

HIG

the Hydro unit commitment Instances Generator

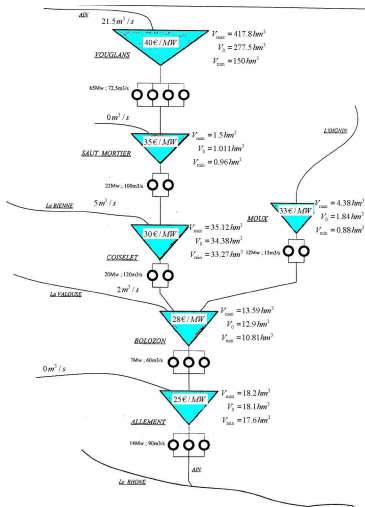
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(joint work with Dimitri Thomopulos)

CNRS & École Polytechnique, France

PGMO Days 2018

The Hydro Unit Commitment & Scheduling Problem

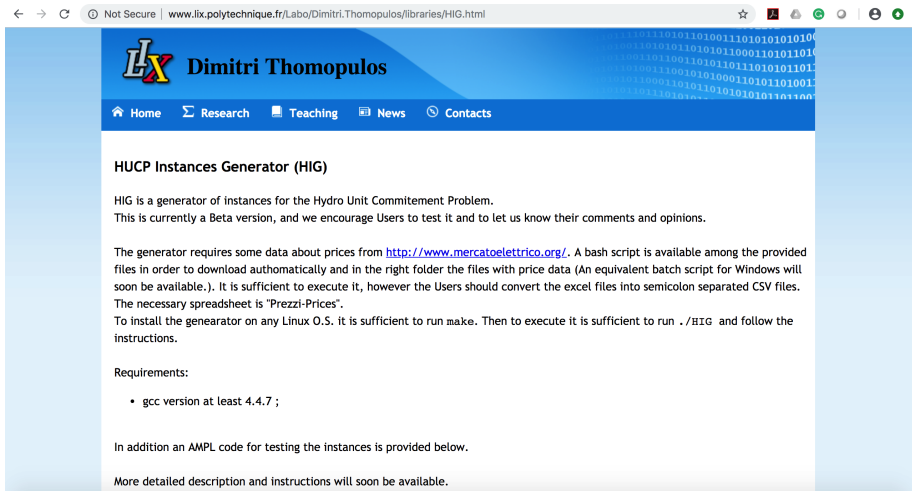


- Find the **optimal scheduling** of several plants with multi-unit pump-storage hydro power station.
- Short term.
- **Assumptions:** forecast electricity prices and inflows, price-taker.
- **16.4 %** of the total energy produced worldwide.
- **71 %** of all renewable electricity.

- To the best of our knowledge, no instances testbed available for HUC
- Useful to the community to compare methods
- Open-source code to generate a large number of instances:

<http://www.lix.polytechnique.fr/Labo/Dimitri.Thomopoulos/libraries/HIG.html>

Where and how to download the HIG code



The screenshot shows a web browser window with the address bar displaying "www.lix.polytechnique.fr/Labo/Dimitri.Thomopoulos/libraries/HIG.html". The page header features the "Lx" logo and the name "Dimitri Thomopoulos". A navigation menu includes "Home", "Research", "Teaching", "News", and "Contacts". The main content area is titled "HUCP Instances Generator (HIG)" and contains the following text:

HIG is a generator of instances for the Hydro Unit Commitment Problem. This is currently a Beta version, and we encourage Users to test it and to let us know their comments and opinions.

The generator requires some data about prices from <http://www.mercatoelettrico.org/>. A bash script is available among the provided files in order to download automatically and in the right folder the files with price data (An equivalent batch script for Windows will soon be available.). It is sufficient to execute it, however the Users should convert the excel files into semicolon separated CSV files. The necessary spreadsheet is "Prezzi-Prices".

To install the generator on any Linux O.S. it is sufficient to run `make`. Then to execute it is sufficient to run `./BIG` and follow the instructions.

Requirements:

- gcc version at least 4.4.7 ;

In addition an AMPL code for testing the instances is provided below.

More detailed description and instructions will soon be available.

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More detailed description and instructions will soon be available.

Codes (click the name of a code to download it, or to access it through a link).

[HIG](#) (hig.zip)

[AMPL_model](#) (math_model_MILP_lin2vars.zip)



"The best thing one can do when it's raining is to let it rain."

