



IBM Software Group

Using IBM CPLEX Optimization Studio with MathWorks MATLAB

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WebSphere® Support Technical Exchange



Agenda

- Explain the architecture of CPLEX to MATLAB connector.
- Illustrate how to model and solve an optimization problem.
- Offer troubleshooting and solutions for some common errors.



Interaction between IBM ILOG CPLEX and MathWorks MATLAB



Overview

■ CPLEX

- ▶ Product of IBM.
- ▶ A tool for solving mathematical optimization problems.
 - Minimize or maximize linear and convex quadratic objectives.
- ▶ Components:
 - CPLEX Interactive Optimizer.
 - Class libraries: Concert Technology and CPLEX Callable Library.
 - Python API for CPLEX.
- ▶ Tools for infeasible model analysis.



Overview

- MATLAB
 - ▶ Product of The MathWorks, Inc.
 - ▶ High-level language and interactive environment for numerical computation, visualization, and programming.
 - ▶ Widely used for technical computing.



Overview

- CPLEX connector for MATLAB
 - ▶ A high-performance interactive environment allowing computation, visualization and programming for solving mathematical scripts.
 - ▶ Two API for solving mathematical optimization problems:
 - The MATLAB Toolbox.
 - Special CPLEX class defined the MATLAB language.



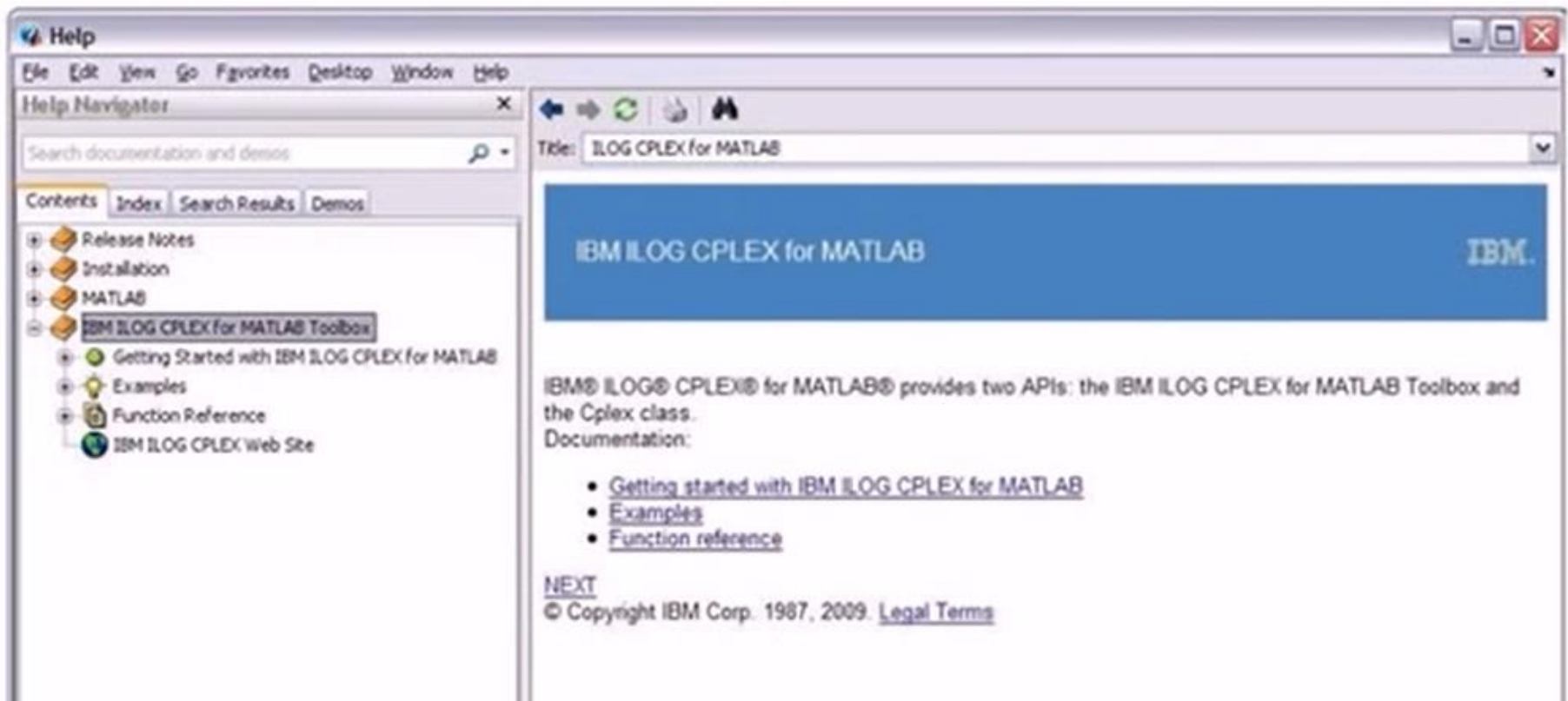
Setting Up CPLEX for MATLAB

- Connector installation location (for a 64bit system):
- `<CPLEX install dir>\cplex\matlab\x64_win64`
 - ▶ Contains header m files, parsed p files and mex files for the CPLEX class and toolbox.
 - ▶ `>> addpath ('<CPLEX install dir>\cplex\matlab\x64_win64')`
- `<CPLEX install dir>\cplex\examples\src\matlab`
 - ▶ Contains MATLAB examples for the CPLEX API utilization.
 - ▶ `>> addpath ('<CPLEX install dir>\cplex\examples\src\matlab')`
- Save the path for the next session:
 - ▶ `>> savepath`



