IBM Software Group

# Using IBM CPLEX Optimization Studio with MathWorks MATLAB

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# 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

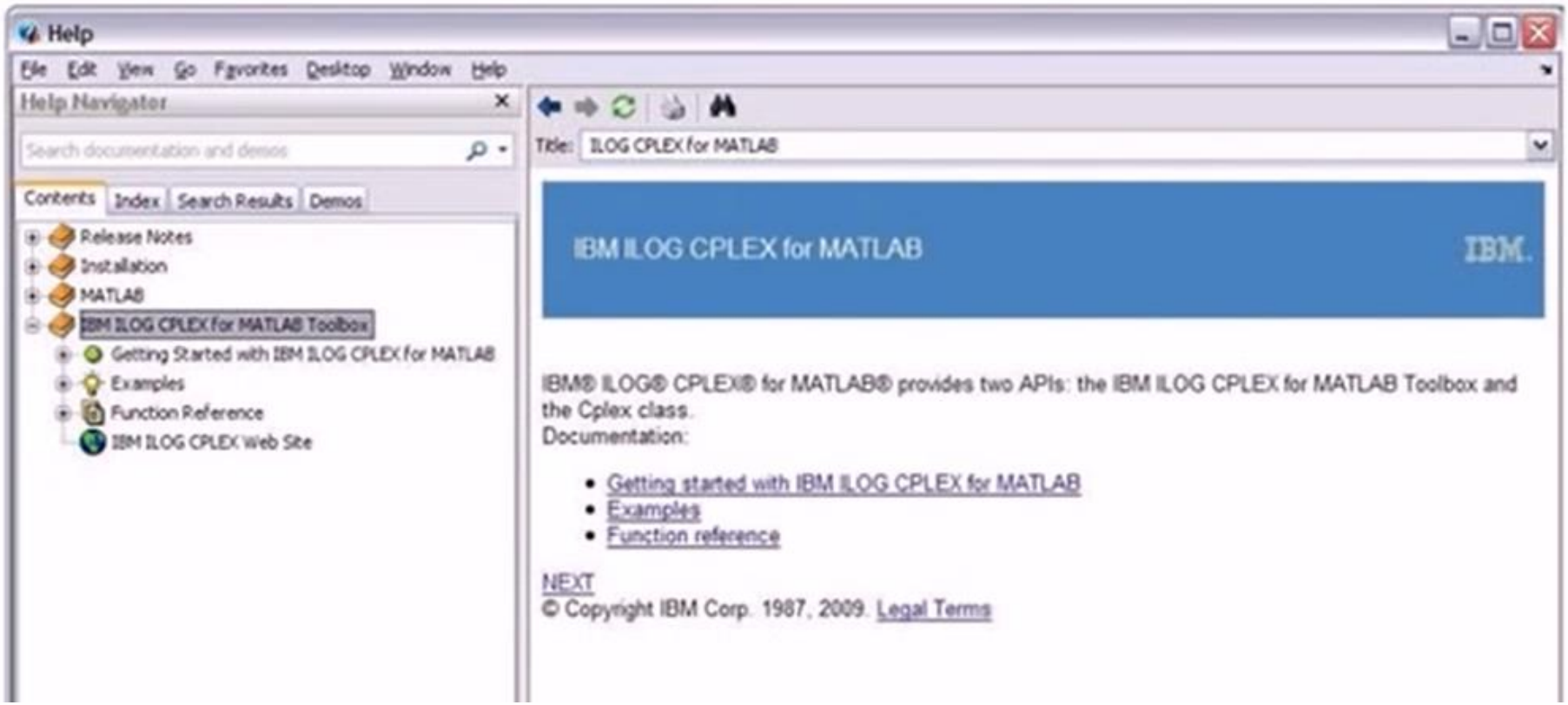
- CPLEX connector for MATLAB
  - A high-performance interactive environment allowing computation, visualization and programming for solving mathematical scripts.
  - Two API for solving mathematical optimization problems:
    - The MATLAB Toolbox.
    - Special CPLEX class defined the MATLAB language.