Henry Wadsworth Longfellow



How to compile and run the HIG code

```
unzip -f /usr/local/anaconda3/bin/conda-unzip -o /usr/local/anaconda3/bin/conda-unzip -d /usr/local/anaconda3/bin/conda-unzip
Clausias-MacBook-Pro:Downloads claudias$ unzip hig.zip -d hig
Archive:  hig.zip
  creating:  hig/Inflows/
  inflating:  hig/Inflows/Suviana_2004_2012.csv
  creating:  hig/src/
  inflating:  hig/src/head.h
  inflating:  hig/src/Main.cpp
  inflating:  hig/src/read.cpp
  inflating:  hig/src/read.h
  inflating:  hig/src/write_instance.cpp
  inflating:  hig/src/write_instance.h
  inflating:  hig/getPrices.sh
  inflating:  hig/Makefile
  inflating:  hig/Readme.txt
Clausias-MacBook-Pro:Downloads claudias$ cd hig
Clausias-MacBook-Pro:hig claudias$ chmod +x getPrices.sh
Clausias-MacBook-Pro:hig claudias$ ./getPrices.sh
./getPrices.sh: line 39: [: =: unary operator expected
./getPrices.sh: line 39: [: =: unary operator expected
./getPrices.sh: line 53: [: =: unary operator expected
./getPrices.sh: line 53: [: =: unary operator expected
./getPrices.sh: line 61: [: =: unary operator expected
--2018-11-16 15:46:59-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2004.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org|5.249.130.157|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 2389791 (2.2M) [application/x-zip-compressed]
Saving to: 'Anno2004.zip'
Anno2004.zip  100%[=====>]  2.20M  512KB/s  in 4.4s
2018-11-16 15:47:04 (512 KB/s) - 'Anno2004.zip' saved [2389791/2389791]
--2018-11-16 15:47:04-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2005.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org|5.249.130.157|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 10570909 (10M) [application/x-zip-compressed]
Saving to: 'Anno2005.zip'
Anno2005.zip  100%[=====>] 10.08M  1.29MB/s  in 12s
```

How to compile and run the HIG code

```
Anno2005.zip 100%[----->] 10.08M 1.29MB/s in 12s
2018-11-16 15:47:16 (888 KB/s) - 'Anno2005.zip' saved [10570909/10570909]
--2018-11-16 15:47:16-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2006.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 5781101 (5.9M) [application/x-zip-compressed]
Saving to: 'Anno2006.zip'
Anno2006.zip 100%[----->] 5.51M 879KB/s in 8.0s
2018-11-16 15:47:24 (707 KB/s) - 'Anno2006.zip' saved [5781101/5781101]
--2018-11-16 15:47:24-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2007.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 11642528 (11M) [application/x-zip-compressed]
Saving to: 'Anno2007.zip'
Anno2007.zip 100%[----->] 11.10M 1.46MB/s in 9.4s
2018-11-16 15:47:34 (1.18 MB/s) - 'Anno2007.zip' saved [11642528/11642528]
--2018-11-16 15:47:34-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2008.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 11790111 (11M) [application/x-zip-compressed]
Saving to: 'Anno2008.zip'
Anno2008.zip 100%[----->] 11.24M 1.42MB/s in 12s
2018-11-16 15:47:45 (996 KB/s) - 'Anno2008.zip' saved [11790111/11790111]
--2018-11-16 15:47:45-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2009.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 10378890 (9.9M) [application/x-zip-compressed]
Saving to: 'Anno2009.zip'
Anno2009.zip 100%[----->] 9.90M 1.49MB/s in 22s
```

