

In the name of God

Part 3. ILOG CPLEX

3.2. Interactive Optimizer

Spring 2010

Instructor: Dr. Masoud Yaghini

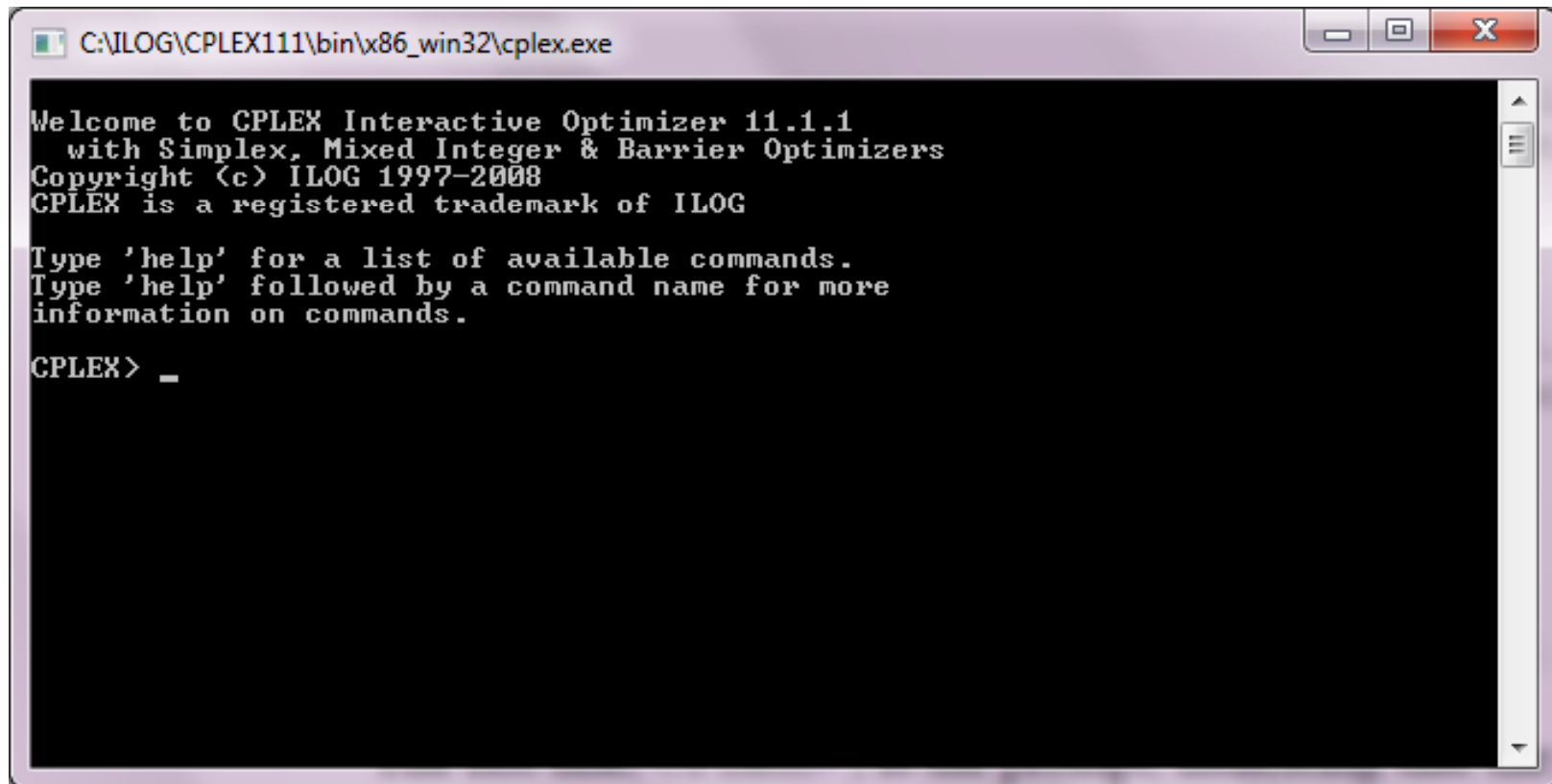
Outline

- Starting and Quitting CPLEX
- Entering a problem
- Displaying a problem
- Solving a problem
- Writing problem and solution files
- Reading problem files
- Setting CPLEX parameters
- References

Starting and Quitting CPLEX

Starting CPLEX

- To start the ILOG CPLEX Interactive Optimizer Click on **Cplex.exe**
- A message similar to the following one appears on the screen:

A screenshot of a Windows command window titled "C:\ILOG\CPLEX111\bin\x86_win32\cplex.exe". The window has a black background with white text. The text reads: "Welcome to CPLEX Interactive Optimizer 11.1.1 with Simplex, Mixed Integer & Barrier Optimizers. Copyright (c) ILOG 1997-2008. CPLEX is a registered trademark of ILOG. Type 'help' for a list of available commands. Type 'help' followed by a command name for more information on commands. CPLEX> _".

```
C:\ILOG\CPLEX111\bin\x86_win32\cplex.exe

Welcome to CPLEX Interactive Optimizer 11.1.1
  with Simplex, Mixed Integer & Barrier Optimizers
Copyright (c) ILOG 1997-2008
CPLEX is a registered trademark of ILOG

Type 'help' for a list of available commands.
Type 'help' followed by a command name for more
information on commands.

CPLEX> _
```