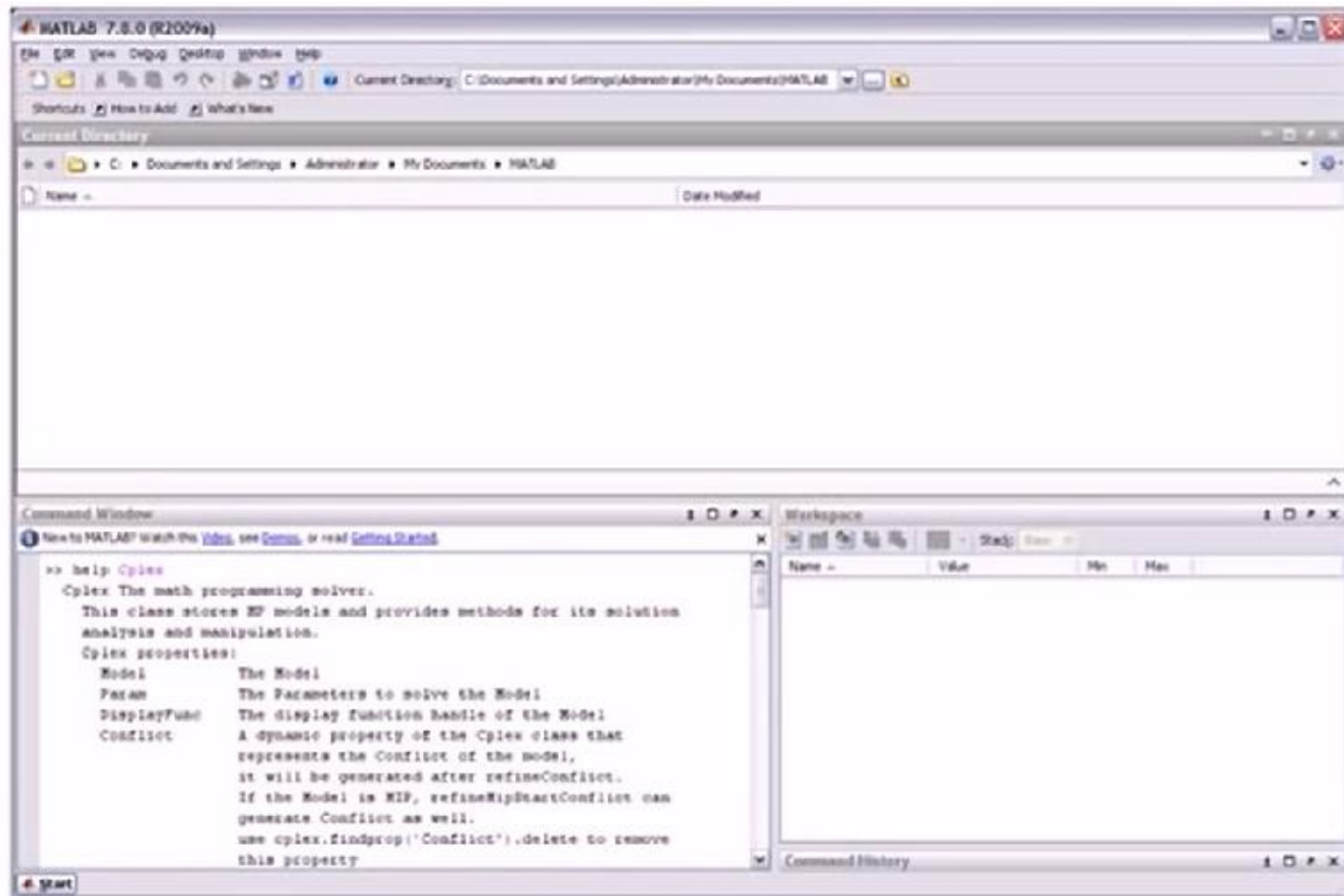
Online help in MATLAB

- Online help is available from MATLAB Help > Product Help on the MATLAB toolbar.



Online help in MATLAB

- Toolbox and CPLEX API help from command prompt.



Model and solve an optimization problem with CPLEX for MATLAB connector



CPLEX toolbox functions

- Solve mathematical optimization model.
 - ▶ Objective minimization sense only.
 - ▶ Linear programming, quadratic programming, mixed integer and least square problems.
 - ▶ `x = cplexlp(f,Aineq,beq,Aeq,beq,lb,ub)`

solves the mathematical optimization problem:

$$\min f^*x \text{ st.}$$
$$A_{ineq}^*x \leq b_{ineq}$$
$$A_{eq}^*x = b_{eq}$$
$$lb \leq x \leq ub$$

CPLEX toolbox functions

- Arguments:
 - ▶ Matrices and vectors with problem data.
 - ▶ Options structure to control solution process.
- Returns:
 - ▶ Solution vectors (x, lambda).
 - ▶ Objective function value.
 - ▶ Exit flag.
 - ▶ Solution statistics.



CPLEX toolbox functions – example cplexlpex.m

```
function cplexlpex
% Use the function cplexlp to solve a linear
% programming problem
%
% The LP problem solved in this example is
% Maximize x1 + 2 x2 + 3 x3
