical model and generate several matrix instances of the same model. By grouping different matrix instances of the same model into a set and then allowing Xpress-Tuner to find a good tuned strategy for the set, you can better ensure that the settings will work well on new instances of the same model.

The *Strategy Rankings* window looks different when comparing set runs:

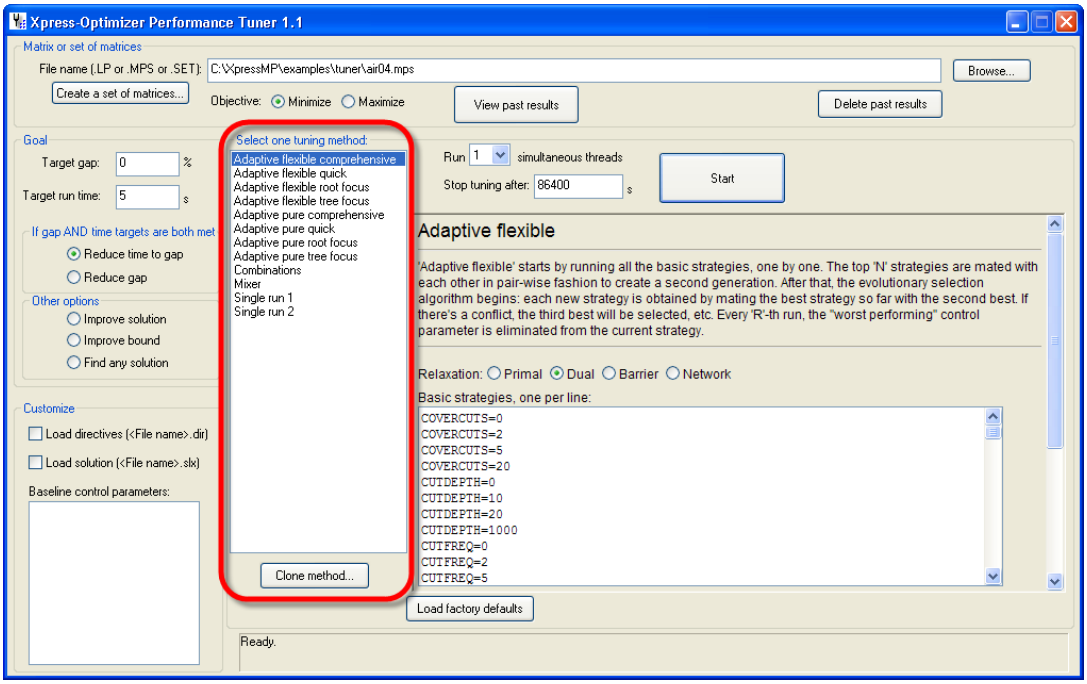


Machine	Xpress Version	When	Alg	File	MAXTIME	MIPRELSTOP	COVERCUTS	CUTDEPTH	CUTFREQ	Rank	Run Time	Gap	Objective	Bound	Root Gap	Root Objective	Root Bound	Solutions	Nodes
HORIAAMD	18.00.00	20071119.141725.421	Dual	air04.mps	-5	0	2			1	7.1	0.0133086	56416	55665.2	1	1e+040	55665.2	1	3
HORIAAMD	18.00.00	20071119.200656.015	Dual	air.set	-5	0	0			1	12.8	0.0426847	1e+100	1e+100	1e+100	1e+100	1e+100	7	0
HORIAAMD	18.00.00	20071119.200656.015	Dual	air05.mps	-5	0	0			1	5.7	0.0243406	26592	25944.7	1	1e+040	25911	6	5
HORIAAMD	18.00.00	20071119.141718.093	Dual	air04.mps	-5	0	0			2	7.1	0.0610288	59199	55586.2	0.0610288	59199	55586.2	1	1
HORIAAMD	18.00.00	20071119.200701.890	Dual	air.set	-5	0	2			2	12.7	0.0686501	1e+100	1e+100	1e+100	1e+100	1e+100	2	0
HORIAAMD	18.00.00	20071119.200707.734	Dual	air05.mps	-5	0	5			2	5.7	0.0486998	27387	26053.3	1	1e+040	25982.1	5	7
HORIAAMD	18.00.00	20071119.141815.859	Dual	air04.mps	-5	0			0	3	7	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200707.734	Dual	air.set	-5	0	5			3	12.8	0.52435	1e+100	1e+100	1e+100	1e+100	1e+100	5	0
HORIAAMD	18.00.00	20071119.200756.390	Dual	air05.mps	-5	0			0	3	5.6	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.141801.421	Dual	air04.mps	-5	0		20		4	7	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200731.031	Dual	air.set	-5	0		20		4	12.6	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	0
HORIAAMD	18.00.00	20071119.200750.546	Dual	air05.mps	-5	0		1000		4	5.7	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.141739.843	Dual	air04.mps	-5	0	20			5	7	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200713.593	Dual	air.set	-5	0	20			5	12.6	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	0
HORIAAMD	18.00.00	20071119.200731.031	Dual	air05.mps	-5	0		20		5	5.5	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.141746.000	Dual	air04.mps	-5	0		0		6	7	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200713.593	Dual	air05.mps	-5	0	20			6	5.6	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.200719.406	Dual	air.set	-5	0		0		6	12.7	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	0
HORIAAMD	18.00.00	20071119.141808.625	Dual	air04.mps	-5	0		1000		7	7	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200719.406	Dual	air05.mps	-5	0		0		7	5.6	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.200725.234	Dual	air.set	-5	0		10		7	12.7	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	0
HORIAAMD	18.00.00	20071119.141710.781	Dual	air04.mps	-5	0				8	7	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200649.937	Dual	air.set	-5	0				8	12.8	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	0
HORIAAMD	18.00.00	20071119.200725.234	Dual	air05.mps	-5	0		10		8	5.6	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.141754.203	Dual	air04.mps	-5	0		10		9	7.1	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200649.937	Dual	air05.mps	-5	0				9	5.7	0.0779729	28174	25977.2	0.0779729	28174	25977.2	1	1
HORIAAMD	18.00.00	20071119.200756.390	Dual	air.set	-5	0			0	9	12.7	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	2
HORIAAMD	18.00.00	20071119.141823.062	Dual	air04.mps	-5	0			2	10	7.1	1	1e+040	55708.2	1	1e+040	55708.2	0	1
HORIAAMD	18.00.00	20071119.200701.890	Dual	air05.mps	-5	0	2			10	5.6	0.123992	29642	25966.6	1	1e+040	25966.6	1	3
HORIAAMD	18.00.00	20071119.200750.546	Dual	air.set	-5	0		1000		10	12.8	0.538986	1e+100	1e+100	1e+100	1e+100	1e+100	1	2
HORIAAMD	18.00.00	20071119.141732.640	Dual	air04.mps	-5	0	5			11	7.1	1	1e+040	55681.8	1	1e+040	55681.8	0	1