Interactive Optimizer

Starting CPLEX

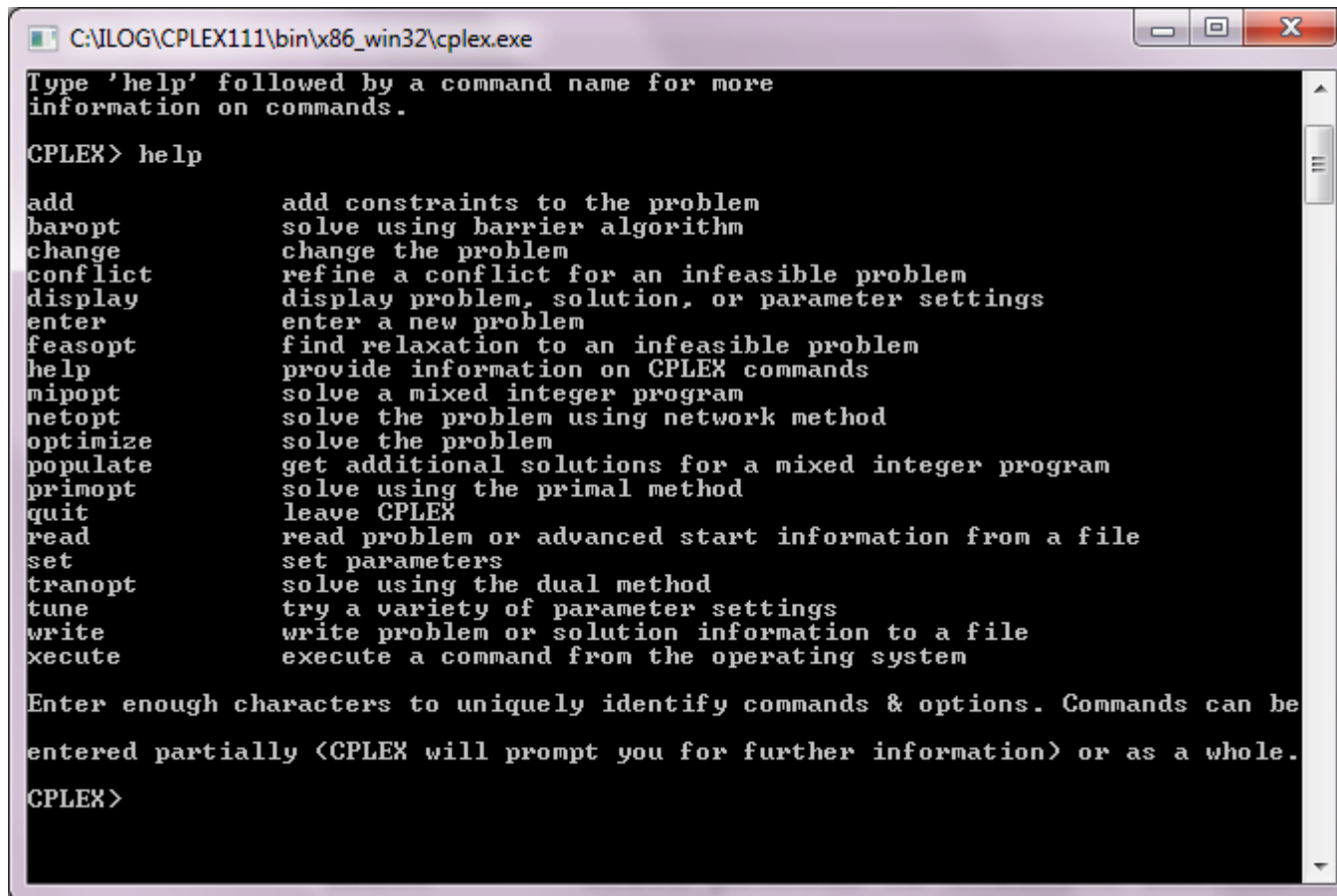
- The last line, **CPLEX>** , is the prompt, indicating that the product is running and is ready to accept one of the available ILOG CPLEX commands.
- Use the **help** command to see a list of these commands.

Using help

- You can type either the **full command name**, or any **shortened form** that uniquely identifies that name.
- Enter **help** after the CPLEX> prompt, as shown:
CPLEX> **help**
- You will see a list of the ILOG CPLEX commands on the screen.
- You could also enter just the single letter **h**.
CPLEX> **h**
- ILOG CPLEX does not distinguish between upper- and lower-case letters, so you could enter **h**, **H**, **help**, or **HELP**.

Using help

- After you type the **help** command, a list of available commands with their descriptions appears on the screen, like this:



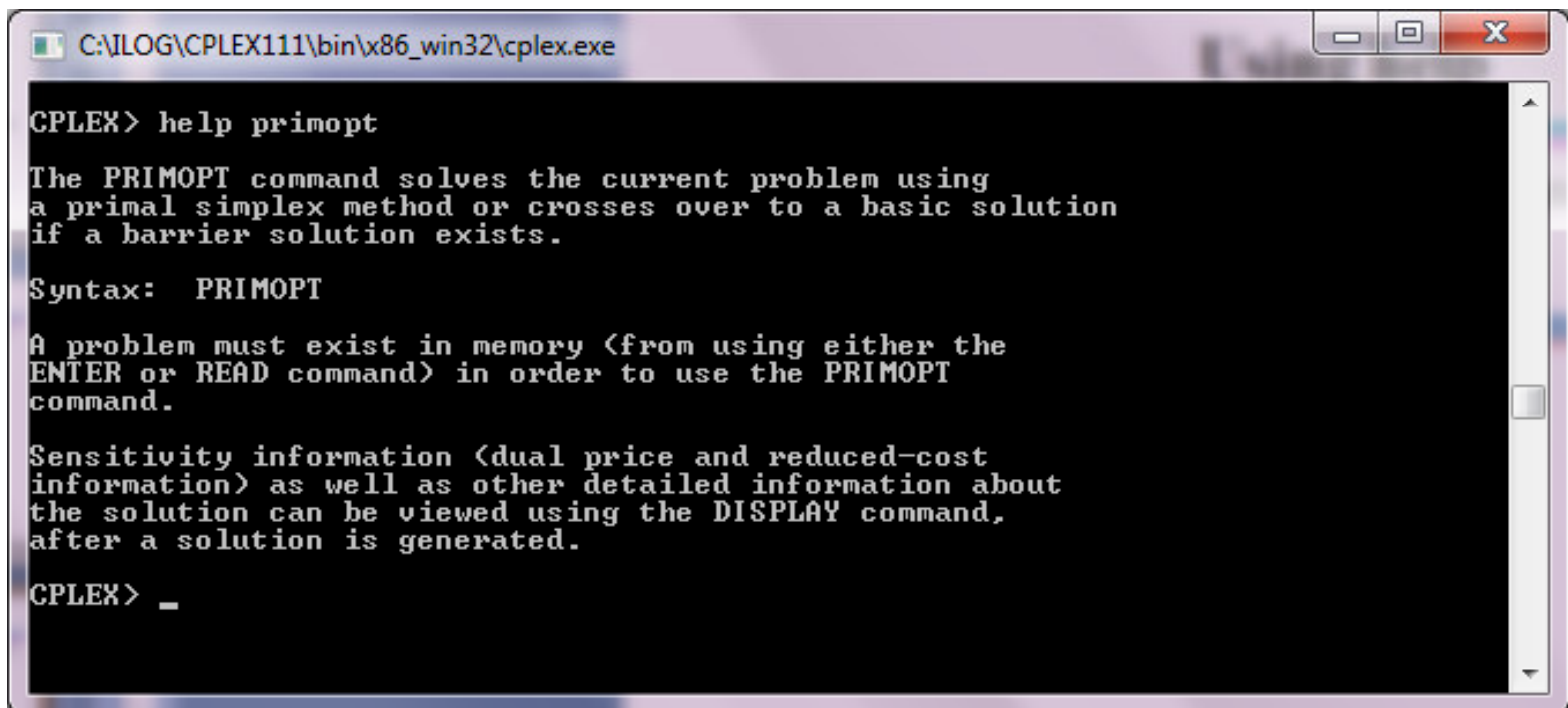
```
C:\LOG\CPLEX111\bin\x86_win32\cplex.exe
Type 'help' followed by a command name for more
information on commands.
CPLEX> help

add                add constraints to the problem
baropt             solve using barrier algorithm
change            change the problem
conflict          refine a conflict for an infeasible problem
display          display problem, solution, or parameter settings
enter            enter a new problem
feasopt          find relaxation to an infeasible problem
help             provide information on CPLEX commands
mipopt           solve a mixed integer program
netopt           solve the problem using network method
optimize         solve the problem
populate         get additional solutions for a mixed integer program
primopt         solve using the primal method
quit            leave CPLEX
read            read problem or advanced start information from a file
set            set parameters
tranopt         solve using the dual method
tune            try a variety of parameter settings
write          write problem or solution information to a file
xecute         execute a command from the operating system

Enter enough characters to uniquely identify commands & options. Commands can be
entered partially (CPLEX will prompt you for further information) or as a whole.
CPLEX>
```

Using help

- To find out more about a specific command, type **help** followed by the name of that command.
- For example, to learn more about the **primopt** command type:
help primopt / h primopt



```
C:\ILOG\CPLEX111\bin\x86_win32\cplex.exe

CPLEX> help primopt

The PRIMOPT command solves the current problem using
a primal simplex method or crosses over to a basic solution
if a barrier solution exists.

Syntax:  PRIMOPT

A problem must exist in memory (from using either the
ENTER or READ command) in order to use the PRIMOPT
command.

Sensitivity information (dual price and reduced-cost
information) as well as other detailed information about
the solution can be viewed using the DISPLAY command,
after a solution is generated.

CPLEX> _
```


Quitting CPLEX

- When you are finished using ILOG CPLEX and want to leave it, type:
quit
- If a problem has been modified, be sure to save the file before issuing a quit command.
- ILOG CPLEX will not prompt you to save your problem.

Entering a problem

Entering a problem

- Most users with larger problems enter problems by reading data from formatted files.
- That practice is explained later.
- For now, you will enter a smaller problem from the keyboard by using the **enter** command.

Entering a problem

- An example:

Maximize $x_1 + 2x_2 + 3x_3$

subject to $-x_1 + x_2 + x_3 \leq 20$

$$x_1 - 3x_2 + x_3 \leq 30$$

with these bounds $0 \leq x_1 \leq 40$

$$0 \leq x_2 \leq +\infty$$

$$0 \leq x_3 \leq +\infty$$

Entering a problem

- At the CPLEX> prompt type:
enter
- A prompt appears on the screen asking you to give a name to the problem that you are about to enter.
- The problem name may be anything that is allowed as a file name in your operating system.
- If you decide that you do not want to enter a new problem, just press the <return> key without typing anything.
- For now, type in the name **example** at the prompt.

