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### MSC PHD (OR)

#### PART (1) and PART(2)

Given that

$A=\{a_1, a_2, a_3, \dots, a_n\}$  is the set of symbols that we'll have in the string

A string  $s=s_1 s_2 s_3 \dots s_l$  of length  $l$  where each character belongs to  $A$

Given  $S=\{s^1, s^2, \dots, s^M\}$

Aim is to find the string  $c=c_1 c_2 c_3 c_4 \dots c_l$  such that  $\sum_{m=1}^M H(sm, c)$  is minimum.

We can do this by giving each alphabet in  $A$  a number (eg 1, 2, 3, 4)

Defining a parameter  $l$  where  $l$  is the length of each string.

Defining a set  $STRCH=\{1, 2, 3, \dots, l\}$ .

We give each  $a_i$  in  $A$  a number and let that set of numbers be  $NUM=\{1, 2, 3, \dots, n\}$

Defining a matrix named 'string' such that  $string_{S \times STRCH}$  where each element of the matrix will tell the corresponding number of that character of the string, eg  $string_{s1,3}$  will tell the number corresponding to the 3<sup>rd</sup> character of  $s^1$ .

An example of 'string' can be:

**matrix** string:

	1	2	3	4	5	6	7	8	9	10:=
s1	2	3	1	1	1	4	4	1	1	4
s2	2	3	3	4	4	4	2	1	4	1
s3	2	2	3	1	2	2	3	2	2	1
s4	2	1	1	4	2	3	2	3	2	1;

Now, Defining the decision variables:

Let  $x_{[S, STRCH]}$  be variables in  $[S, STRCH]$  such that  $x$  is binary.

Let  $c_{[STRCH]}$  be variables in  $STRCH$  such that  $c$  is integer.

Defining the objective function:

**MINIMIZE**  $\sum_{i \in S, j \in STRCH} x[i, j]$

subject to constraints:-

$x[i,j] \geq (c[j] - \text{string}[i,j])/50$  , for all  $i$  in  $S$ ,  $j$  in STRCH.

$x[i,j] \geq -(c[j] - \text{string}[i,j])/50$  , for all  $i$  in  $S$ ,  $j$  in STRCH.

We have formulated the above question as an integer linear programming problem. In the above problem, we have taken each character of the string to be a number and then made the constraints in such a way that it will give the make a string in such a way that it will minimize  $\sum_{m=1}^M H(sm, c)$ .

## PART (3)

```
AMPL
amp1: include run1.run;
Gurobi 8.1.0: timing 1

Times (seconds):
Input = 0
Solve = 0.015625 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 17
5 simplex iterations
c [*] :=
1 5
2 9
3 9
4 15
5 5
6 18
7 5
8 15
9 5
10 15
;

amp1:

param l:=10;
set CHAR := 's1' 's2' 's3' 's4' 's5' 's6' 's7' 's8' 's9' 's10';
set GIVEN:= 'O' 'E' 'I' 'R';
param string:
1 2 3 4 5 6 7 8 9 10:=
s1 18 18 5 9 5 5 5 18 5 18
s2 9 9 9 18 5 9 5 5 9 5
s3 15 9 18 5 9 9 9 9 15 15
s4 9 9 5 9 9 15 5 9 18 5
s5 9 9 15 5 9 5 15 5 9 15
s6 5 9 9 18 15 5 9 15 5 18
s7 5 9 9 9 9 5 15 5 18 18
s8 9 15 5 5 18 9 15 5 5 9
s9 5 9 5 5 5 5 5 9 5 15
s10 15 15 9 9 9 5 9 15 5 9
s11 15 18 15 9 18 18 9 5 5
s12 18 18 18 9 15 5 9 9 18 9
s13 9 9 5 15 9 9 9 15 18 18
s14 18 9 9 5 18 9 9 15 5 18
s15 9 18 9 5 18 9 9 5 5 5;
```

The string  $c$  is : 'eiioereoeo'

