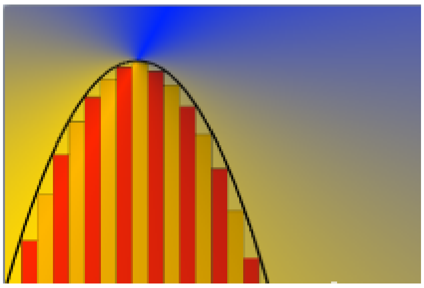
Tutorial 3: Interpolation and Integration

Tutorial 3 Interpolation and integration	**Learning goals** 1. Using data stored in objects. 2. Using the LININT, DQUAD and LEASQ functions to interpolate in datasets. 3. Using an object as a function. 4. Using the INTEGR function to perform numerical integration. 5. Using the LEASQ function	**Prior Knowledge** 1. Interface 2. Tutorial 1: Getting Started 3. Tutorial 2: Objects and TeLiTabs	

1 Objective

In this third tutorial, you will store the waterline data of the previous tutorial in a new object within the object `Ships`. You will perform linear and quadratic interpolation to obtain the relative width of unknown frames at the waterline. This will be checked with the exact solution, and the error is to be calculated. Some hydrostatic calculations will be performed: by numerical integration the waterplane area and the moment of inertia of this area are calculated. The stability GM will be calculated and compared to other ships using the least squares method.

Start

For this tutorial, the knowledgebase from tutorial 2 is used. You can either use your own (verified) knowledgebase, or download it here: [Tutorial 3 Start]

2 Creating a new object within a data object

The solution `Waterline` containing the shape of the dimensionless waterline, has been created in tutorial 2. In order to store this data and use it for further operations, the contents will be placed in a new object within the object Ships.

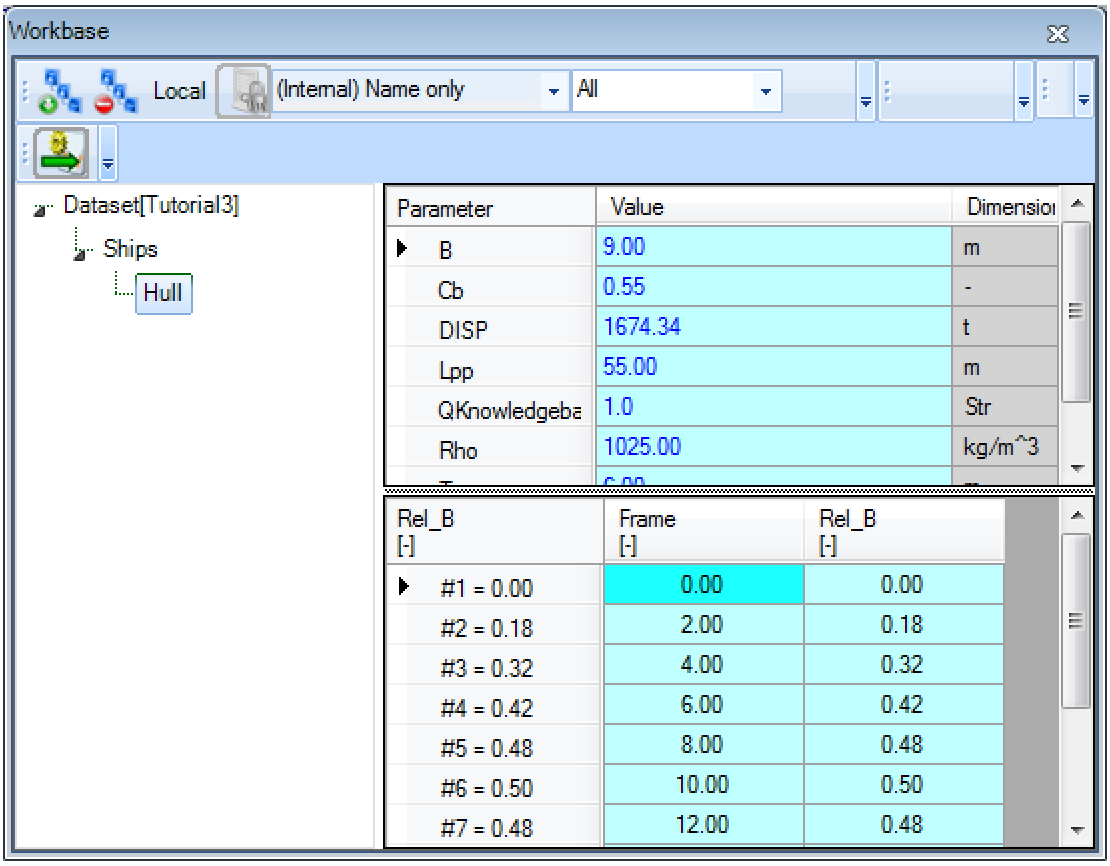
- In the class `Geometry`, create a new object (i.e. a parameter of type Object) called `Hull`. As you need to store static data in this object, make sure it is determined by *Value from Object/Database* (as described in tutorial 2).
- In the **Workbase**, select the object `Ships` (under *Dataset*). In the Knowledge Browser, right click the parameter `Hull` and select *Parameter to Dataset* (or press *Ctrl+O* or drag `Hull` tot `Ships`). The new object is now placed within `Ships`.