Enter name for problem: example

Entering a problem

- You can also type the problem name directly after the **enter** command and avoid the intermediate prompt.

Using the LP format

- The problem should be entered in the following order:
 - 1. Objective function
 - 2. Constraints
 - 3. Bounds
- Objective function
 - Before entering the objective function, you must state whether the problem is a minimization or maximization.
 - For this example, you type:

maximize

$x_1 + 2x_2 + 3x_3$

Using the LP format

- The limitations on variable names in LP format
 - the names must be no more than 255 characters long
 - the names use only the alphanumeric characters (a-z, A-Z, 0-9) and certain symbols: ! " # \$ % & () , . ; ? @ _ ' ' { } ~ .
 - A variable name cannot begin with a number or a period
 - one character combination that cannot be used: the letter **e** or **E** alone or followed by a number or another **e** , since this notation is reserved for exponents. Thus, a variable cannot be named e24 nor e9cats nor eels nor any other name with this pattern.
 - This restriction applies only to problems entered in LP format.

Using the LP format

- **Constraints**

- the term **subject to** or **st** must precede the constraints section.
- You can type in the constraints in the following way:

st

$$\mathbf{-x1 + x2 + x3 \leq 20}$$

$$\mathbf{x1 - 3x2 + x3 \leq 30}$$

Using the LP format

- **Constraint Names**

- it may be advantageous to name constraints so that they are easier to identify.
- Type a constraint name and a colon before the actual constraint.
- If you do not give the constraints explicit names, ILOG CPLEX will give them the default names c_1, c_2, \dots, c_n .
- In the example, if you want to call the constraints **time** and **labor**, for example, enter the constraints like this:

st

time: $-x_1 + x_2 + x_3 \leq 20$

labor: $x_1 - 3x_2 + x_3 \leq 30$

Using the LP format

- **Constraint names** are subject to the same guidelines as variable names.
- **Objective Function Names**
 - The objective function can be named in the same manner as constraints.
 - The default name for the objective function is **obj**.

Using the LP format

● Bounds

- Finally, you must enter the lower and upper bounds on the variables.
- If no bounds are specified, CPLEX will automatically set the lower bound to 0 and the upper bound to $+\infty$.
- In our example, the lower bound on x_1 is 0, which is the same as the default. The upper bound 40, however, is not the default, so you must enter it explicitly.
- You must type **bounds** on a separate line before you enter the bound information:

bounds

$x_1 \leq 40$

Using the LP format

- You have finished entering the problem, so to indicate that the problem is complete, type:
end
- on the last line. The CPLEX> prompt returns, indicating that you can again enter a ILOG CPLEX command.

Using the LP format

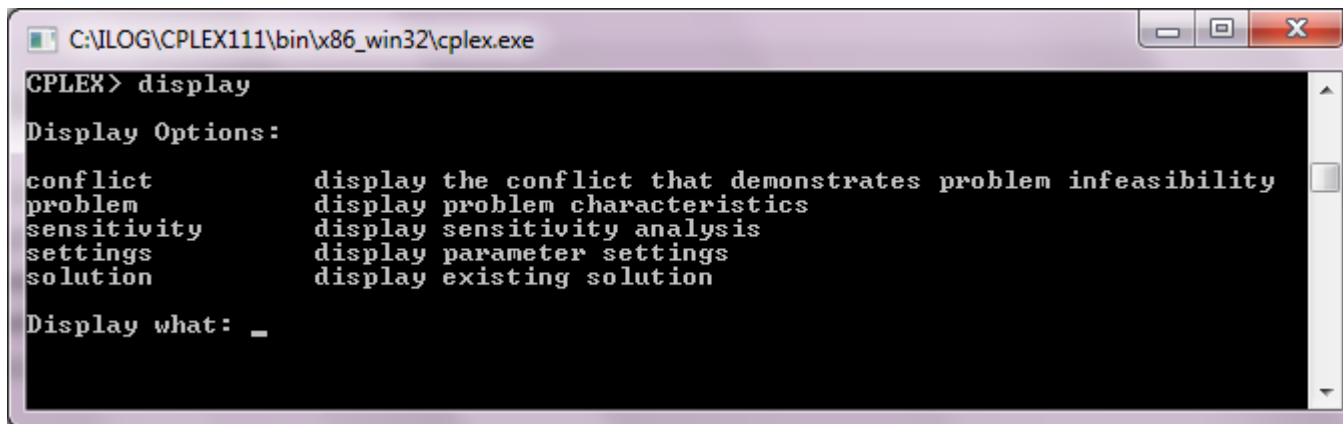
- **Notes:**

- You can use the <return> key to split long constraints, and ILOG CPLEX still interprets the multiple lines as a single constraint.
- When you are entering a problem is that after you have pressed <return> , you can no longer directly edit the characters that precede the <return> .
- After <return> has been pressed, the **change** command must be used to modify the problem.

