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Technische Universität
Cottbus - Senftenberg

Energy systems modelling

Tutorial 1: A few detail on GAMS, math programming and Homer Simpson`s exercise

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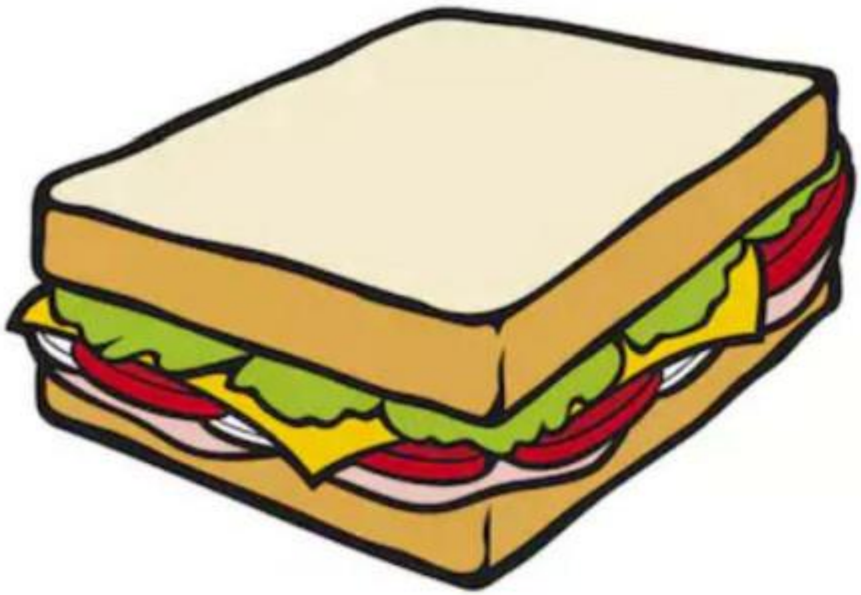
Some words about mathematically-oriented languages (in addition to GAMS guide your read)

The algebraic languages are *declarative* rather than *imperative*



Some words about mathematically-oriented languages (in addition to GAMS guide your read)

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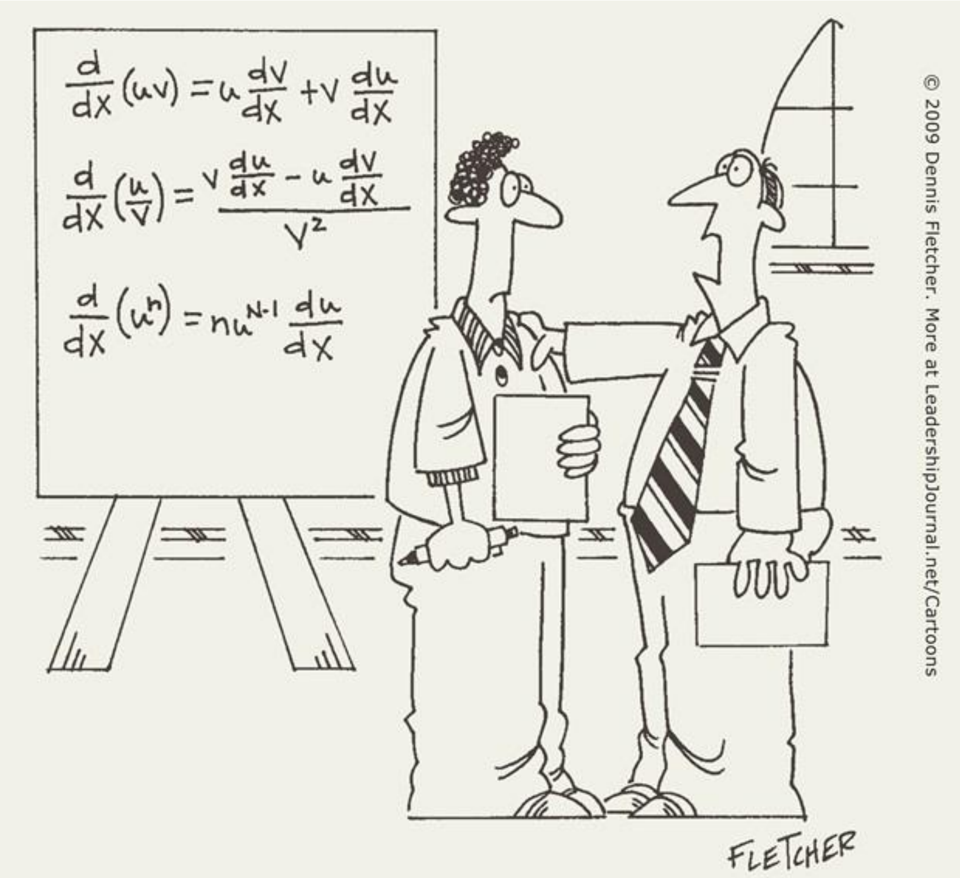
Strengths of such languages is supposed to be determined by an external program (algorithm) called ***solver.***