How to compile and run the HIG code

```
Anno2009.zip 100%[----->] 9.90M 1.49MB/s in 22s
2018-11-16 15:48:08 (452 KB/s) - 'Anno2009.zip' saved [10378890/10378890]
--2018-11-16 15:48:08-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2010.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 11216663 (11M) [application/x-zip-compressed]
Saving to: 'Anno2010.zip'
Anno2010.zip 100%[----->] 10.70M 1.77MB/s in 9.6s
2018-11-16 15:48:17 (1.19 MB/s) - 'Anno2010.zip' saved [11216663/11216663]
--2018-11-16 15:48:17-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2011.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 11398991 (11M) [application/x-zip-compressed]
Saving to: 'Anno2011.zip'
Anno2011.zip 100%[----->] 10.87M 1.50MB/s in 12s
2018-11-16 15:48:29 (906 KB/s) - 'Anno2011.zip' saved [11398991/11398991]
--2018-11-16 15:48:29-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2012.zip
Resolving www.mercatoelettrico.org... 5.249.130.157
Connecting to www.mercatoelettrico.org[5.249.130.157]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 6133393 (5.8M) [application/x-zip-compressed]
Saving to: 'Anno2012.zip'
Anno2012.zip 100%[----->] 5.85M 1.08MB/s in 9.1s
2018-11-16 15:48:38 (668 KB/s) - 'Anno2012.zip' saved [6133393/6133393]
Archive: Anno2004.zip
  inflating: Prices/Anno2004.xls
Archive: Anno2005.zip
  inflating: Prices/Anno 2005.xls
Archive: Anno2006.zip
  inflating: Prices/Anno 2006.xls
Archive: Anno2007.zip
  inflating: Prices/Anno 2007.xls
1 of 200 selected, 377.8 GB available
```


How to compile and run the HIG code

```
Archive: Anno2004.zip
  inflating: Prices/Anno2004.xls
Archive: Anno2005.zip
  inflating: Prices/Anno 2005.xls
Archive: Anno2006.zip
  inflating: Prices/Anno 2006.xls
Archive: Anno2007.zip
  inflating: Prices/Anno 2007.xls
Archive: Anno2008.zip
  inflating: Prices/Anno 2008.xls
Archive: Anno2009.zip
  inflating: Prices/Anno 2009.xls
Archive: Anno2010.zip
  inflating: Prices/Anno 2010.xls
Archive: Anno2011.zip
  inflating: Prices/Anno 2011.xls
Archive: Anno2012.zip
  inflating: Prices/Anno 2012.xls
(Claudio@MacBook-Pro:~$ hg clone http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2011.zip
bla=)
for file in Main.o read.o write_instance.o; do bla="$bla `echo obj/$file`; done; \
g++ -O3 -pipe -DIL_STD -DNDERUG -o HIG $bla
```

How to compile and run the HIG code

```
claudias-MacBook-Pro:~$ cd /Users/claudia/HIG
claudias-MacBook-Pro:HIG claudia$ ./HIG
Instanceinator v0.99

The generator of instances for the HUCP can be used in two possible ways:
- Create a specific instance;
- Create some random instances.

In addition, three possible formats are available:
  0 Single-reservoir instance format with one unique pair of volume bounds;
  1 Multi-reservoir instance format.

Please, select the format of instances you want to create.
An integer value in [0,1] is required. Press enter for the default value { 0 }: 0

Please, select the number of instances you want to create.
An integer value in [1,300] is required. Press enter for the default value { 1 }: 1

Please, select the year of the starting date.
An integer value in [2004,2012] is required. Press enter for the default value { 2004 }:
Default value: 2004

Please, select the month of the starting date.
An integer value in [4,12] is required. Press enter for the default value { 4 }:
Default value: 4

Please, select the day of the starting date.
An integer value in [1,30] is required. Press enter for the default value { 5 }:
Default value: 5

Please, select the number of periods.
An integer value in [24, 48, 72, 96, 120, 144, 168] is required. Press enter for the default value { 24 }: 168

Please, select the number of operational points for turbines.
An integer value in [3,36] is required. Press enter for the default value { 16 }: 3

*** Reading prices ***
*** [-----] 100% ***
*** Reading prices - Complete ***

*** Reading inflows ***
*** [-----] 100% ***
*** Reading inflows - Complete ***

Please, select the number of volume steps.
An integer value in [1,25] is required. Press enter for the default value { 2 }:
```