Let's add the content of the `Waterline` object in the `Waterline` solution to the object `Hull`.

- In the solution `Waterline`, in the tree of the Workbase, right-click on the `Waterline` object (so the tree node in the solution) and select *All to Clipboard* (or press *F4*). The **Workbase Clipboard** now pops up. Click on *Preview.* The contents of the `Waterline` object are now displayed. You temporarily have to use a workaround now, because the Paste function is not yet implemented. Press *Ctrl+A* followed by *Ctrl+C* to copy the contents to the Windows clipboard. Click *Cancel* and close the clipboard. No need to save the values in there. Then right-click on the `Hull` object in the Dataset and select *Database Input* or press *Shift+F3*. In the pop-up window that appears, select *Use Editor* and click *Continue*. In the window that appears next, press *Ctrl+V* to paste the data in the object. Click *OK*. Select *Yes to All* and click *Continue*.

When you are done, you will have a `Ships` object containing data in a `Hull` object. The `Hull` object should be part of the `Ships` object because the `Ships` object is the database entry point. And because you want to use all `Waterline` data as one set, it should be in one `Hull` object (or as a TeLiTab value as an alternative).

The workbase is full of solutions you'll not use anymore. So now first let's clean it up.



3 Interpolation

The relative width `Rel_B` at every frame was calculated directly using a polynomial formula. In reality, the waterline of a ship will be defined more likely by a number of points than by a formula. To obtain the width at a certain location, you should interpolate between these points. You can use the LININT( ) function to perform a linear interpolation.

- Add the following relation in `Top Goals/Undefined`:

```
Intpol_Rel_B=LININT(@Hull,2,@Frame,@Rel_B,Frame)
```

- Make sure `Intpol_Rel_B` is dimensionless and determined by *SYS: System/Equation*.

The syntax of every intrinsic function in Quaestor is described in this documentation, see the functions overview. The syntax above means the following.

1. The parameter `Inpol_Rel_B` will be the linear interpolated dimensionless width at a desired frame number (`Frame`).
2. `@Hull` is the object containing all the data you want to use for the interpolation.
3. 2 is the number of dimensions in which the interpolation will take place.
4. `@Frame` makes sure the column `Frame` of object `Hull` will be used as the parameter X in the interpolation.
5. `@Rel_B` makes sure the column `Rel_B` of object `Hull` will be used as the parameter Y in the interpolation.
6. `Frame` is the input parameter for which an interpolated value should be obtained.

When Quaestor calculates this function, it determines the value of `Frame` (which is user input). This value is then compared to the values of the given column for *X* (which is the column `Frame` of the object `Hull`), and an interpolated value for `Rel_B` with respect to the input `Frame` is assigned to the parameter `Intpol_Rel_B`. Notice that an `@` is used to identify the data within the object.