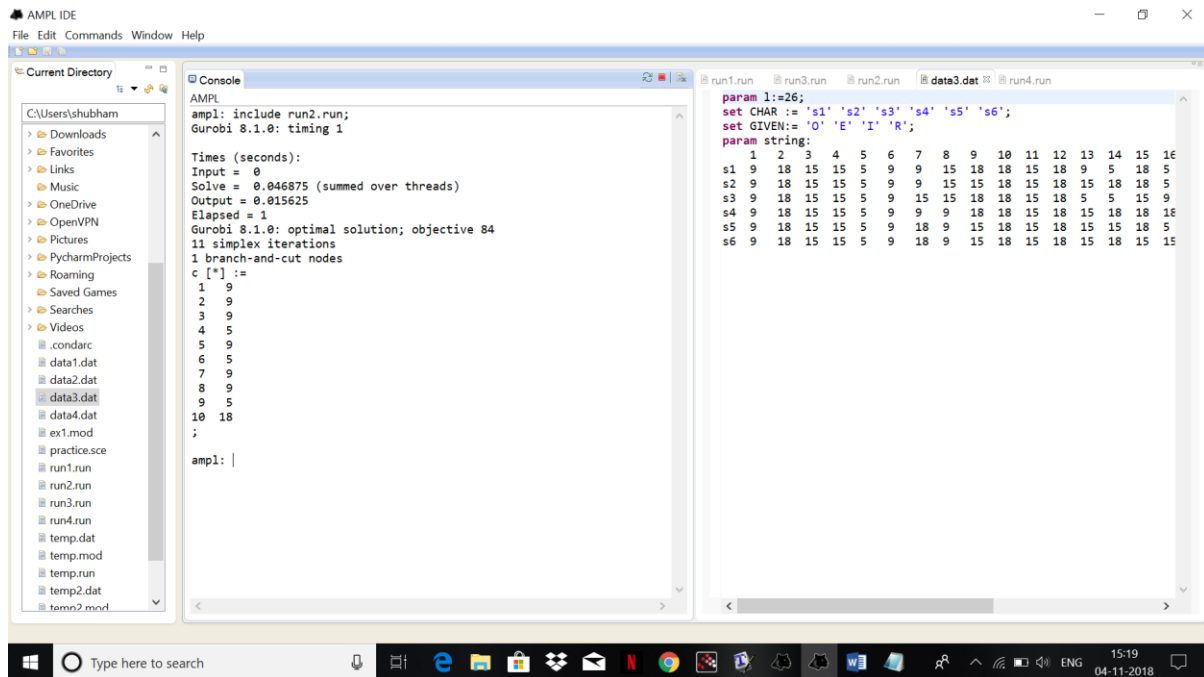
Times (seconds):

Input = 0.015625

Solve = 0 (summed over threads)