How to compile and run the HIG code

```
Please, select the number of operational points for turbines.
An integer value in [3,36] is required. Press enter for the default value { 3 } : 3
100%[=====]

*** Reading prices ***
*** [-----] 100% *** 08 (452 KB/s) - 'Anno2009.zip' saved [10378890/10378890]
*** Reading prices - Complete ***

*** Reading inflows ***
*** [-----] 100% *** 8:08-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2010.zip
*** Reading inflows - Complete ***
mercatoelettrico.org... 5.249.130.157:80... connected.

Please, select the number of volume steps.
An integer value in [1,25] is required. Press enter for the default value { 2 } :
Default value: 2
request sent, awaiting response... 200 OK

Please, select the modifier of the LB on the volume.
An integer value in [0,900] is required. Press enter for the default value { 0 } :
Default value: 0
Anno2010.zip

Please, select the modifier of the UB on the volume.
An integer value in [0,900] is required. Press enter for the default value { 0 } :
Default value: 0
100%[=====]

Please, select the initial volume.
An integer value in [0,900] is required. Press enter for the default value { 304 } :
Default value: 304
16 15:48:17 (1.19 MB/s) - 'Anno2010.zip' saved [11216663/11216663]

Please, select the target volume.
An integer value in [0,847] is required. Press enter for the default value { 304 } :
Default value: 304
16 15:48:17-- http://www.mercatoelettrico.org/En/MenuBiblioteca/Documenti/Anno2011.zip
5.249.130.157

Single-reservoir_instances/Suviana_040405_168_3_2_000_000_304_304.dat
*** Writing instance ***
*** [-----] 100% *** mercatoelettrico.org/5.249.130.157:80... connected.
*** Writing instance - Complete ***
request sent, awaiting response... 200 OK

Claudias-MacBook-Pro:~$ cd Single-reservoir_instances/
Claudias-MacBook-Pro:~$ cd Single-reservoir_instances/
Claudias-MacBook-Pro:Single-reservoir_instances$ ls
Makefile      Readme.txt   getPrices.sh  src/
Inflows/     Prices/      Single-reservoir_instances/obj/

Claudias-MacBook-Pro:Single-reservoir_instances$ ls
total 24
drwxr-xr-x  3 claudia staff   96 Nov 16 15:53 .
drwxr-xr-x 11 claudia staff  382 Nov 16 15:53 ..
-rw-r--r--  1 claudia staff 10040 Nov 16 15:53 Suviana_040405_168_3_2_000_000_304_304.dat
100%[=====]

Claudias-MacBook-Pro:~$ cd Single-reservoir_instances/
```

Instance file name description

For example, Suviana_040405_168_3_2_000_000_304_304 stands for:

- Name of the reservoir
- Date considered for the inflows and electricity prices in the format YYMMDD
- Time horizon duration
- Number of operational points of the turbine/pump unit
- Number of levels of water volume considered
- Modification of the default lower bound on the water volume
- Modification of the default upper bound on the water volume
- Modification of the default water volume at time step 0
- Modification of the default target water volume at the last time step

The AMPL files: hydro_scaling.run

```
1 *****
2 # Hydro Unit Commitment model
3 # MILP with standard linearization of 2 variables (q and v), single reservoir
4 # modified to be compatible with HUC instances generator by Dimitri
5 # Author: Claudia D'Ambrosio
6 # Data: 20181114
7 *****
8
9 reset;
10 reset options;
11
12 model hydro_scaling.mod;
13
14 param datFileName symbolic;
15 let datFileName := $datFile;
16
17 data (datFileName);
18
19
20 *****
21 *****
22
23
24 option presolve 0;
25
26
27 option solver cplexAMPL;
28 option cplex_options 'nodefile=2 \
29   threads=1 \
30   mipdisplay=2 \
31   mipinterval=100 \
32   file=model.lp \
33   timelimit=7200 \
34   logfile=cplex.log';
35
36
37 *****
38 *****
39 *****
40
41
```

Line: 94-94:6 | Plain Text | Tab Size: 4 | [Icons]

