Meeting #17:

Data modeling or curve-fitting (cont.)

Preparation for final ‘curve-fitting’ step using Solver:

	A	B	C	D	E	F
1	Tomas Materdey			2/19/2004		
2	x (Periods	y (lengths	a,b,c guesses	y'=a*x^2+b*x+c	(y-y')^2	
3	4.5	5	**0.23**	4.6575	0.11731	
4	6.35	10	**0**	9.274175	0.52682	
5	7.75	15	**0**	13.814375	1.40571	
6	9.2	20		19.4672	0.28388	
7					**0.58343**	
8	Typed in	Typed in	Typed in	Formula	Formula	
9	This is the preparation for doing the quadratic curve-fitting, which is done					
10	by minimizing the 'standard deviation' 0.58343 changing the coefficients					
11	a,b,c (contained in cells c3:c5) using Solver.					

How to minimize the parameter s using Solver?

Select cell containing the ‘standard deviation’, then select Tools/Solver (use add-ins if it is not there). Three steps:

(a) Make sure Target cell is that containing the ‘standard deviation’

(b) Choose ‘Set target cell (the ‘standard deviation’ cell) to minimum’

(c) Choose ‘By changing cells” those containing the coefficients of your model (a,b,c in y’=a*x^2+b*x+c in this example).

Then hit Solve.

	A	B	C	D	E	F
1	Tomas Materdey			2/24/2004		
2	x (Periods	y (lengths	a,b,c guesses	y'=a*x^2+b*x+c	(y-y')^2	
3	4.5	5	**0.133672108**	4.948402258	0.00266	
4	6.35	10	**1.387171999**	10.19780384	0.03913	
5	7.75	15	**-4.00073192**	14.77853205	0.04905	
6	9.2	20		20.07525769	0.00566	
7					**0.02413**	New 'standard deviation'
8	Typed in	Typed in	Changed by Solver	Formula	Formula	smaller is better
9	Results are shown in blue after minimizing the 'standard deviation' by changing the coefficients a,b,c of the quadratic model with Solver					
10	Final values for a,b,c which specify our quadratic models are shown in cells C3, C4, C5, respectively.					
11	Final value for 'standard deviation' is shown in cell E7; smaller means better model					

$$s = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n}$$

(i) **What is this curve-fitting process for, what is the application**?

Well, now that we know how to do a curve-fitting, it is time to keep our focus on its purpose. It is an important tool in the analysis and testing of a device. Predictability is an important characteristic of a good design. If it is possible to model the behavior of a device with a function (i.e., to relate the output variable to the input variable via a function) and to check the device behavior against the function, then the device is predictable. For example, in Project 2 ("Roulette of Fortune"), if after taking data for the odd sectors (rotation produced X and force needed Y), doing a curve-fitting, predicting needed forces for rotations into the even sectors using the obtained function, you can check that the predictions are good, then your "Roulette of Fortune" is predictable.

(ii) **How can we know what is the best model**?

The "standard deviation" can represent how far our data are from their average: $s = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n}$

This would indicate how well our judges agree on certain grade (for example, the peer evaluations in Project 0), or it can also represent how far our model is from the data: $s = \frac{\sum_{i=1}^{n}(y_i' - y_i)^2}{n}$

The smaller the deviation, the closer is our model to the data, or the better is our model. So you may ask, can we find a better model? This is a good question, this is what you should "ask when trying to find the best model for your "Roulette of Fortune"

-A quadratic model: a quadratic function relating two variables, e.g. ‘x’ and ‘y’
$f(x)= y = a*x^2 + b*x + c$