- Run a solution for `Intpol_Rel_B` using the *Process Manager* and selecting the `Ships` object. Make sure that `Intpol_Rel_B` is in the class `Top Goals/Undefined` to see it in the Process Manager. The Process Manager is crucial here, as static data from the `Ships` object should be used (which contains the object `Hull`). For `Frame`, enter *3.20*.

Quaestor should return 0.26 for `Intpol_Rel_B`.

To find out how accurate the interpolation is, let's introduce an `Error` parameter. The interpolated parameter uses static data from the object `Hull`, but you also defined the relative width analytically (the parameter `Rel_B`).

- Add the following relation to your `Top Goals/Undefined` class:

```
Error = Intpol_Rel_B - Rel_B
```

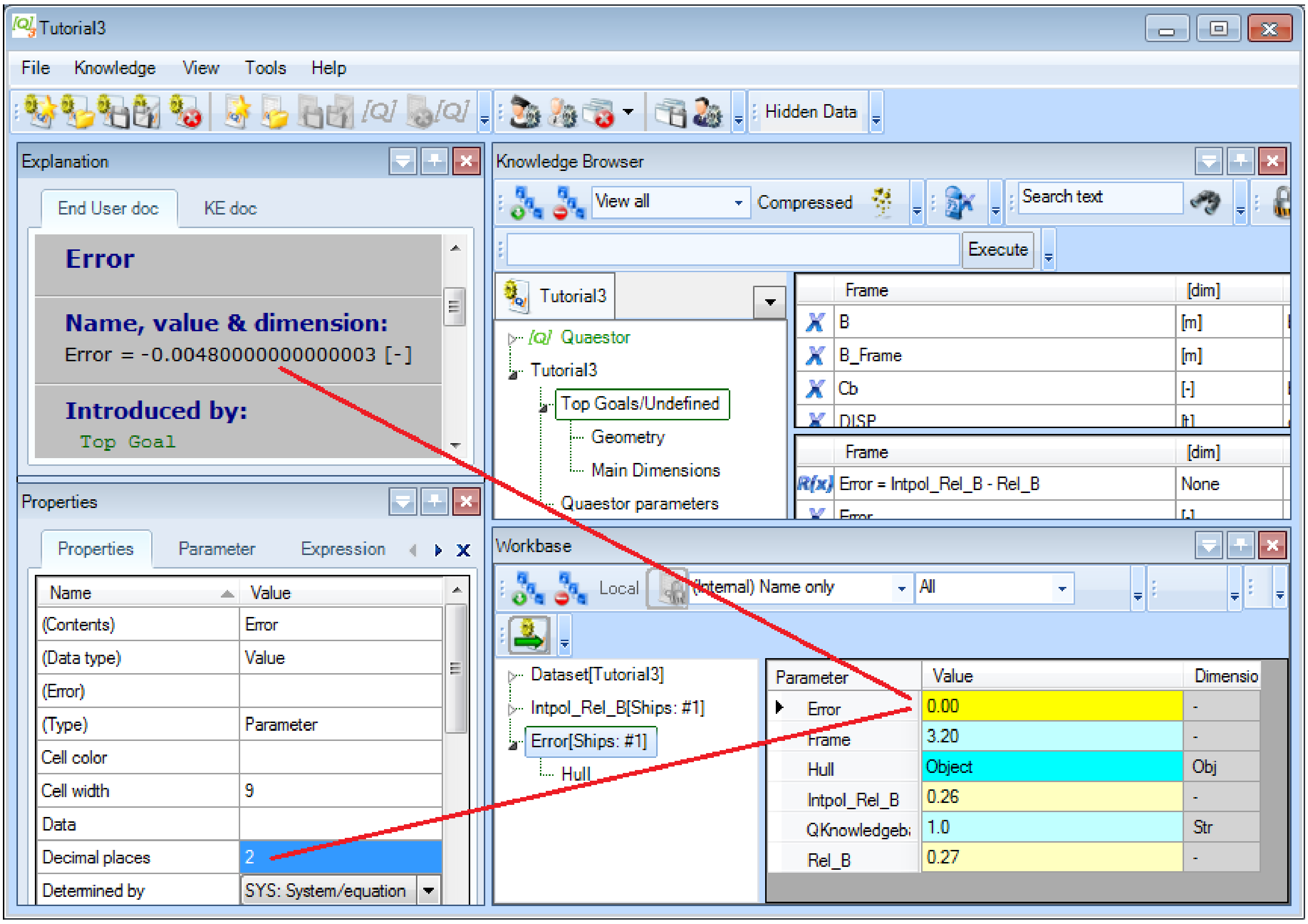
in which `Error` is a dimensionless *SYS* parameter.