The AMPL files: hydro_scaling.run

```
hydro_scaling.mod  untitled 2  hydro_scaling.run — MILP_2vars  Add License
37 #####
38 #####
39 #####
40
41
42 # fix redundant variables
43 fix (n in TURBINES, t in PERIODS, j in 0..0, i in 0..NOPT[n]) b_alpha[n,t,j,i] := 0;
44 fix (n in TURBINES, t in PERIODS, j in 0..0, i in 0..NOPT[n]) b_alphaU[n,t,j,i] := 0;
45 fix (n in TURBINES, t in PERIODS, j in 0..R, i in 0..0) b_alphaL[n,t,j,i] := 0;
46 fix (n in TURBINES, t in PERIODS, j in 0..R, i in 0..0) b_alphaU[n,t,j,i] := 0;
47 fix (n in TURBINES, t in PERIODS, i in 0..0) b_alpha_p[n,t,i] := 0;
48 fix (n in TURBINES, t in PERIODS, i in 0..0) b_alpha_p[n,t,i] := 0;
49
50 # relax integrality requirement for alphas if the turbine type is not 'D'
51 for (n in TURBINES: type[n]!='D'){
52   let {t in PERIODS, j in LEVELS, i in OPT[n]} alpha[n,t,j,i].relax := 1;
53 }
54
55 # FOR WRITING OUT THE .nl FILE OF THE RESTRICTION
56 #write gmodel;
57
58 solve; #> output.out;
59
60
61
62 #####
63 #####
64 # Writing .txt file
65 #####
66 #####
67 # Modified by Claudia - 11/17/06
68 #####
69 #####
70 printf "Input Data\n\n" > sol.txt;
71
72 printf "delta_t\trampup\trampdown\tv_min\tv_max\tv_T\tpump_activation_via_turbine\ttheta_min\n" > sol.txt;
73 printf "%.2f\t%.2f\t%.2f\t%.2f\t%.2f\t%.2f\t%.2f\t%.2f\n",delta_t,rampup,rampdown,v_min,v_max,v_T,pump_activation_via_turbine,theta_min > sol.txt;
74
75 printf "\n\n" > sol.txt;
76
77 printf "\tinflows\trprice\n" > sol.txt;
```

The mathematical model: hydro_scaling.mod

Independent variables:

- For each time step t and each unit j (turbine or pump): **water flow** $_{jt}$;
- For each time step t : **spillage** $_t$;

Dependent variables:

- For each time step t : **water volume** $_t$ in the basin;
- For each time step t and each unit j (turbine or pump): **power** $_{jt}$ (generated or consumed).

Plus auxiliary variables for modeling discontinuities, linearization, etc.

Physical constraints:

- Water flow balance equations
- Respect allowed operational points: (dis-)continuous, discrete, turbine/pump related
- Forbid of simultaneous pump and turbine mode
- Power production depending on water flow and head effect
- Minimum number of periods to be spent in a status by the unit (minimum starting up/down times)
- spillage
- ...

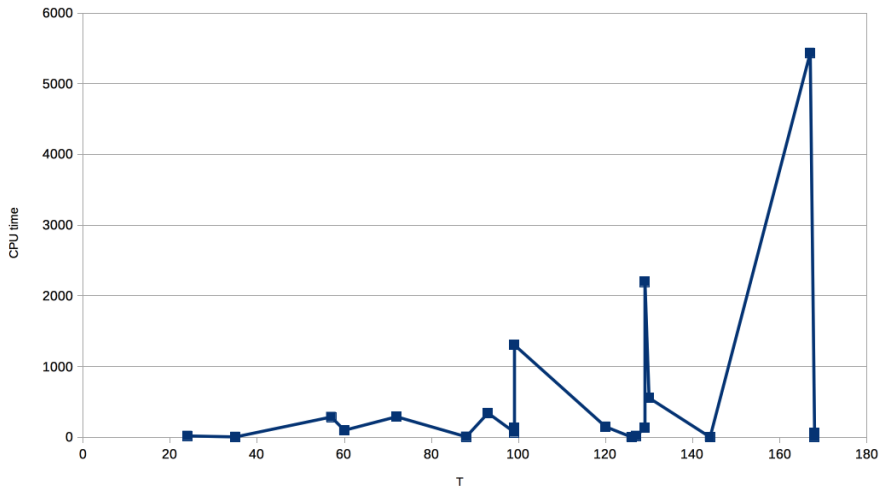
Strategic (soft) constraints:

- Ramp up/down bound constraint
- Load balance equations constraints
- Minimum release of water per period
- Minimum final reservoir level