Solvers are algorithms designed to find solutions for particular problem types, e.g.:

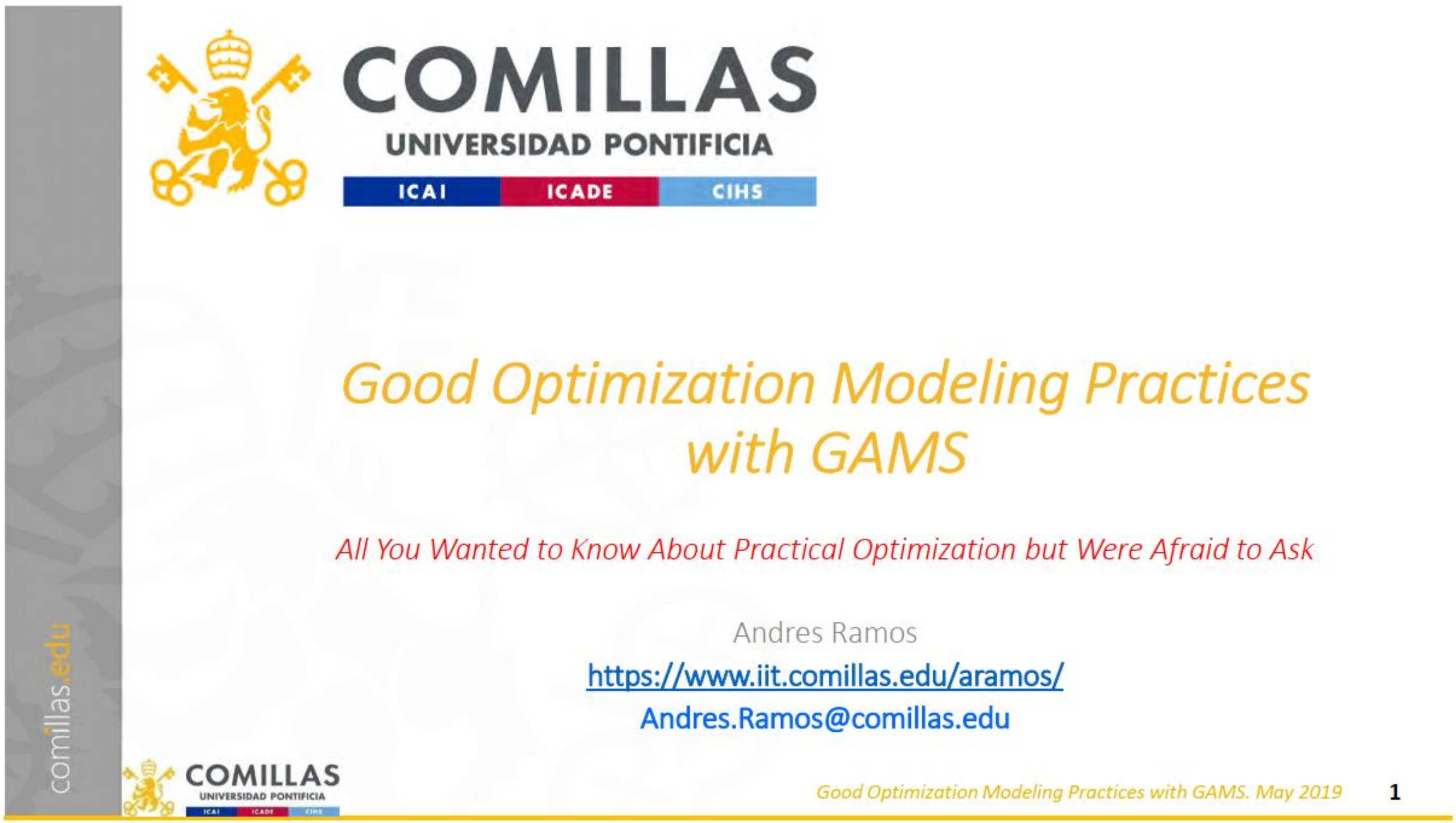
- CPLEX for LP/MIP/QCP
- IPOPT for LP/NLP/DNLP
- PATH for MCP



"Ted, as your pastor, I admit that your particular problem may be too complex for my expertise."