% Subject to
%      - x1 + x2 + x3 <= 20
%      x1 - 3 x2 + x3 <= 30
% Bounds
%      0 <= x1 <= 40
%      0 <= x2
%      0 <= x3
```

CPLEX toolbox functions – example cplexlpex.m

```
try
% Since cplexlp solves minimization problems and the problem
% is a maximization problem, negate the objective
f      = [-1 -2 -3]';
Aineq  = [-1  1  1;  1 -3  1];
bineq  = [20 30]';

lb = [0  0  0]';
ub = [40 inf inf]';

% Toolbox options are set with the function cplexoptimset
options = cplexoptimset;
options.Display = 'on';

[x, fval, exitflag, output] = cplexlp ...
    (f, Aineq, bineq, [], [], lb, ub, [], options);

fprintf ('\nSolution status = %s\n', output.cplexstatusstring);
fprintf ('Solution value = %f\n', fval);
disp ('Values =');
disp (x');
catch m
    disp(m.message);
end
end
```



CPLEX toolbox, further help

- Function descriptions available through MATLAB online help or CPLEX online documentation:

<http://pic.dhe.ibm.com/infocenter/cosinfoc/v12r6/index.jsp>

CPLEX > CPLEX for MATLAB > Function reference

- For MATLAB Cplex Class API applications, MATLAB Toolbox the names of parameters resemble the names in the CPLEX Interactive Optimizer.