- Run a solution for this parameter, `Intpol_Rel_B` will be calculated by Quaestor automatically because it is required by `Error`. Make sure you use the Process Manager to select the `Ships` object as dataset. For `Frame`, enter 3.20 again.

The solution in two-digit format (0.00) will be presented in the list of the Workbase. When you select this value, more digits are shown in the Explanation window.

> You can change the number of decimal places presented in the Workbase by changing the value *Decimal places* in the **Properties** window.

> For input values, the number of decimal places also defines the maximum accuracy accepted for this input. So, when you define `B` as having two decimal places, providing input with three will give a warning followed by rounding the provided number to two decimals.



- Change the number of decimals to 4 for `Error`, `Intpol_Rel_B` and `Rel_B` to 4.
- Change the relation (find the relation and press *F2*) for `Intpol_Rel_B` to

```
Intpol_Rel_B = DQUAD(@Hull, 2, @Frame, @Rel_B, Frame)
```

which uses the same data, but now performs a quadratic interpolation. It's not necessary to initialize existing solutions.

Editing relations was covered in tutorial 2. Remember that the use, syntax and examples of all Quaestor functions are available in the documentation: functionsoverview.

- Run the solution `Error` again with the same value of `Frame`.

The error now turns out to be zero. This makes sense, as DQUAD is a quadratic interpolation method and this waterline is defined by a quadratic function as well.

Parameter	Value
Error	0.0000
Frame	3.20
Hull	Object
Intpol_Rel_B	0.2688
QKnowledgebaseVersion	1.0
Rel_B	0.2688

4 Integration : waterplane area

By numerical integration, the waterplane area can be calculated. Therefore, the dimensionless length and width should be transformed to the real length and width. For the width you can use the existing relation for `B_Frame`, for the length in meters a new relation is needed.

- In the class `Geometry`, add the following relation:

```
X = Frame/20 * Lpp
```

which is the position in meters along the longitudinal direction of the ship. By now you should know what proper dimension, reference and determined by value must be provided.

To calculate the waterplane area for a certain ship, Quaestor has to integrate the width with respect to *X*. The dimensionless width table is already present in your object `Hull`, so let's use it in the integration.

- In the `Top Goals/Undefined` class, add the following relation:

```
Waterplane_Area = INTEGR(Hull(@X, @B_Frame, Lpp, B), 2, @X, @B_Frame, 2, 0, Lpp)
```

which is the waterplane area in square meters (m^2).

The syntax used here may seem a bit confusing at first.