-A cubic model: $f(x) = y = d*x^3 + a*x^2 + b*x + c$

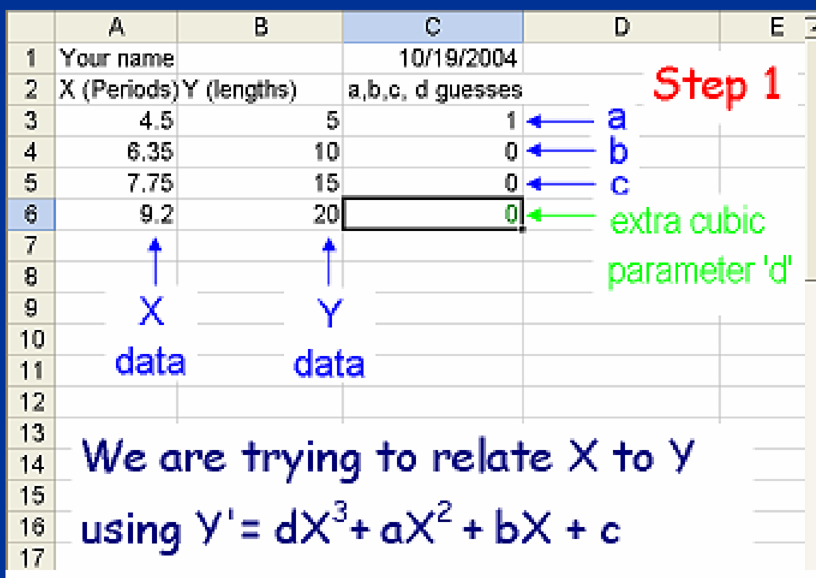
	A	B	C	D	E	F
1						
2	x (Periods)	y (lengths)	a,b,c, d guesses	y'=d*x^3+a*x^2+b*x+c	(y-y')^2	
3	4.5	5	1.497724051	4.998711912	1.7E-06	
4	6.35	10	-7.652800717	9.998057939	3.8E-06	
5	7.75	15	15.13332749	14.99956898	1.9E-07	
6	9.2	20	-0.066128114	20.00175582	3.1E-06	
7					2.2E-06	standard deviation'
8	Typed in	Typed in	Changed by Solver	Formula	Formula	smaller is better
9	Results are shown in blue after minimizing the 'standard deviation' by changing the coefficients a,b,c, d of the cubic model with Solver					
10	Final values for a,b,c, d which specify our cubic models are shown in cells C3, C4, C5, C6, respectively.					
11	Final value for 'standard deviation' is shown in cell E7; smaller means better model					

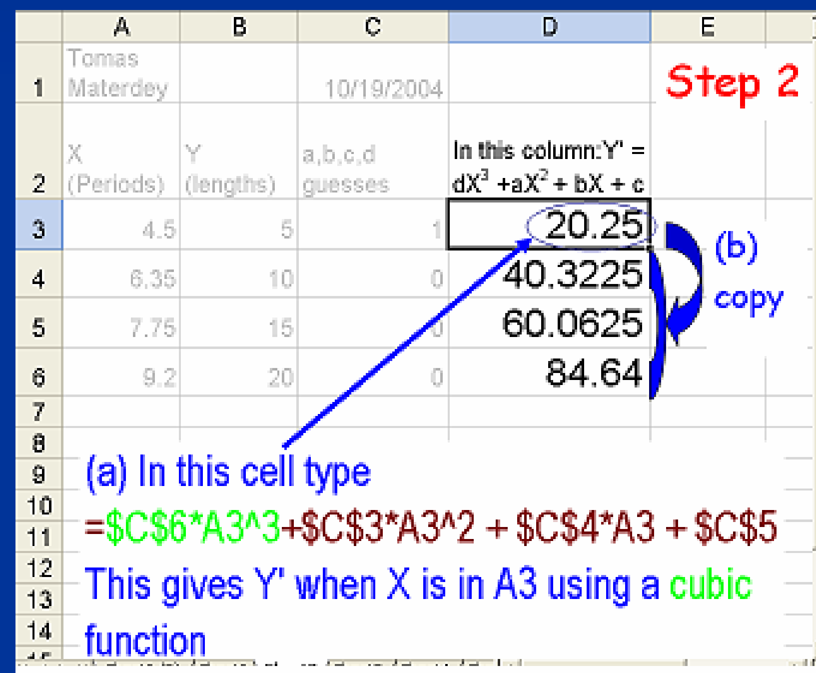
-A linear model: $f(x) = y = b*x+c$ (it is a quadratic model with a=0)