CPLEX > Parameters of CPLEX > List of CPLEX parameters

- To maintain compatibility with the MATLAB Optimization Toolbox, a number of parameters may be set using the MATLAB Optimization Toolbox parameter names:

```
options = cplexoptimset('MaxNodes', 400); .
```



Cplex Class API

- Mathematical optimization problems are modeled by special objects. The objects carry persistent state information.
- A model can be build gradually by manipulating a CPLEX object.
- Computation methods such as `Cplex.solve()` and `Cplex.refineConflict()` can modify the object so results can be queried as needed.
- Restarts can be performed after manipulation.
- Possible to attach an output parser, a GUI with stop buttons, and other controls.



CPLEX Class API

- Access to advanced CPLEX features:
 - ▶ Conflict refinement.
 - ▶ FeasOpt.
 - ▶ Solution pools.
 - ▶ Parameter tuning.
 - ▶ InfoCallback.
 - ▶ Reading and writing of problem and solution files.



CPLEX Class API - example lpex1.m

```
% Initialize the CPLEX object
```

```
    cplex = Cplex('lpex1');
```

```
% Now populate the problem with the data
```

```
% Use arrays to populate the model
```

```
    cplex.Model.sense = 'maximize';
```

```
    cplex.Model.obj    = [1; 2; 3];
```

```
    cplex.Model.lb     = [0; 0; 0];
```

```
    cplex.Model.ub     = [40; inf; inf];
```

```
    cplex.Model.A      = [-1 1 1; 1 -3 1];
```

```
    cplex.Model.lhs     = [-inf; -inf];
```

```
    cplex.Model.rhs     = [20; 30];
```

```
% Optimize the problem
```

```
cplex.solve();
```

```
% Write the solution
```

```
    fprintf ('\nSolution status
```

```
%s\n', cplex.Solution.statusstring);
```

```
    fprintf ('Solution value = %f\n', cplex.Solution.objval);
```

```
    disp ('Values = ');
```

```
    disp (cplex.Solution.x');
```



CPLEX class API, further help

- The following methods are provided to solve and analyze the model, solution and mipstart:
 - ▶ `Cplex.solve` `Cplex.populate`
 - ▶ `Cplex.feasOpt` `Cplex.refineConflict`
 - ▶ `Cplex.terminate`
- For reading and writing to files:
 - ▶ `Cplex.readModel,` `Cplex.writeModel`
 - ▶ `Cplex.readSolution,` `Cplex.writeSolution`
 - ▶ `Cplex.readMipStart,` `Cplex.writeMipStart`
 - ▶ `Cplex.readParam,` `Cplex.writeParam`
 - ▶ `Cplex.writeConflict`
- CPLEX Class API information available through MATLAB online help or CPLEX online documentation:
<http://pic.dhe.ibm.com/infocenter/cosinfoc/v12r6/index.jsp>
 - ▶ *CPLEX > CPLEX for MATLAB > Function reference > Class List > CPLEX Class Reference*
 - ▶ *CPLEX > CPLEX for MATLAB > Getting Started with CPLEX for MATLAB > Overview of the CPLEX for MATLAB APs*



Troubleshooting common issues



CPLEX connector functions and help pages are not enabled in MATLAB

- Cause: the CPLEX connector home directory was not correctly added to the MATLAB path.
- Make sure you enclose the directory by quotation marks if you are using a special character in the path (such as the space in “Program files”).
- Typical path on a Windows system:

```
>> addpath ('C:\Program  
Files\IBM\ILOG\CPLEX_Studio126\matlab\x64_win64')
```

- Typical path on a Linux system:

```
>> addpath ('usr/ibm/ilog/CPLEX_Studio126/matlab/')
```



CPLEX connector crashes during solve

- Cause: if input data is invalid, the CPLEX MATLAB connector might crash. If you turn on the datacheck parameter, CPLEX can report the data error first.

`Cplex.BooleanParam.DataCheck`

- For more information, see:

http://pic.dhe.ibm.com/infocenter/cosinfoc/v12r6/index.jsp?topic=%2Filog.odms.cplex.help%2FCPLEX%2FMATLAB%2Ftopics%2Fgs_param.html



Conclusion



Additional WebSphere Product Resources

- Learn about upcoming WebSphere Support Technical Exchange webcasts, and access previously recorded presentations at:
http://www.ibm.com/software/websphere/support/supp_tech.html
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