If you want your next 2 hours to be amazing

Find in Moodle…



Solution of “Homer: true story” home task

Toy Model: a True Story

The Springfield's energy program is one of the world´s most ambitious initiatives to transform and decarbonize the entire energy system of a region. The program includes deregulation of the electricity sector. From now on, independent suppliers have to participate on the newly established electricity market to win the right to sell energy.

The Springfield's Ministry for Energy (SMfE) urgently needs tools that allow for modelling and efficient planning of electricity market operation. Homer Jay Simpson, a research scientist at the SMfE, is asked to develop a cost optimization model of electricity market.

Your task is to help Homer!

Homer reads a GAMS guide

Toy model: Market Data and Tasks

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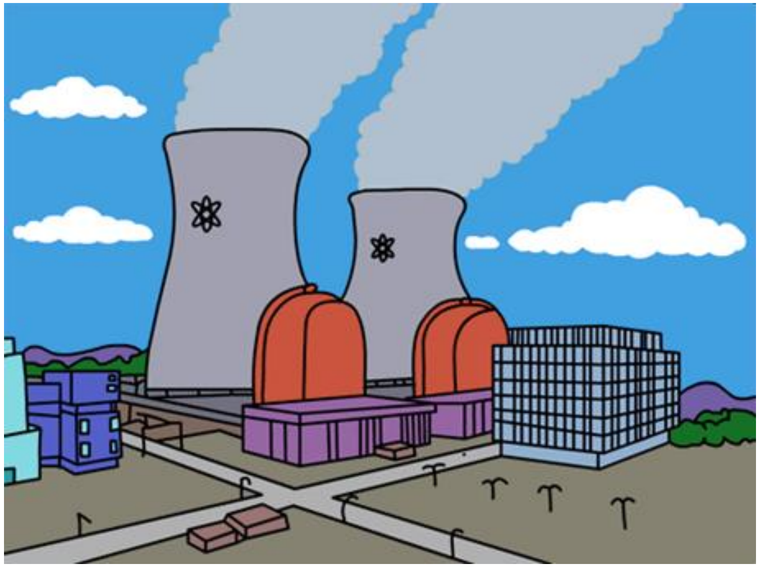
Springfield has two power plants with the following characteristics:

Variable costs: **C_1 = 4 and C_2 = 7 [Cent/kWh].**

Available capacities: **X_1 = 800 and X_2 = 500 [MW].**

The electricity demand: **D = 1000 [MW].**



The Springfield's 800 MW power plant.

Tasks:

1. Draw the merit-order chart representing Springfield's electricity market.
2. Write the complete mathematical formulation of the cost minimization problem.
3. Specify the optimal solution to this problem.
4. Solve the problem in GAMS using linear programming.

Simple optimization model

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Imagine that there are two power generation technologies in a market.

- The costs are c_1 = 40 and c_2 = 70 [$/MWh].
- The capacity available is x_1 = 800 and x_2 = 500 [MW].
- The demand on a market is d = 1000 [MW].

$X_2 = 20$

Simple optimization model

- What is the optimal solution of this problem?

$$40 \cdot X_1 + 70 \cdot X_2 = C$$

$$X_1 = 800$$

$$X_2 = 200$$

$$40 \cdot 800 + 70 \cdot 200 = 46000 = C$$

Simple optimization model

- What is the complete mathematical formulation of this optimization problem? (Hint: production at lowest total cost)