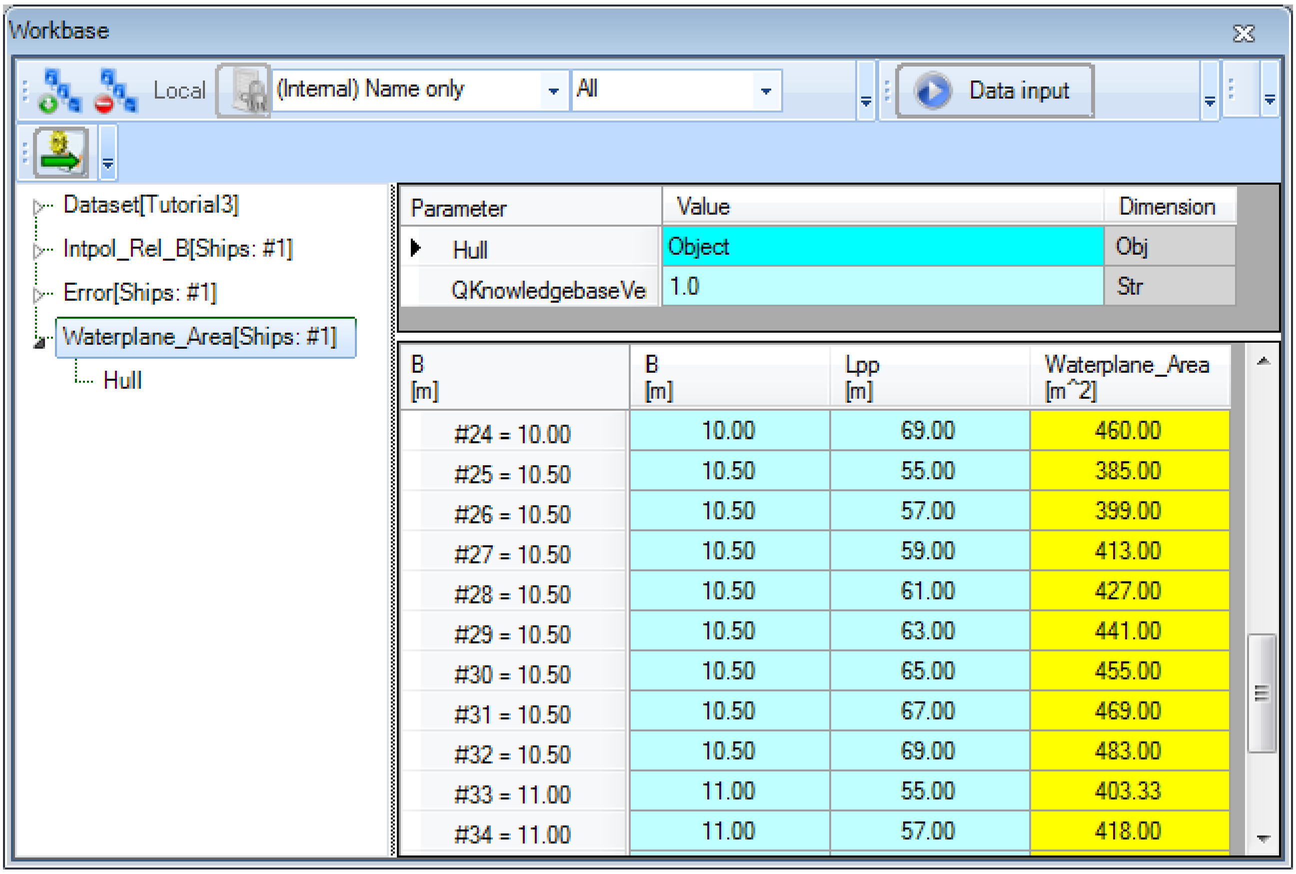
First, take a look at the arguments after `Hull`. Data within the object `Hull` will be used in the integration, but yet it only contains dimensionless frame numbers and dimensionless widths. By putting `(@X, @B_Frame, Lpp, B)` behind it, you ask Quaestor to calculate `X` and `B_Frame` using data from within `Hull`, using `Lpp` and `B` from outside `Hull` and add all these parameters to the object `Hull`. You do actually use the object `Hull` as a function to calculate other parameters. This is a very powerful ability of Quaestor (see also QuaestorSyntax).

The arguments for the INTEGR function are as follows:

1. `HULL(..)` is the object from which data will be used, now containing the columns `X` and `B_frame`
2. 2 is the number of dimensions = always 2 using INTEGR.
3. `@X` refers to the column that will be used as the parameter X in the integration: `X`
4. `@B_Frame` refers to the column that will be used as the parameter Y in the integration: `B_Frame`
5. 2 is the mode of integration, either Riemann (0), Trapezium (1) or Simpson (2). The latter is chosen here.
6. `0` and `Lpp` are the values between which will be integrated.