# 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`

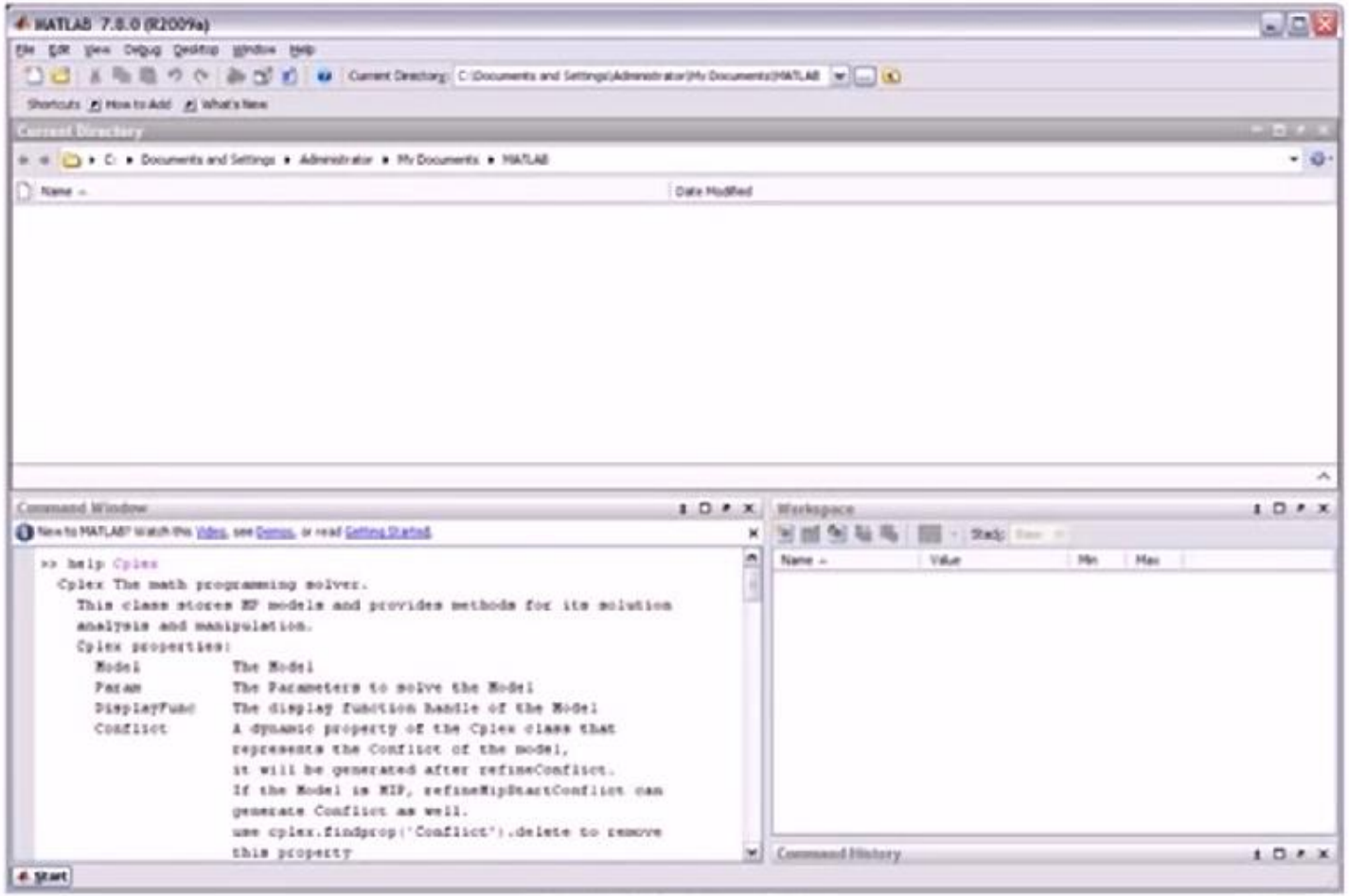
# Online help in MATLAB

- Online help is available from MATALAB 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 st.
    Aineq*x <= bineq
    Aeq*x = beq
    lb <= x <= 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.feasOpt`
  - `Cplex.terminate`
  - `Cplex.populate`
  - `Cplex.refineConflict`
- For reading and writing to files:
  - `Cplex.readModel,`
  - `Cplex.readSolution,`
  - `Cplex.readMipStart,`
  - `Cplex.readParam,`
  - `Cplex.writeConflict`
  - `Cplex.writeModel`
  - `Cplex.writeSolution`
  - `Cplex.writeMipStart`
  - `Cplex.writeParam`
- 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:
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