Output = 0

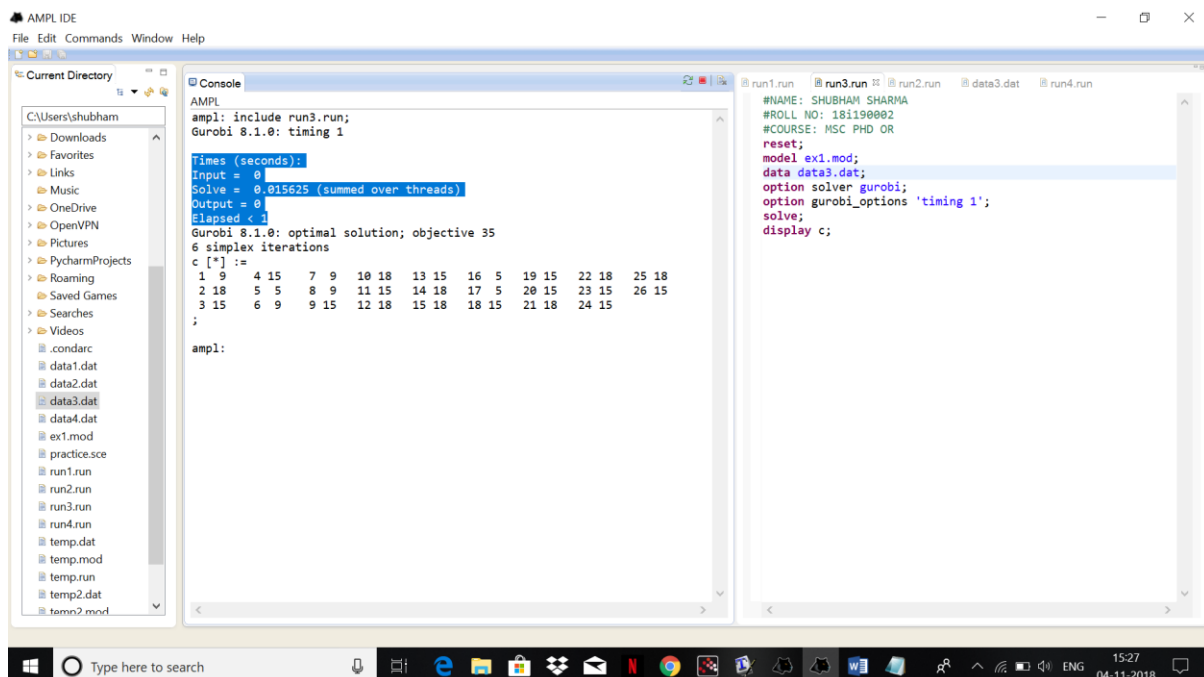
Elapsed < 1



The string c is : 'iiiiieiier'

Times (seconds):  
 Input = 0  
 Solve = 0.046875 (summed over threads)  
 Output = 0.015625  
 Elapsed = 1

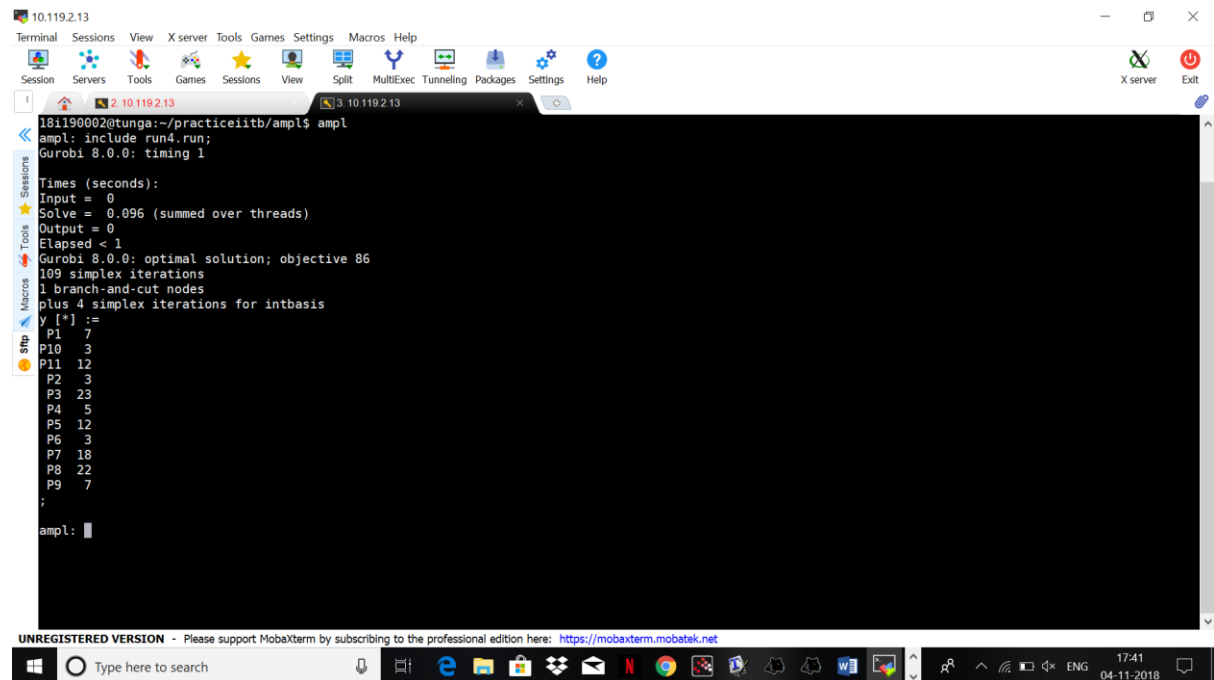
## PART (4)



The string c is : 'irooeiiiorororoeooooorooro'

```
Times (seconds):
Input = 0
Solve = 0.015625 (summed over threads)
Output = 0
Elapsed < 1
```