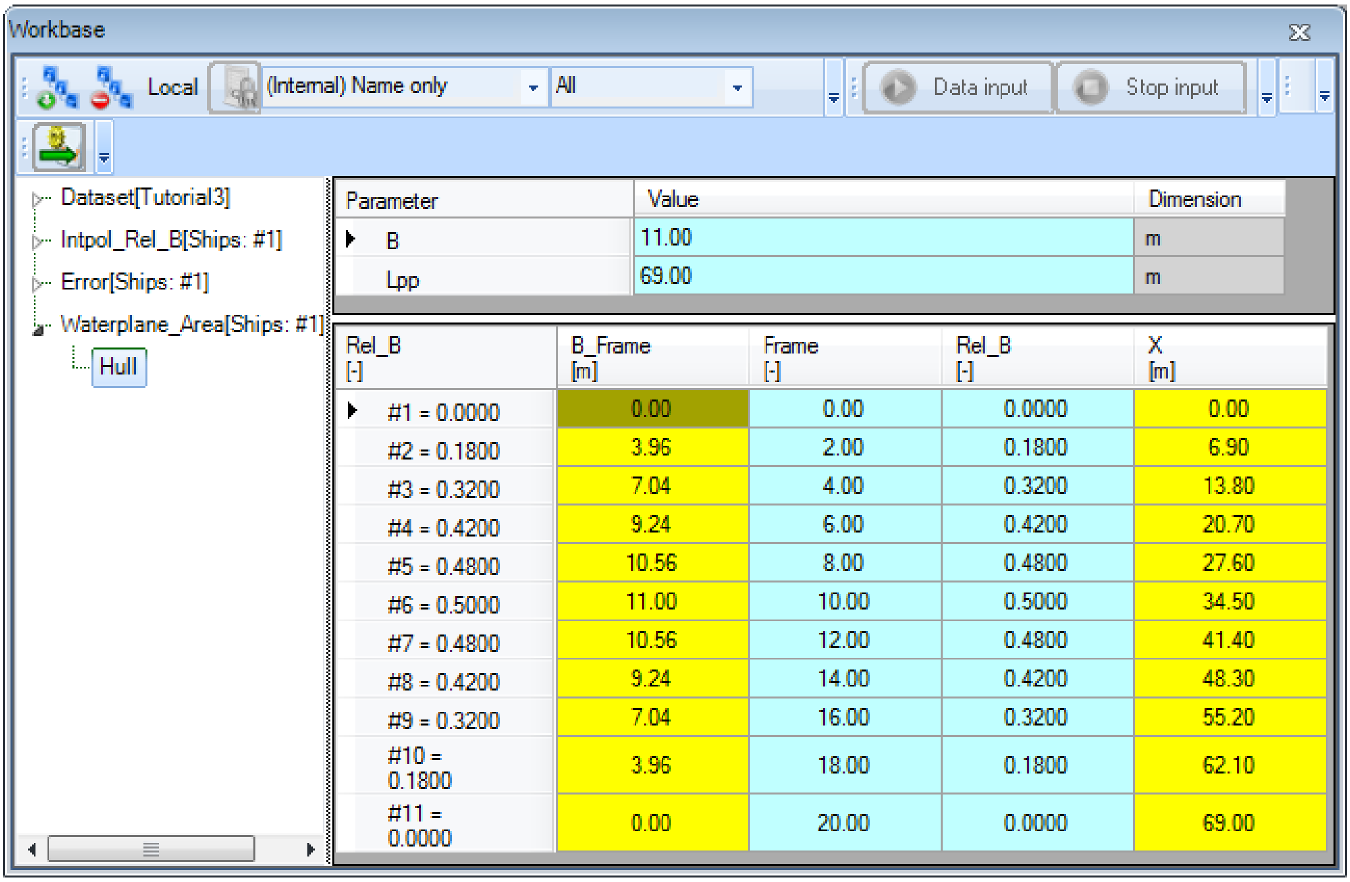
- Run a solution for `Waterplane_Area`, using the *Process Manager*.

The waterplane area is calculated for every variation in length and breadth of the ship.



- In the `Waterplane_Area` solution tree, select the object `Hull`.

Because you solved a multiple case problem, the object has been used as function and reused for every case. Only the content of the last case calculated remains in the object. The columns `X` and `B3_Frame` are added to the object. These values are calculated for every case of `Frame` and `Rel_B` within `Hull`.