Displaying a problem

Displaying a problem

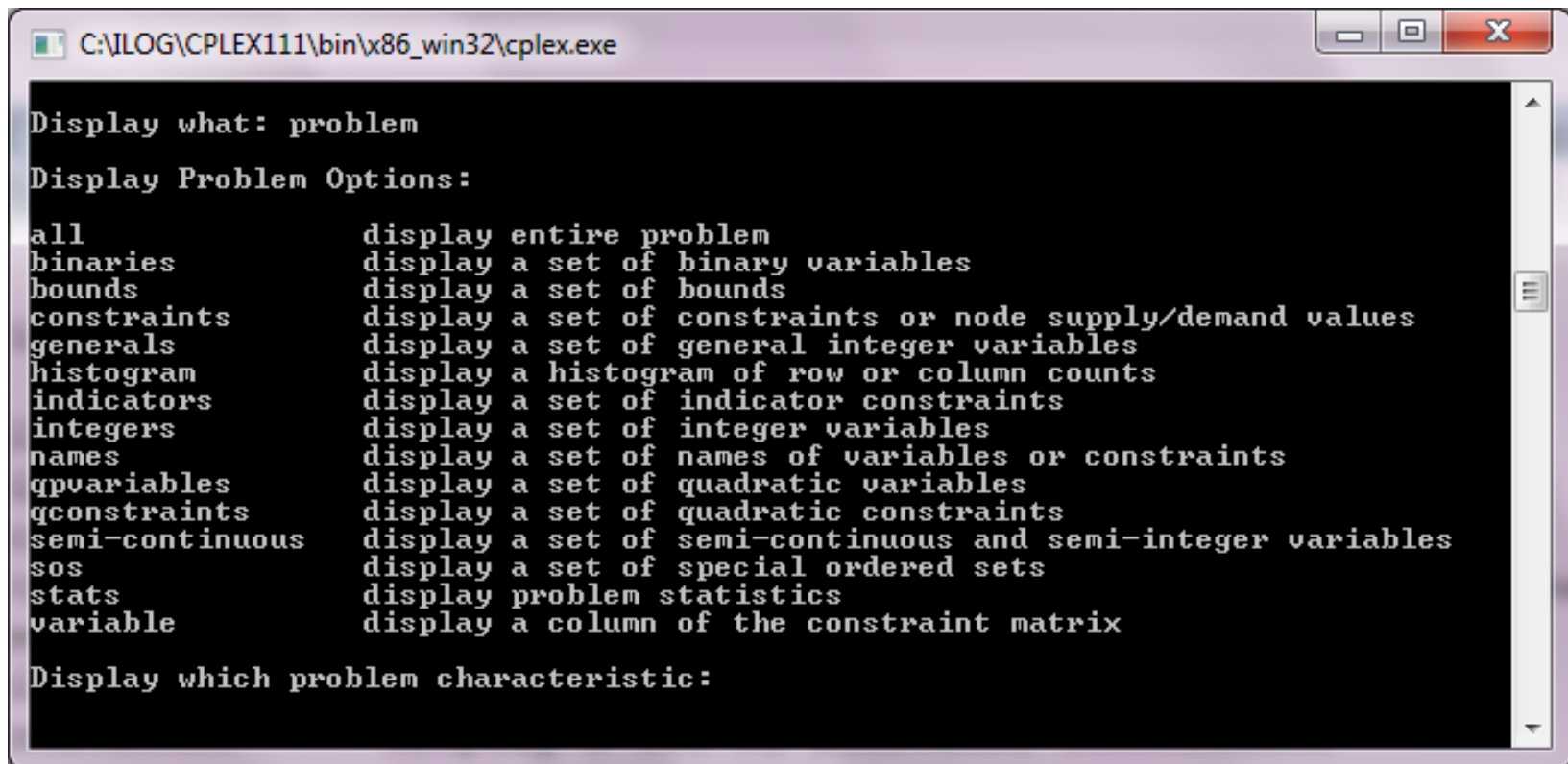
- Now that you have entered a problem, you must verify that the problem was entered correctly.
- To do so, use the display command:
display or **d**
- A list of the items that can be displayed then appears.



```
C:\LOG\CPLEX111\bin\x86_win32\cplex.exe
CPLEX> display
Display Options:
conflict          display the conflict that demonstrates problem infeasibility
problem          display problem characteristics
sensitivity       display sensitivity analysis
settings         display parameter settings
solution         display existing solution
Display what: _
```