## PART (5)



```
10.119.2.13
Terminal Sessions View X server Tools Games Settings Macros Help
Session Servers Tools Games Sessions View Split MultiExec Tunneling Packages Settings Help
181190002@tunga:~/practiceitb/ampl$ ampl
ampl: include run4.run;
Gurobi 8.0.0: timing 1

Times (seconds):
Input = 0
Solve = 0.096 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.0.0: optimal solution; objective 86
109 simplex iterations
1 branch-and-cut nodes
plus 4 simplex iterations for intbasis
y [*] :=
P1 7
P10 3
P11 12
P2 3
P3 23
P4 5
P5 12
P6 3
P7 18
P8 22
P9 7
;
ampl: 
```

the string c is : 'gcwelcrvgcl'

```
Times (seconds):
Input = 0
Solve = 0.096 (summed over threads)
Output = 0
Elapsed < 1
```

## PART (6)

For data 1  
cohesiveness=2

For data 2

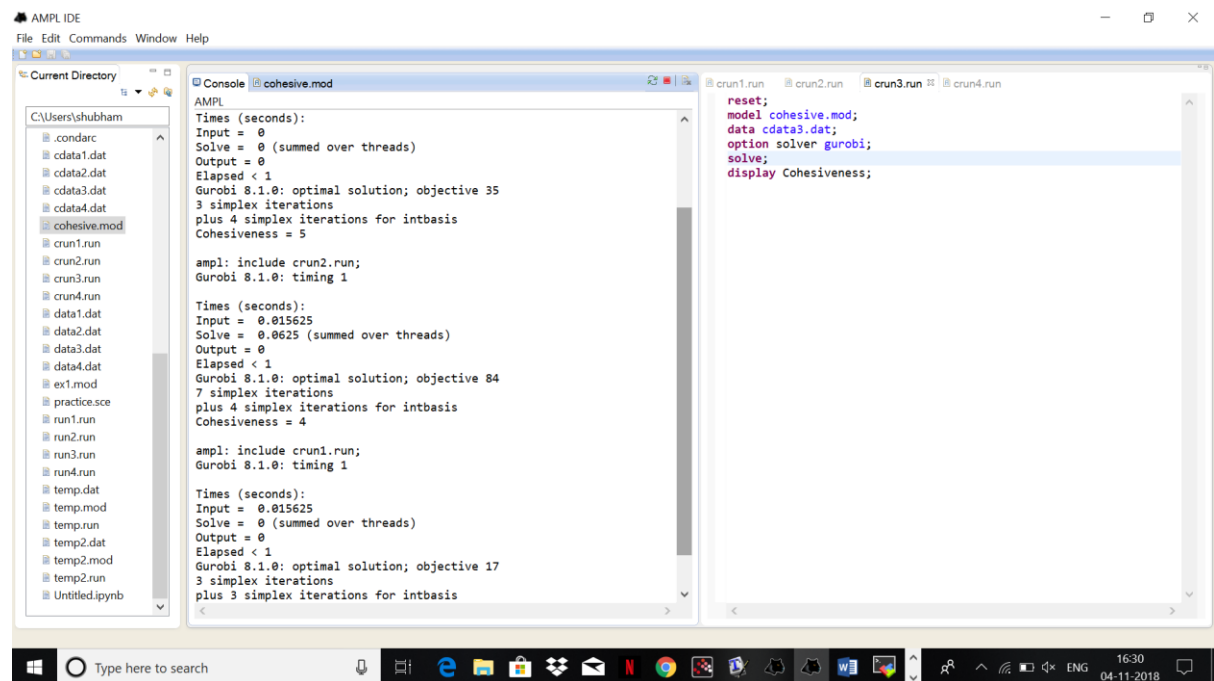
cohesiveness=4

For data 3

cohesiveness=5

For data 4

Cohessiveness=3



The screenshot shows the AMPL IDE interface. On the left, the 'Current Directory' pane lists files including 'cohesive.mod' and 'crun1.run' through 'crun4.run'. The central 'Console' pane displays the output