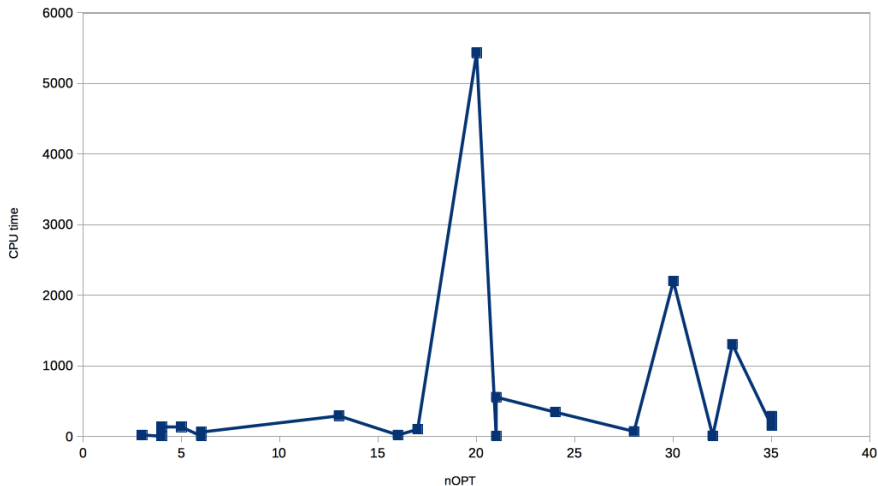
Objective function:

- Maximize the profit

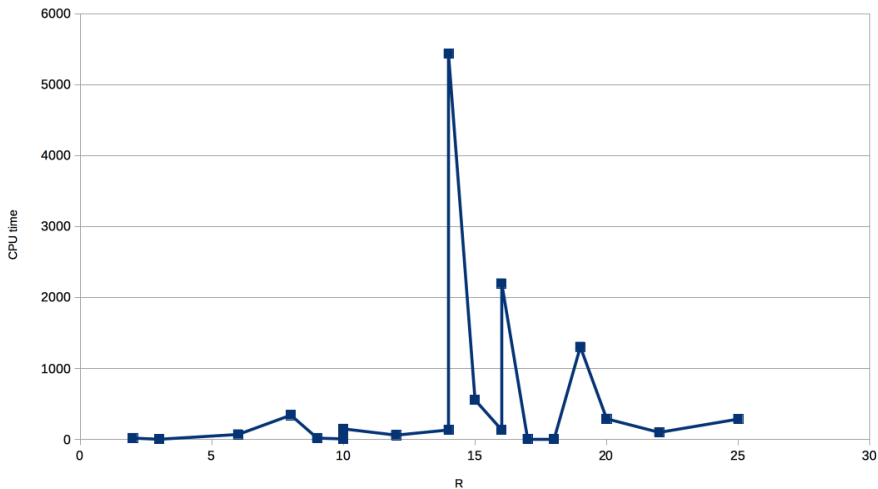
CPU time as a function of the # of time steps



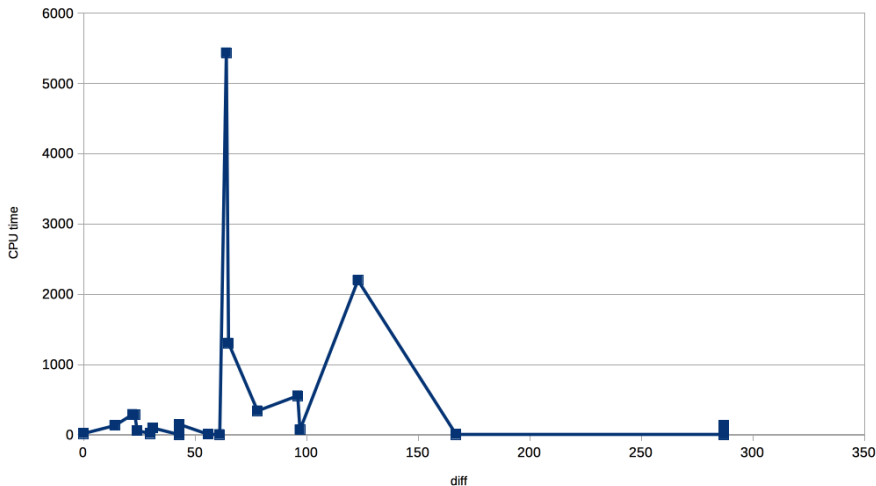
CPU time as a function of the # of operational points