Displaying a problem

- If you type **problem** in reply to that prompt, that option will list a set of problem characteristics, like this:



```
C:\VLOG\CPLEX111\bin\x86_win32\cplex.exe

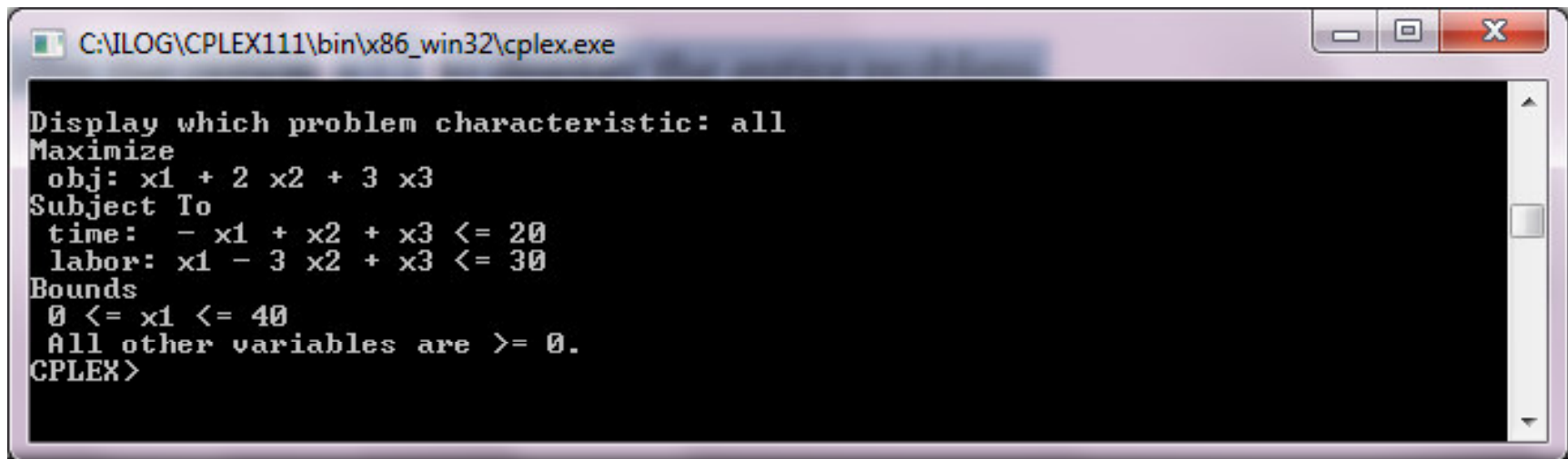
Display what: problem
Display Problem Options:

all          display entire problem
binaries    display a set of binary variables
bounds      display a set of bounds
constraints  display a set of constraints or node supply/demand values
generals    display a set of general integer variables
histogram   display a histogram of row or column counts
indicators  display a set of indicator constraints
integers    display a set of integer variables
names       display a set of names of variables or constraints
qpvariables display a set of quadratic variables
qconstraints display a set of quadratic constraints
semi-continuous display a set of semi-continuous and semi-integer variables
sos         display a set of special ordered sets
stats       display problem statistics
variable    display a column of the constraint matrix

Display which problem characteristic:
```

Displaying a problem

- Enter the option **all** to display the entire problem.

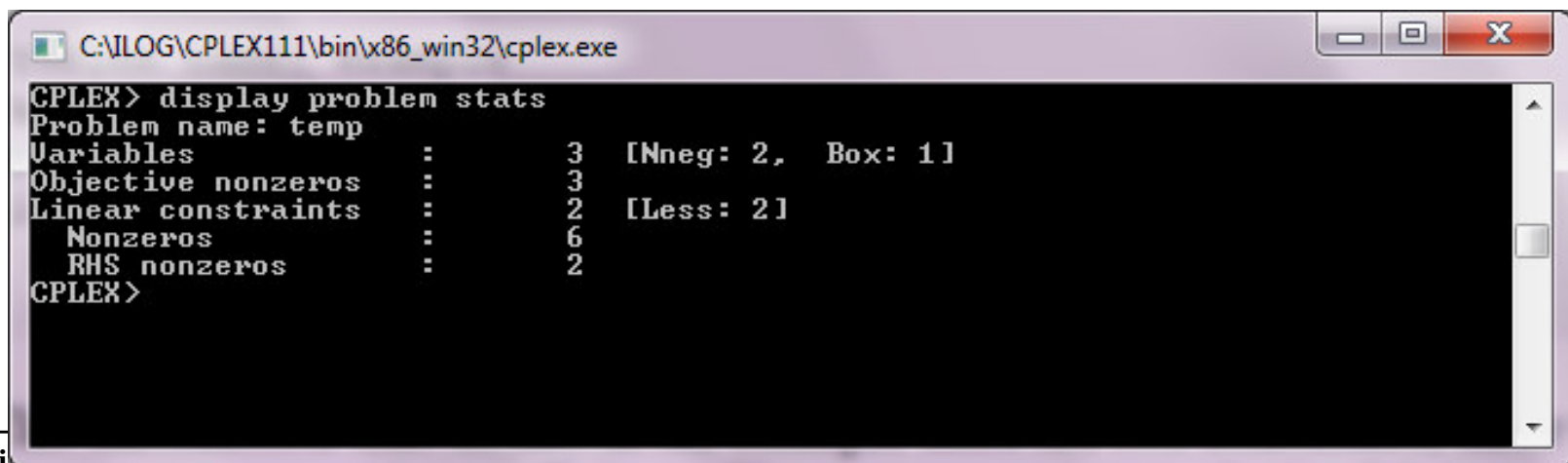


```
C:\ILOG\CPLEX111\bin\x86_win32\cplex.exe
Display which problem characteristic: all
Maximize
  obj: x1 + 2 x2 + 3 x3
Subject To
  time: - x1 + x2 + x3 <= 20
  labor: x1 - 3 x2 + x3 <= 30
Bounds
  0 <= x1 <= 40
  All other variables are >= 0.
CPLEX>
```

- You can also type the command like this:
display problem all

Displaying problem statistics

- When you select **stats** option of the **display problem** command, the following attributes of the problem appears:
 - the number and type of constraints
 - the number and type of variables
 - nonzero constraint coefficients
- Try this feature by typing:
display problem stats



```
C:\LOG\CPLEX111\bin\x86_win32\cplex.exe
CPLEX> display problem stats
Problem name: temp
Variables          :          3 [Nneg: 2,  Box: 1]
Objective nonzeros :          3
Linear constraints  :          2 [Less: 2]
  Nonzeros         :          6
  RHS nonzeros     :          2
CPLEX>
```

Displaying problem statistics

- This information tells us that in the example there are:
 - two constraints, three variables, and six nonzero constraint coefficients.
 - The two constraints are both of the type less-than-or-equal-to.
 - Two of the three variables have the default nonnegativity bounds ($0 \leq x \leq +\infty$) and one is restricted to a certain range (a box variable).
 - A constraint matrix nonzero count, there is a count of nonzero coefficients in the objective function and on the righthand side.