Parameter	Value	Dimension
B	11.00	m
Lpp	69.00	m

Rel_B [-]	B_Frame [m]	Frame [-]	Rel_B [-]	X [m]
#1 = 0.0000	0.00	0.00	0.0000	0.00
#2 = 0.1800	3.96	2.00	0.1800	6.90
#3 = 0.3200	7.04	4.00	0.3200	13.80
#4 = 0.4200	9.24	6.00	0.4200	20.70
#5 = 0.4800	10.56	8.00	0.4800	27.60
#6 = 0.5000	11.00	10.00	0.5000	34.50
#7 = 0.4800	10.56	12.00	0.4800	41.40
#8 = 0.4200	9.24	14.00	0.4200	48.30
#9 = 0.3200	7.04	16.00	0.3200	55.20
#10 = 0.1800	3.96	18.00	0.1800	62.10
#11 = 0.0000	0.00	20.00	0.0000	69.00

5 Calculating the stability

The initial stability (GM) of the ships can also be calculated using numerical integration.

- Add a new class, called `Stability`, as sub-class of `Geometry`. Add the following relation to this class:

```
GM = KB + BM - KG
```

The dimensions of all new parameters must be meters (m), and they are *SYS* parameters. Their relations follow. `GM` is a Top Goal and should be moved to `Top Goals/Undefined`.

- In the class `Stability`, enter the following relations.

  Distance between keel K and center of buoyancy B, select KB , right-click and select *New Relation...* (or press *Ctrl+N*). By selecting KB it is automatically presented as left side part of the relation:

```
KB = 0.7 * T
```

  Distance between keel K and center of gravity G, KG, in meters:

```
KG = 0.8 * T
```

  Distance between center of buoyancy B and metacenter M, BM, in meters:

```
BM = Moment_of_Inertia / (DISP * 1000/ Rho)
```

  Third power of the width at a specified frame number in m^3:

```
B3_Frame = B_Frame^3
```

  Moment of inertia of the waterplane area in m^4:

```
Moment_of_Inertia = 1/12 * INTEGR(Hull(@X, @B3_Frame, Lpp, B), 2, @X, @B3_Frame, 2, 0, Lpp)
```

Note that the syntax of the moment of inertia relation is similar to that of the waterplane area relation.

Do not forget to provide all dimensions and references, and change the *Determined by* fields to *SYS: System/equation.*

- Add `@RANGEALLOWED` to parameter `DISP` (Parameter tab, Data field of Properties window).
- Run a solution for the initial stability `GM` of every possible ship, by selecting the `Ships` object and `GM` as task in the Process Manager. Press *Ne xt* repeatedly until the text on the button turns to *Data input* again and the solution is completed.
- In the `GM` solution tree, select the object `Hull`.

Frame [-]	B3_Frame [m^3]	B_Frame [m]	Frame [-]	Rel_B [-]	X [m]
#1 = 0.0000	0.00	0.00	0.0000	0.0000	0.00
#2 = 2.0000	62.10	3.96	2.0000	0.1800	6.90
#3 = 4.0000	348.91	7.04	4.0000	0.3200	13.80
#4 = 6.0000	788.89	9.24	6.0000	0.4200	20.70
#5 = 8.0000	1,177.58	10.56	8.0000	0.4800	27.60
#6 = 10.0000	1,331.00	11.00	10.0000	0.5000	34.50
#7 = 12.0000	1,177.58	10.56	12.0000	0.4800	41.40
#8 = 14.0000	788.89	9.24	14.0000	0.4200	48.30
#9 = 16.0000	348.91	7.04	16.0000	0.3200	55.20
#10 = 18.0000	62.10	3.96	18.0000	0.1800	62.10
#11 = 20.0000	0.00	0.00	20.0000	0.0000	69.00

If the object `Hull` in the solution is now opened again, you'll see that, like for the waterplane area, the columns `X` and `B3_Frame` are added to the object, whose values are calculated for every case of `Frame` and `Rel_B` within `Hull`. Note that the parameter `B_Frame` is also added, as it is used to calculate `B3_Frame`. Again, only the values of the last ship (last input case) are stored in the object.