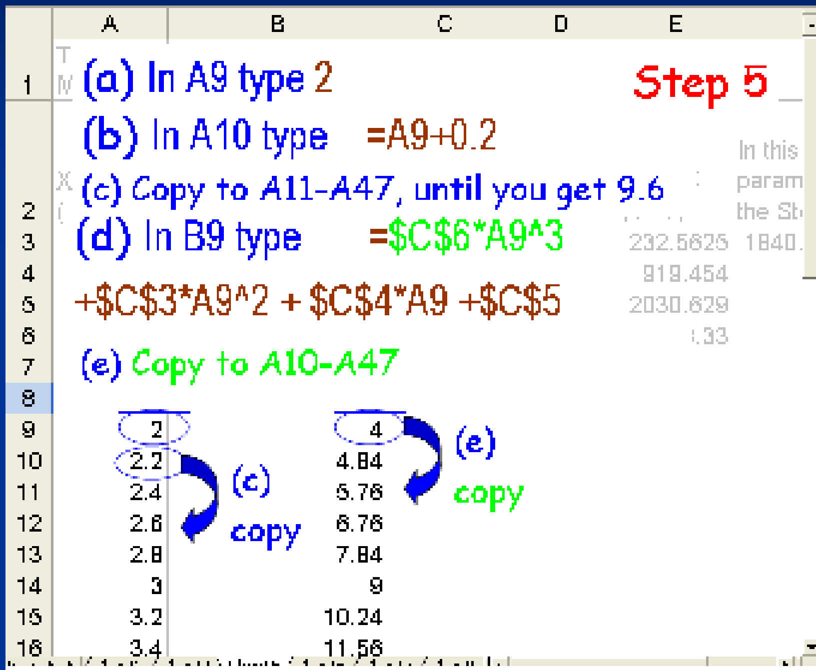
	A	B	C	D	E	F
1						
2	x (Periods)	y (lengths)	a,b,c, d guesses	y'=d*x^3+a*x^2+b*x+c	(y-y')^2	
3	4.5	5	0	4.631166342	0.13604	
4	6.35	10	3.211769401	10.57293973	0.32826	
5	7.75	15	-9.821795963	15.0694169	0.00482	
6	9.2	20	0	19.72648253	0.07481	
7					0.13598	standard deviation'
8	Typed in	Typed in	Changed by Solver	Formula	Formula	larger is worse
9	Results are shown in blue after minimizing the 'standard deviation' by changing the coefficients b,c in a linear model with Solver					
10	Final values for b,c which specify our linear model are shown in cells C4, C5, respectively. Note that coefficients a and d are left as zeroes.					
11	Final value for 'standard deviation' is shown in cell E7; larger means worse model					