Specifying item ranges

- **Hyphen (-)**

- Whenever input defining a range of items is required, CPLEX expects two indices separated by a hyphen (the range character -).
- Example: The sequence of characters c1-3

- **Question mark (?)**

- for a single character
- Example: The sequence of characters c1? matches the name of every constraint in the range from c10 to c19

- **Asterisk (*)**

- for zero or more characters

Displaying variable or constraint names

- You can display a variable name by using the **display** command:

display problem names variables

- In response, CPLEX prompts you :

Display which variable name(s):

- Type the following command:

***** : to display all variable names

x2- : to display variable names x2 and x3

2- : to display variable names x2 and x3

2 : to display variable names x2

Displaying variable or constraint names

- You can display constraint names by entering the command:

display problem names constraints

Displaying constraints

- To view constraints, use the command and the constraint numbers or names.
- Type the following for display second constraint
display problem constraints 2
- To display a range of constraints, like this:
display problem constraints *

Displaying the objective function

- When you want to display only the objective function, you must enter its name (obj by default) or an index number of 0.

display problem constraints

Display which constraint name(s): 0

- The result is:

Maximize

obj: $x_1 + 2 x_2 + 3 x_3$

Displaying bounds

- To see only the bounds for the problem, type the following command (don't forget the hyphen or wildcard):

display problem bounds *

display problem bounds 1-2

- The result is:

$0 \leq x1 \leq 40$

All other variables are ≥ 0 .

Solving a problem

Solving a problem

- The **optimize** command tells CPLEX to solve the LP problem.
- CPLEX uses the **dual simplex optimizer**, unless another method has been specified by setting
- At the CPLEX> prompt, type the command:
optimize

Solving a problem

- **Preprocessing**

- First, CPLEX tries to simplify or reduce the problem using its presolver and aggregator.
- If any reductions are made, a message will appear.
- However, in our small example, no reductions are possible.

Solving a problem

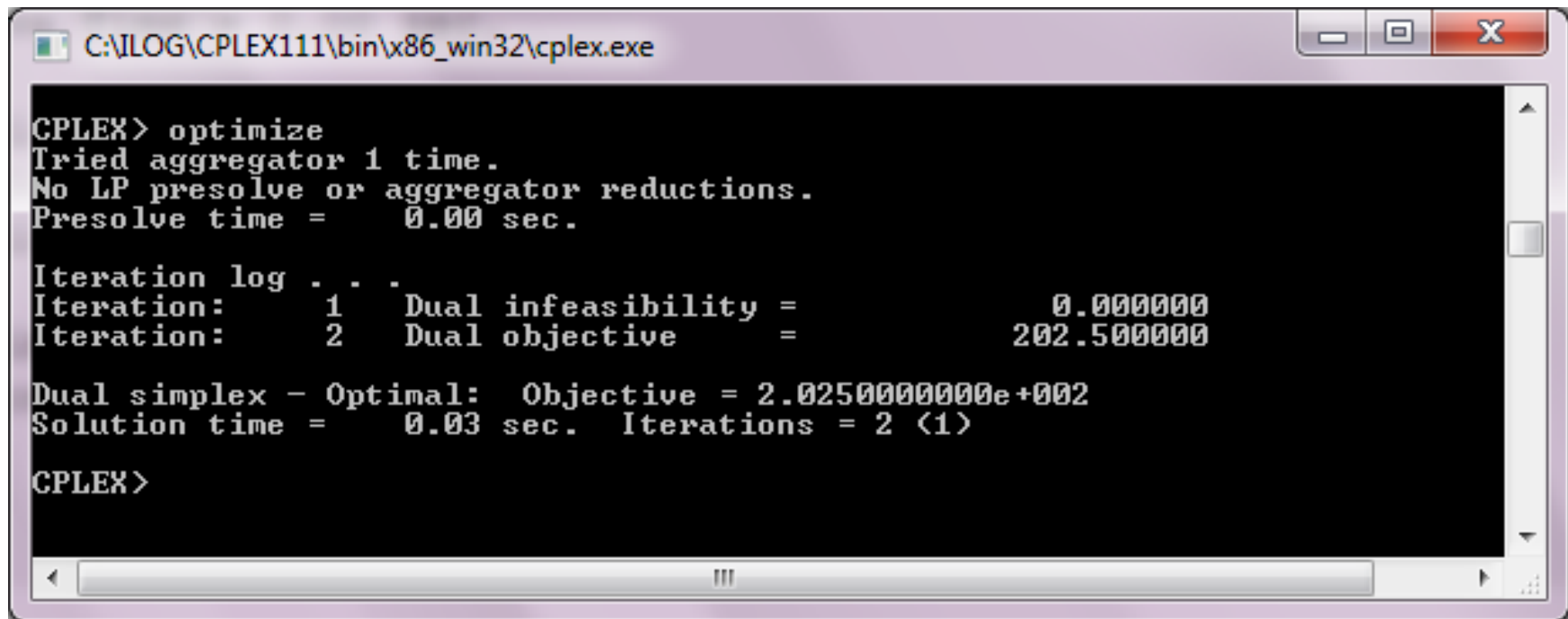
- **Monitoring the iteration log**
 - Next, an iteration log appears on the screen.
 - CPLEX reports its progress as it solves the problem.
- The solution process involves two stages:
 - **Phase I:** CPLEX searches for a feasible solution
 - **Phase II:** CPLEX searches for the optimal feasible solution.
- The iteration log periodically displays the current iteration number and either the current scaled infeasibility during Phase I, or the objective function value during Phase II.