for 'cohesive.mod', showing three solves with increasing 'Cohesiveness' values of 5, 4, and 2. The right pane shows the code in 'crun3.run', which includes a 'reset;' command, loads 'cohesive.mod' and 'cdata3.dat', sets the solver to 'gurobi', and displays the 'Cohesiveness' value.

```
AMPL
Times (seconds):
Input = 0
Solve = 0 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 35
3 simplex iterations
plus 4 simplex iterations for intbasis
Cohesiveness = 5

ampl: include crun2.run;
Gurobi 8.1.0: timing 1

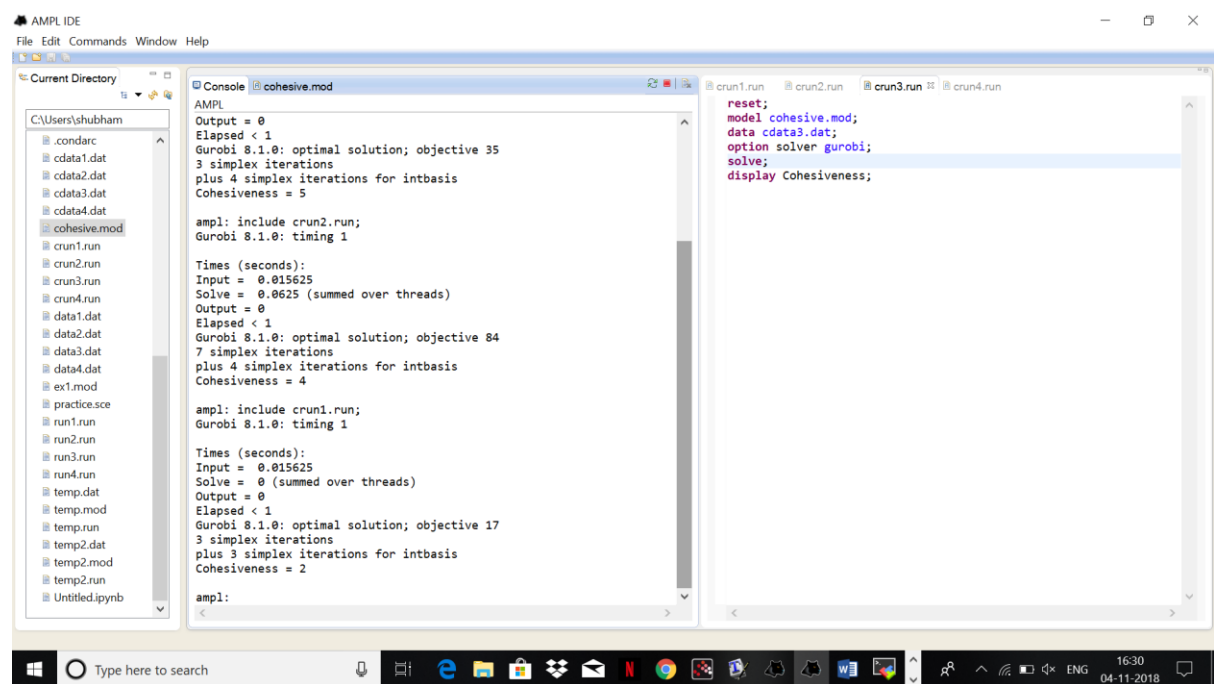
Times (seconds):
Input = 0.015625
Solve = 0.0625 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 84
7 simplex iterations
plus 4 simplex iterations for intbasis
Cohesiveness = 4

ampl: include crun1.run;
Gurobi 8.1.0: timing 1

Times (seconds):
Input = 0.015625
Solve = 0 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 17
3 simplex iterations
plus 3 simplex iterations for intbasis
Cohesiveness = 2

ampl:
```

```
reset;
model cohesive.mod;
data cdata3.dat;
option solver gurobi;
solve;
display Cohesiveness;
```