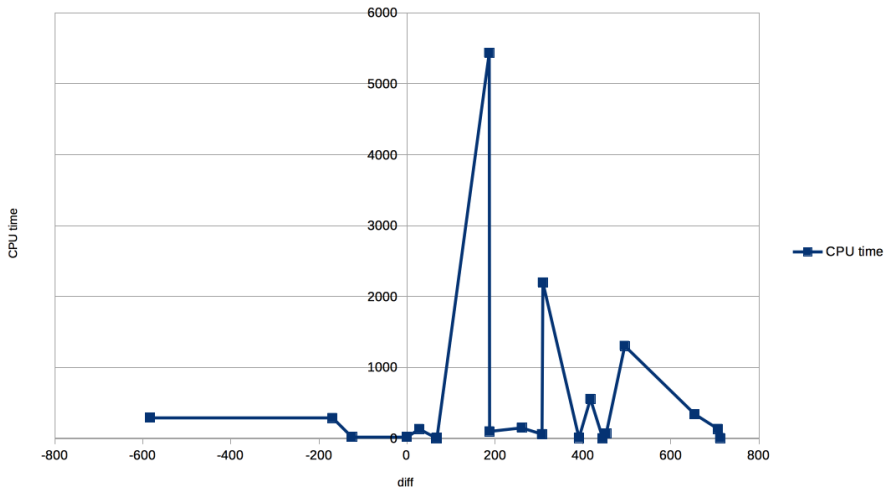
CPU time as a function of the # of water volume levels



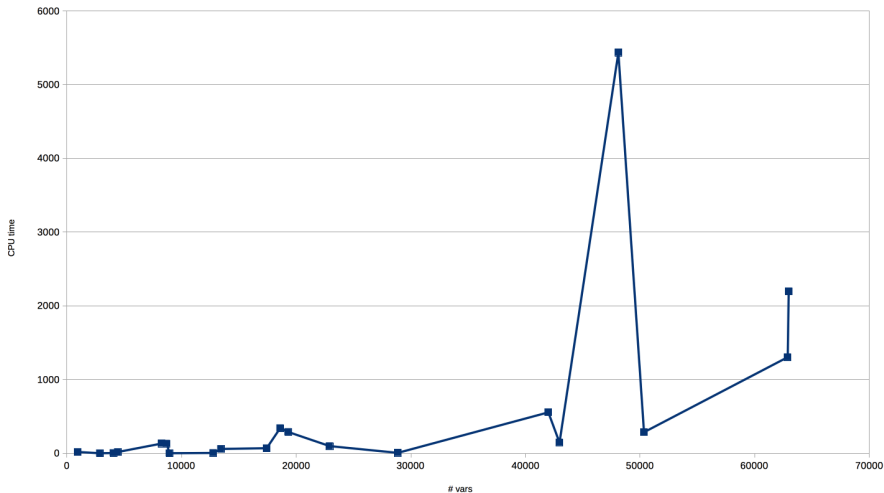
CPU time as a function of the difference between the initial water volume and the target water volume



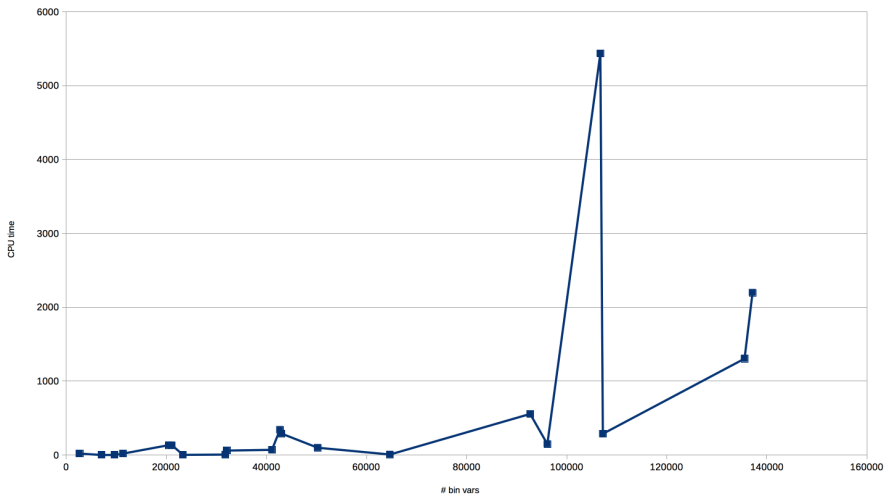
CPU time as a function of the difference between the upper and the lower bound on the water volume



CPU time as a function of the # of variables



CPU time as a function of the # of binary variables



- Beta version, we hope to have feedback and contributions
- Enrich the variety of potentially generated instances (different valleys, reservoirs, turbines, pumps, etc)
- Enrich the list of available mathematical models (comparison)

Thanks!