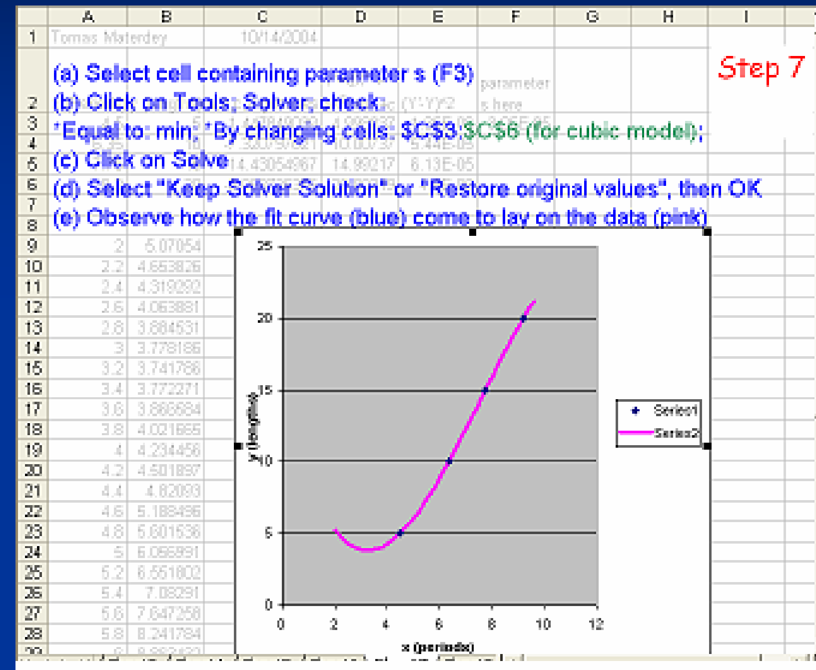
What changes should we make to produce a cubic model?

To produce a cubic model make the following changes, in your Excel file, as shown in green font






Step 5
(a) In A9 type 2
(b) In A10 type =A9+0.2
(c) Copy to A11-A47, until you get 9.6
(d) In B9 type =$C$6*A9^3 +$C$3*A9^2 + $C$4*A9 +$C$5
(e) Copy to A10-A47
(c) copy
(e) copy

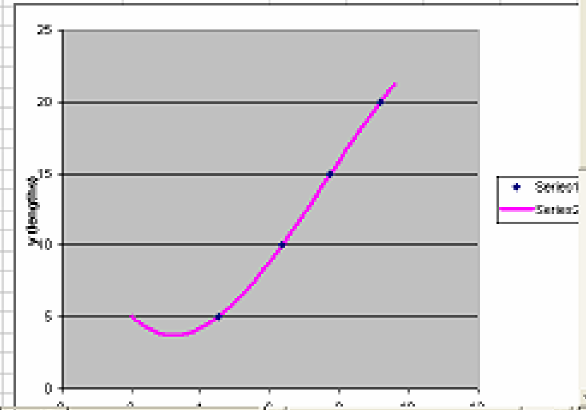

Step 7
(a) Select cell containing parameter s (F3)
(b) Click on Tools; Solver; check:
*Equal to: min; *By changing cells: $C$3:$C$6 (for cubic model);
(c) Click on Solve
(d) Select "Keep Solver Solution" or "Restore original values", then OK
(e) Observe how the fit curve (blue) come to lay on the data (pink)
Series1
Series2
x (periods)

$$Y' = dX^3 + aX^2 + bx + C$$

CUBIC model using
modified steps outlined
In previous slides

	A	B	C	D	E	F	G	H
1	Tomas Materdey							
2	X (Periods)	Y (lengths)	a,b,c,d guesses	$Y'=dX^3 + aX^2 + bX + c$	$(Y'-Y)^2$	s parameter		
3	4.5	5	1.449273268	4.998225484	3.15E-06	2.86E-05		
4	6.35	10	-7.329719765	10.00708409	5.02E-05			
5	7.75	15	14.44774473	14.99256703	5.52E-05			
6	9.2	20	-0.063797684	20.00232116	5.39E-06			
7								
8								
9	2	5.075016797		CUBIC Model				
10	2.2	4.657526121						
11	2.4	4.322292129						
12	2.6	4.066252533						
13	2.8	3.886345043						
14	3	3.77960737						
15	3.2	3.742677227						
16	3.4	3.772792323						
17	3.6	3.88679037						
18	3.8	4.02160908						
19	4	4.234186163						
20	4.2	4.501459331						
21	4.4	4.820366294						
22	4.6	5.187844764						
23	4.8	5.600832453						
24	5	6.056267071						
25	5.2	6.551086329						
26	5.4	7.082227938						
27	5.6	7.64662961						
28	5.8	8.241229057						
29	6	8.862963988						
30	6.2	9.508772115						