This screenshot is similar to the one above, showing the AMPL IDE interface. The 'Console' pane shows the same three solves, but the 'Cohesiveness' values are 5, 4, and 2. The right pane shows the code in 'crun3.run', which is identical to the one above.

```
AMPL
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 35
3 simplex iterations
plus 4 simplex iterations for intbasis
Cohesiveness = 5

ampl: include crun2.run;
Gurobi 8.1.0: timing 1

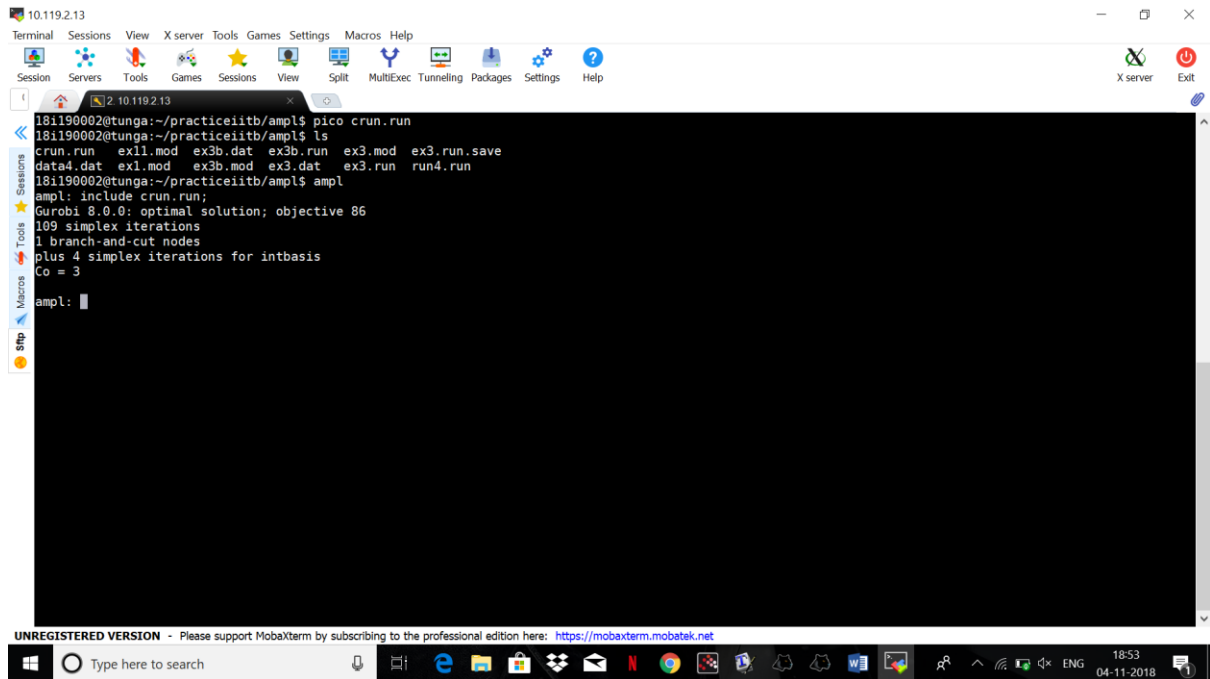
Times (seconds):
Input = 0.015625
Solve = 0.0625 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 84
7 simplex iterations
plus 4 simplex iterations for intbasis
Cohesiveness = 4

ampl: include crun1.run;
Gurobi 8.1.0: timing 1

Times (seconds):
Input = 0.015625
Solve = 0 (summed over threads)
Output = 0
Elapsed < 1
Gurobi 8.1.0: optimal solution; objective 17
3 simplex iterations
plus 3 simplex iterations for intbasis
Cohesiveness = 2

ampl:
```

```
reset;
model cohesive.mod;
data cdata3.dat;
option solver gurobi;
solve;
display Cohesiveness;
```



The screenshot shows a MobaXterm terminal window with the title bar '10.119.2.13'. The terminal displays the following commands and output:

```
181190002@tunga:~/practiceiitb/aml$ pico crun.run
181190002@tunga:~/practiceiitb/aml$ ls
crun.run  ex11.mod  ex3b.dat  ex3b.run  ex3.mod  ex3.run.save
data4.dat  ex1.mod  ex3b.mod  ex3.dat  ex3.run  run4.run
181190002@tunga:~/practiceiitb/aml$ ampl
ampl: include crun.run;
Gurobi 8.0.0: optimal solution; objective 86
109 simplex iterations
1 branch-and-cut nodes
plus 4 simplex iterations for intbasis
Co = 3
ampl: 
```

At the bottom of the terminal window, a message reads: 'UNREGISTERED VERSION - Please support MobaXterm by subscribing to the professional edition here: <https://mobaxterm.mobatek.net>'. The Windows taskbar is visible at the bottom, showing the search bar and various application icons. The system clock indicates 18:53 on 04-11-2018.

## PART (7)

If the objective was to minimize Cohesiveness over all possible  $l$  length strings, then we would have made a optimisation model in such a way that it minimises the cohesiveness of all the  $l$  length strings that can be made by the given alphabets. We find the max and min of the sum of variables and find the cohesive minimum