Note that individual matrix runs are listed alongside set runs and ranked relative to each other. The screenshot above was obtained by grouping `air04.mps` and `air05.mps` into a set called `air.set`. A run of `air04.mps` indicating *Rank 1* is better than a run of `air04.mps` indicating *Rank 2*. Thus, the detailed strategy rankings window allows you to compare not only *sets* but also set components against each other. Further insights may be gained from this comparison.

6 Tuning methods

Several tuning methods are available by default:



Note 1: All tuning methods are customizable.
Note 2: Any tuning method can be cloned and then customized.
Tuning methods:

Adaptive flexible comprehensive	The best choice for most purposes. A comprehensive tuning method, it initially contains a large number of diverse strategies to try (this is user customizable).
Adaptive flexible quick	The same tuning method as *Adaptive flexible comprehensive* but with fewer initial strategies. Not as broad as the comprehensive method, this method allows the Tuner to reach the adaptive phase quicker. This method sacrifices some quality to save tuning time.
Adaptive flexible root focus	This method focuses on control parameters that impact the root node of the MIP search.
Adaptive flexible tree focus	This method focuses on control parameters that impact the branching phase of the MIP search.
Adaptive pure comprehensive	This tuning method initially contains the same number of strategies as *Adaptive flexible comprehensive*. It uses a very elitist evolutionary selection scheme for choosing derived strategy candidates.
Adaptive pure quick	Same as *Adaptive pure comprehensive*, but with fewer initial strategies.
Adaptive pure root focus	Same as *Adaptive pure comprehensive*, but with a focus on the root node.

Adaptive pure tree focus	Same as *Adaptive pure comprehensive*, but with a focus on the branch and bound search.
Combinations	Try all combinations of values for a small number of control parameters
Mixer	Read all previous compatible runs from disk and apply the adaptive evolutionary algorithm to all these runs to derive better strategies. For example, a Tuner session focusing on cutting strategies can be combined with a Tuner session focusing on strong branching by running them separately and then starting a third run using the Mixer tuning method.
Single run 1	A shortcut to trying a single strategy.
Single run 2	A shortcut to trying another single strategy.

7 Terminology

Terms used in this user guide are described below in the context of the Xpress-Tuner.

Control parameter setting A control parameter is a named setting which can be used to customize the Xpress-Optimizer. For example, CUTSTRATEGY=0 is a control parameter setting that instructs the Optimizer to disable applying cuts to a problem.

Problem A matrix file to be solved.

Run A run represents one execution of the Xpress-Optimizer on a given **problem** using a given **strategy**.

Session A session refers to the complete execution of a **tuning method**. After clicking the *Start* button to start a tuning session, Xpress-Tuner will try different **strategies** according to selected **tuning method** and either run out of the given time limit or be stopped by the user upon pressing the *Stop* button.

Set A number of **problems** grouped together into a set (using the *Create a set of matrices...* button in the Xpress-Tuner application). Xpress-Tuner will automatically run all the problems in the set and compute results for the entire set. **Note:** Average gap for all **runs** of all the **problems** in the set is the only criterion used for comparing set **runs** against each other.

Strategy A number of **control parameter settings** applied together in a **run**. For example, CUTSTRATEGY=0, HEURSTRATEGY=3 is a strategy.

Tuning method Each of several adaptive or non-adaptive techniques for executing **runs**, whose goal is finding a favorable **strategy** for solving a **problem** or a **set** of problems.