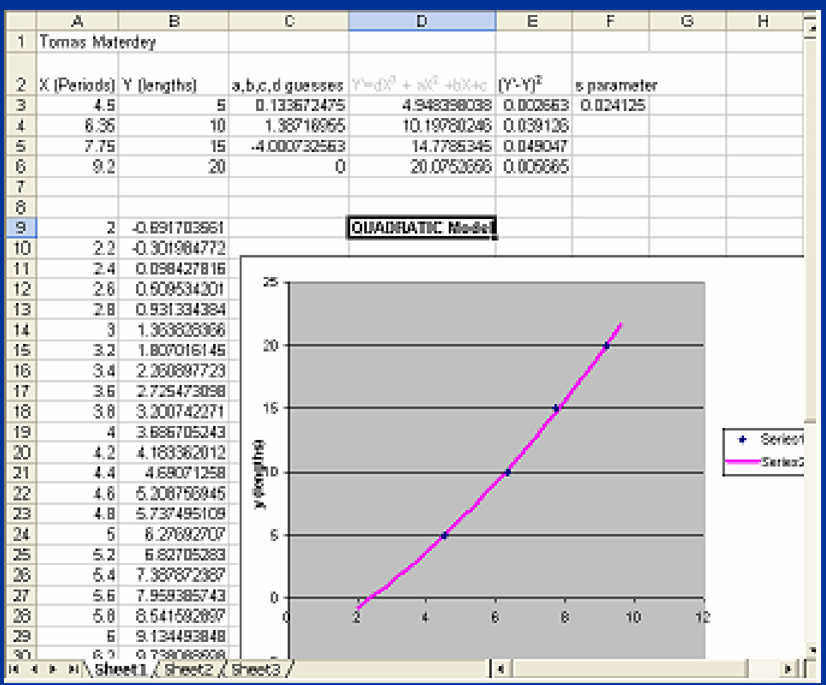
Sheet1 / Sheet2 / Sheet3



$Y' = dX^3 + aX^2 + bx + C$

How to get a QUADRATIC model using the equation for a CUBIC model?

By setting d=0 (in $C$6)and let Solver change a,b,c (in $C$3:$C$5)