Solving a problem

- After it finds the optimal solution, CPLEX reports:
 - the objective function value
 - the problem solution time in seconds
 - the total iteration count
 - the Phase I iteration count (in parentheses)

Solving a problem

- Optimizing our example problem produces a report like the following one:



```
C:\LOG\CPLEX111\bin\x86_win32\cplex.exe
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual infeasibility = 0.000000
Iteration: 2 Dual objective = 202.500000

Dual simplex - Optimal: Objective = 2.02500000000e+002
Solution time = 0.03 sec. Iterations = 2 <1>

CPLEX>
```


Solution options

- Here are some of the basic options in solving linear programm
 - **Filing iteration logs**
 - **Re-solving**
 - **Using alternative optimizers**
 - **Interrupting the optimization**

Solution options

- **Filing iteration logs**

- Every time CPLEX solves a problem, much of the information appearing on the screen is also directed into a **log file**.
- This file is automatically created with the name **cplex.log**.
- If you want to keep a unique log file of a problem session, you can change the default name with the **set logfile** command.
- The log file is written in standard ASCII format and can be edited with any text editor.

Solution options

- **Re-solving**

- You may re-solve the problem by reissuing the optimize command.
- CPLEX restarts the solution process from the previous optimal basis, and thus requires zero iterations.
- If you do not wish to restart the problem from an advanced basis, use the **set advance** command to turn off the advanced start indicator.

Solution options

- **Using alternative optimizers**
 - **primopt** command: the primal simplex optimizer
 - **tranopt** command: the dual simplex optimizer
 - **baropt** command: the barrier optimizer
 - **netopt** command: the network optimizer
 - **mipopt** command: is equivalent to **optimize** command

- Many problems can be solved faster using these alternative optimizers, which are documented in more detail in the *ILOG CPLEX User's Manual*.

Solution options

- **Interrupting the optimization**

- ILOG CPLEX allows such interruptions if you use control-
c .
- Optimization is interrupted, and ILOG CPLEX issues a message indicating that the process was stopped and displays progress information.
- If you issue another optimization command in the same session, ILOG CPLEX will resume optimization from where it was interrupted.

Displaying post-solution information

- The following information is available with the **display solution** command:
 - objective function value
 - solution values
 - numerical quality of the solution
 - slack values
 - reduced costs
 - dual values (shadow prices)
 - basic rows and columns

Displaying post-solution information

- To view the optimal value of each variable:
display solution variables *
- To view the slack values of each constraint:
display solution slacks *
- To view the dual values (or shadow prices) for each constraint:
display solution dual *

Writing problem and solution files

Writing problem and solution files

- The problem or its solution can be saved by using the **write** command.
- This command writes the problem statement or a solution report to a file.
- When you type the **write** command, CPLEX displays a menu of options and prompts you for a file format

Writing LP files

- When you enter the **write** command, the following message appears:

Name of file to write:

- Enter the problem name "**example**", and CPLEX will ask you to select a type from a list of options.
- Try this, using the name **example2**:
write example2 lp
- Try this, using the name **example3.lp**:
write example3.lp

Writing basis files

- It is used to store information about the solution to a problem, information known as a **basis**.
- A basis can be written only after a problem has been solved.
- Try this with the following command:
write example.bas

Using path names

- A full path name may also be included to indicate on which drive and directory any file should be saved.
- The following might be a valid write command if the disk drive on your system contains a root directory named problems:

write /problems/example.lp

Reading problem files

Selecting a read file format

- When you type the **read** command with the name of a file, CPLEX displays the file formats on the screen.
- All these file formats are documented in more detail in the reference manual *ILOG CPLEX File Formats*.

Reading LP files

- At the CPLEX> prompt type:
read
- The following message appears requesting a file name:
Name of file to read:
- Specify the file named **example** that you saved while practicing the **write** command.
- You recall that the example problem was saved in LP format, so in response to the file type prompt, enter:
lp

Reading LP files

- The intermediate prompts for the read command can be avoided by entering the entire command on one line, like this:

read example3.lp

Reading MPS files

- ILOG CPLEX can also read industry-standard MPS formatted files.
- The problem called **afiro.mps** serves as an example.
- If you include the **.mps** extension in the file name, CPLEX will recognize the file as being in MPS format.
- If you omit the extension, ILOG CPLEX will attempt to detect whether the file is of a type that it recognizes.

read afiro mps

Setting CPLEX parameters

Setting CPLEX parameters

- ILOG CPLEX users can vary parameters by means of the **set** command.
- This command is used to set CPLEX parameters to values different from their **default values**.
- Whenever a parameter is set to a new value, CPLEX inserts a comment in the log file that indicates the new value.
- To see the parameters that can be changed, type:
set

Setting CPLEX parameters

- **Resetting defaults**

- After making parameter changes, it is possible to reset all parameters to default values by issuing one command:

set defaults

References

References

- ILOG CPLEX, **Getting Started with ILOG CPLEX**, ILOG CPLEX, 2008.



The End