$$\min_{X_1, X_2} C = c_1 X_1 + c_2 X_2$$

$$s.t.$$

$$X_1 + X_2 = d$$

$$X_i \leq x_i \ \forall i$$

$$X_i \geq 0 \ \forall i$$

Simple optimization model

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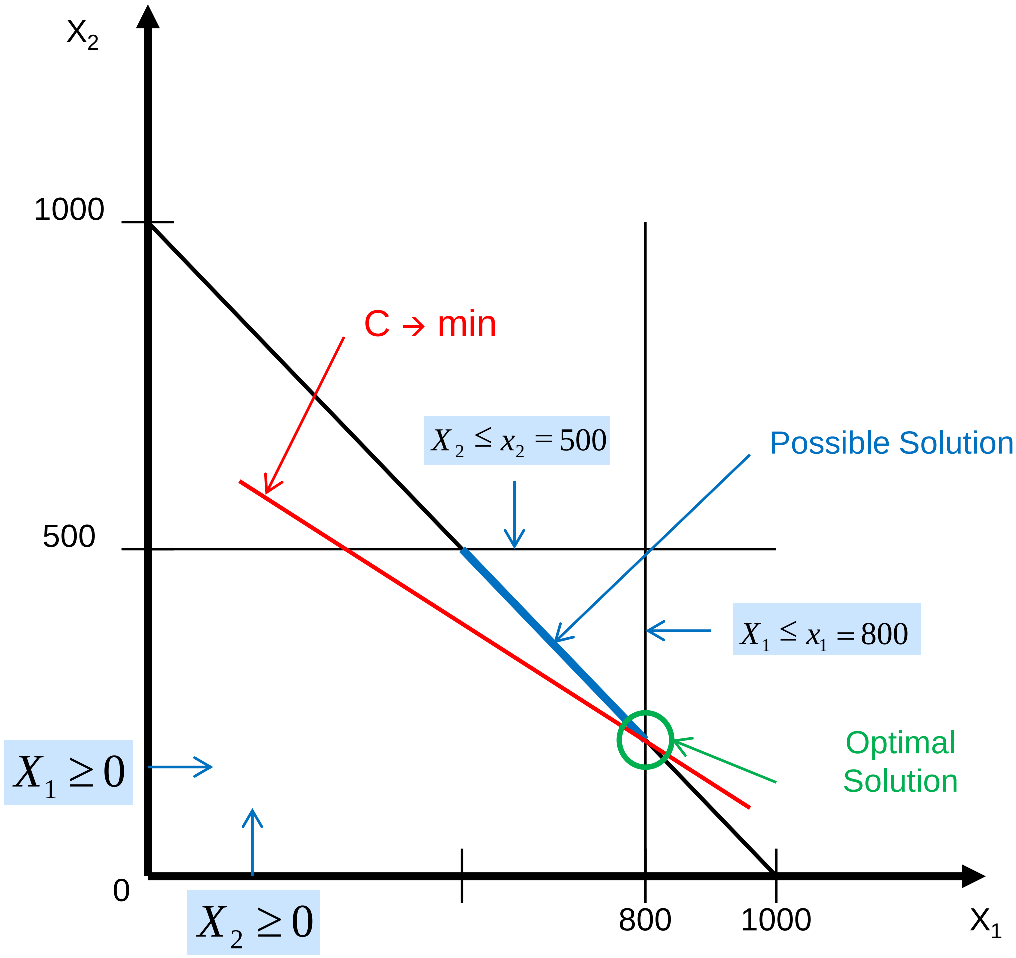

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GAMS implementation

[check Moodle for a GAMS code]

Some more useful features…

i. Variable attributes
ii. $-operator
iii. Solving model in loops
iv. Report parameters

Some more features: variables and suffixes

Variable declarations and types		Default bounds	
Variable	Continuous	−INF	+INF
Positive variable	Continuous	0	+INF
Binary variable	Discrete	0	1
Integer variable	Discrete	0	100
Semicontinuous variable	Either 0 or in [LO;UP]	0	INF
Semi-int variable	Either 0 or in {LO,LO + 1,. . .UP}	0	100

The lower and upper bounds of a variable are set automatically according to the variable's type (*free, positive, binary, or integer*).

These bounds can be overwritten by the GAMS user using:

- .LO for lower bound
- .UP for upper bound
- .FX for fixing a variable to a given value
- .L for initialization of a variable
- .M for marginal or dual value

Some more useful features…

i. Variable attributes
ii. $-operator
iii. Solving model in loops
iv. Report parameters

Some more features: $-operator

The dollar operator can be introduced in GAMS for a number of contexts.