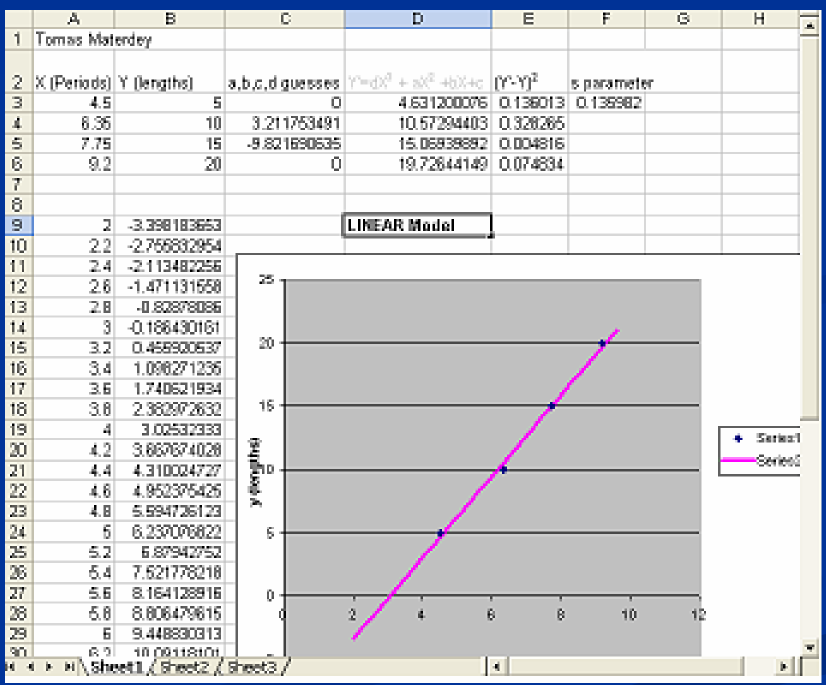


	A	B	C	D	E	F
1	Tomas Materdey					
2	X (Periods)	Y (lengths)	a,b,c,d guesses	$Y'=dX^3 + aX^2 + bX+c$	$(Y'-Y)^2$	s parameter
3	4.5	5	0.133672475	4.948398038	0.002663	0.024125
4	6.35	10	1.38718955	10.19780246	0.039126	
5	7.75	15	-4.000732563	14.7785345	0.049047	
6	9.2	20	0	20.0753656	0.005665	
7						
8						
9	2	-0.691703961		QUADRATIC Model		
10	2.2	-0.301984772				
11	2.4	0.098427816				
12	2.6	0.509534201				
13	2.8	0.931334384				
14	3	1.363828366				
15	3.2	1.807016145				
16	3.4	2.260897723				
17	3.6	2.725473098				
18	3.8	3.200742271				
19	4	3.686705243				
20	4.2	4.183362012				
21	4.4	4.69071258				
22	4.6	5.208756945				
23	4.8	5.737495109				
24	5	6.27692707				
25	5.2	6.82705283				
26	5.4	7.387872387				
27	5.6	7.959385743				
28	5.8	8.541592897				
29	6	9.134493848				
30	6.2	[illegible]				

How to get a LINEAR model using the equation for a CUBIC model?

Setting d=a=0 (in $C$6 and $C$3)

and let Solver change b,c (in $C$4:$C$5)



	A	B	C	D	E	F
1	Tomas Materdey					
2	X (Periods)	Y (lengths)	a,b,c,d guesses	$Y'=dX^3 + aX^2 + bX+c$	$(Y'-Y)^2$	s parameter
3	4.5	5	0	4.631200076	0.136013	0.136982
4	6.35	10	3.211753491	10.57294403	0.328265	
5	7.75	15	-9.821690635	15.06939892	0.004816	
6	9.2	20	0	19.72644149	0.074834	
7						
8						
9	2	-3.398183653		LINEAR Model		
10	2.2	-2.755832954				
11	2.4	-2.113482256				
12	2.6	-1.471131558				
13	2.8	-0.82878086				
14	3	-0.186430161				
15	3.2	0.455920537				
16	3.4	1.098271236				
17	3.6	1.740621934				
18	3.8	2.382972632				
19	4	3.02532333				
20	4.2	3.667674028				
21	4.4	4.310024727				
22	4.6	4.952375425				
23	4.8	5.594726123				
24	5	6.237076822				
25	5.2	6.87942752				
26	5.4	7.521778218				
27	5.6	8.164128916				
28	5.8	8.806479615				
29	6	9.448830313				
30	6.2	10.09118101				

Accuracy & Significant figures

What is a Scientific notation? 3 105 000 m $=$ 3.105 x 10^6 m

3 000 s $=$ 3 x 10^3 s

$$v = \frac{3.105\times10^6\,m}{3\times10^3\,s} = \frac{3.105}{3}\times10^{6-3} = 1.035\times10^3\ {}^{m}\!/_{s}$$

What is Accuracy?

3.1416 is more accurate than 1.14

Related to number of decimal digits

Addition & subtraction: keep same accuracy as least accurate term

3.1416 – 1.14 $=$ 2.0016 $=$ 2.00

What are Significant figures? 6 370 000 three 6 370 001 seven

Multiplication and division: keep smallest number of s.f. except for constants, counting from the left

Earth's circumference $= 2\pi\, R_E = 2 \times 3.1416 \times 6.37 \times 10^6 = 40.02398 \times 10^6$

$= 4.002398 \times 10^7 = 4.00 \times 10^7$ m

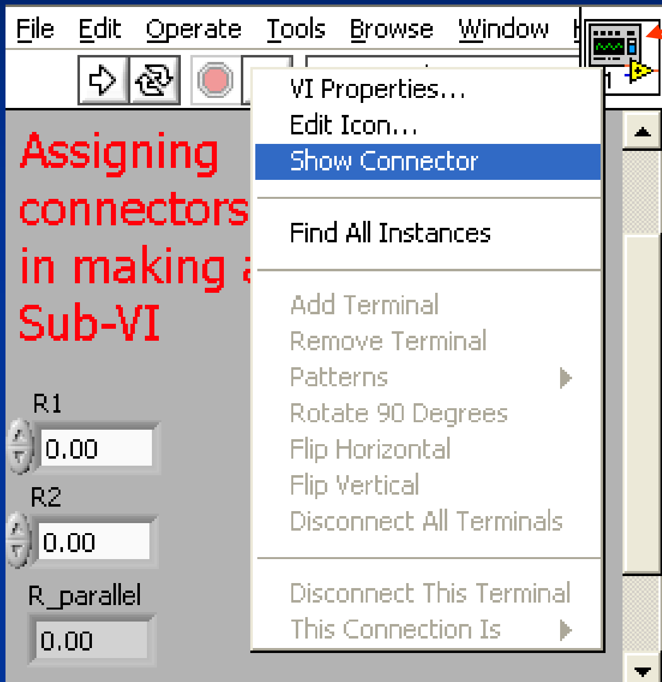
What is Estimation? How to do it?

An important engineering tool.
-Start with some simple factual data, such as cost of one kW-h; litter of paint, brick sizes,etc.
-Then using a simple algebraic equations, geometrical models, etc.
describing the specific situation you are interested in.
-Produce numerical estimates that are not usually available anywhere else.

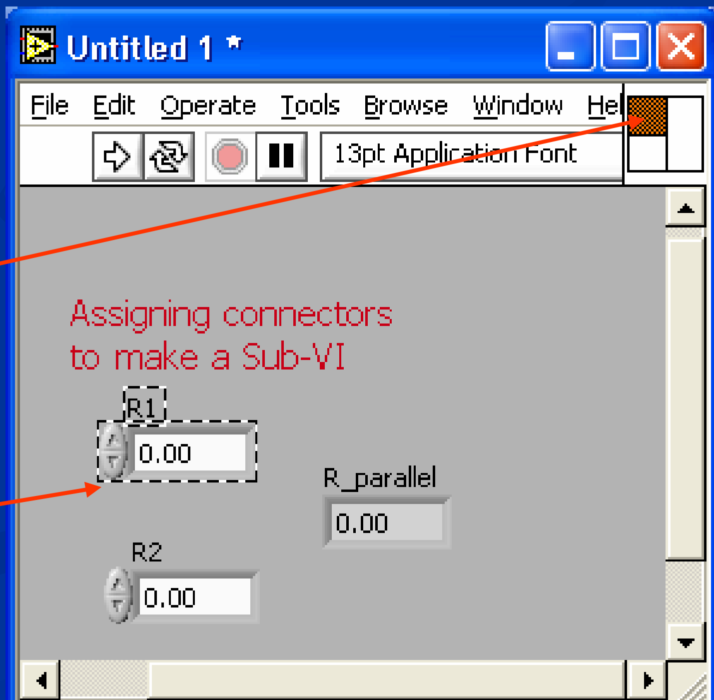
A search example for cost of 1 kW-h is
("kilo-Watt x hour" is an unit of energy)
-open http://www.google.com/
-type 'nstar' in the search box
-click on the link to the nstar website
-click on 'standard offer'
-click on the link to 'prices'
-enter the required info: Boston
-it will show $0.0495

LabVIEW:

How to convert a VI (Virtual Instrument) into a Sub-VI or subroutine or **How to assign connectors?**



1.- Right click on icon, select Show Connectors



2.- Pair connectors (boxes in icon) with input and output elements in Front Panel by clicking on connector, then click on element