- ✓ Conditionally execute an assignment

  ```
  A$(b gt 0) = 20;
  ```

- ✓ Conditionally add a term in sum or other set operation

  ```
  z = sum(i$(y(i) gt 0), x(i));
  ```

- ✓ Conditionally define an equation

  ```
  Equation1(i)$(ii).. sum(i, a(i)*x(i)) =e= 1;
  ```

- ✓ Conditionally include a term in an equation

  ```
  Equation1 .. x + y $(a gt 0) =e= 1;
  ```

Conditionally execute an assignment

✓ Conditionally execute an assignment

```
A$(b gt 0) = 20;

parameter
    flag        put 1 when capacity unlimited;
    flag        = 1;

cap('x1')$(flag=1) = 1e6;

solve ESM_is_a_simple_course using lp minimizing z;
    display x.l, z.l;
```

Conditionally add a term in sum or other set operation

- ✓ Conditionally add a term in sum or other set operation

```
z = sum(i$(y(i) gt 0), x(i));
```

```
SET
      i_conv(i) /x2/;

Parameter
      cap_conv capacity of conventional techs;

cap_conv = sum(i$i_conv(i), cap(i));

display cap_conv
```

Conditionally define an equation

- ✓ Conditionally define an equation

```
Equation1(i)$(ii).. sum(i, a(i)*x(i)) =e= 1;
```

```
SET
      i_conv(i) /x2/;

equation
      cons_conv(i) new constraint;

cons_conv(i)$i_conv(i)..   cap(i)*0.5 =l= x(i);

model ESM2 /all/;
solve ESM2 using lp minimizing z;
     display x.l, z.l, dem.m. cons.m;
```

Conditionally include a term in an equation

- ✓ Conditionally include a term in an equation

```
Equation1 .. x + y $(a gt 0) =e= 1;
```

```
parameters
    cost_co2      guess what's that?
    flag          put 1 if  we include co2 cost;
    cost_co2      = 15;
    flag          = 1;

    c('x2') = 7 + cost_co2$(flag=1);

solve ESM_is_a_simple_course using lp minimizing z;
   display x.l, z.l;
```

Some more useful features…

i. Variable attributes

ii. $-operator

iii. Solving model in loops

iv. Report parameters

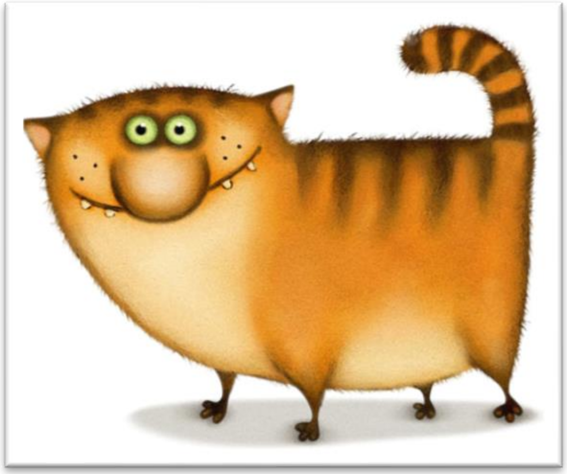
… for the next class

Homework

Real world VS model

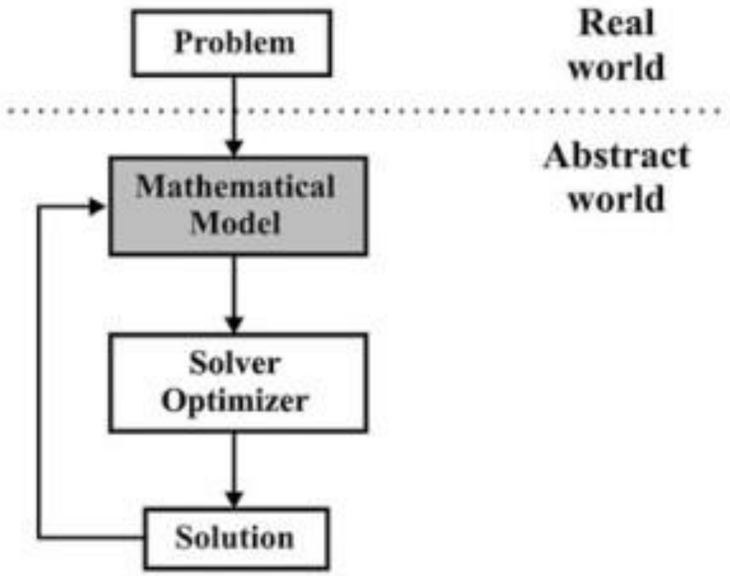
Real world out there

Model



Identification of relevant characteristics. Translation of 'real' object into the model

Homework: make your choice on the modeler's dilemma and vote in Moodle



Dilemma: what is the best course?

to consider an approximate (simplified) mathematical model of a problem and then try to obtain as exact a solution as possible

or

to use a mathematical model as accurately as possible and then determine an approximate solution of it?