6 Comparing the stability to other ships

Finaly, let's compare the obtained values for `GM` to other ships. Data of the `GM` value for a certain ship length is available, so we only have to compare them. You can use the least squares method to obtain an average `GM` value for a certain length, using the data of some other ships.

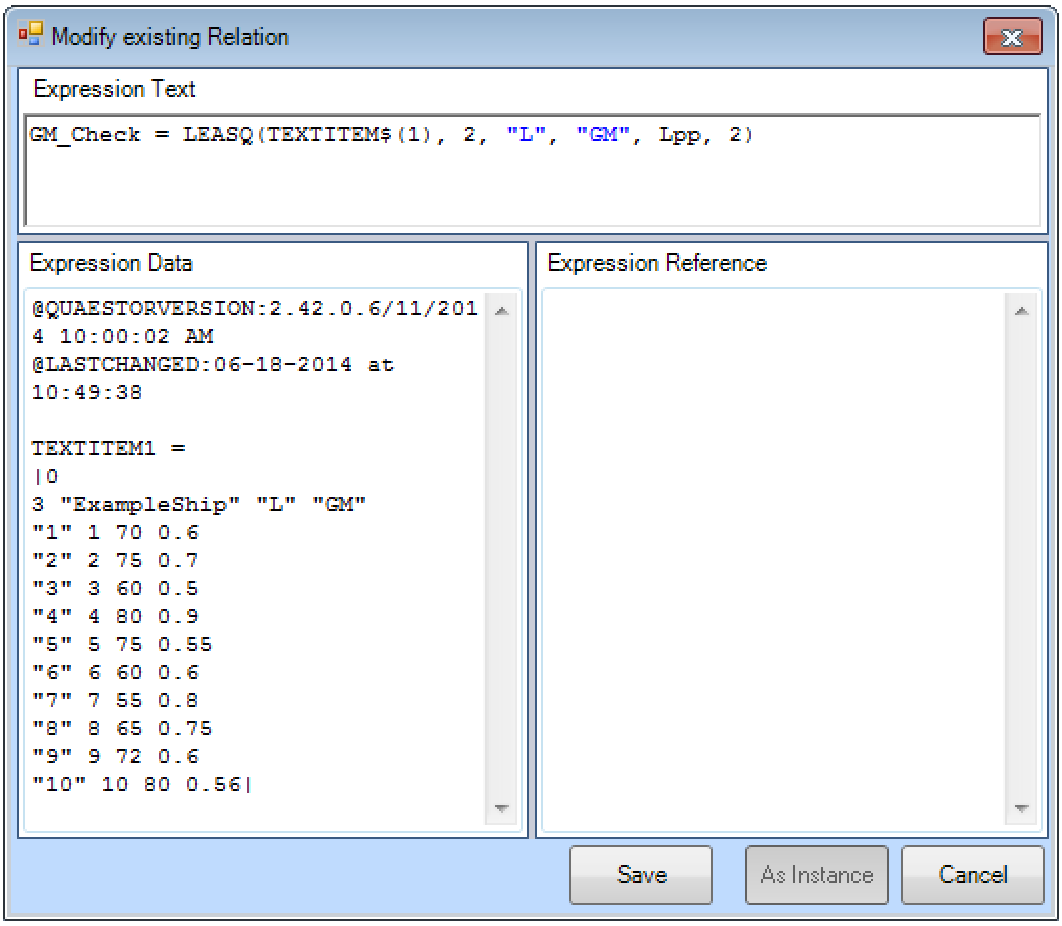
- Add the following new relation to your `Top Goals/Undefined`:

```
GM_Check = LEASQ(TEXTITEM$(1), 2, "L", "GM", Lpp, 2)
```

`GM_Check` is in meters.

- Enter the following text in the *Expression Data* field in the Expression Editor of the relation `GM_Check`:

```
TEXTITEM1 =
|0
3 "ExampleShip" "L" "GM"
"1" 1 70 0.6
"2" 2 75 0.7
"3" 3 60 0.5
"4" 4 80 0.9
"5" 5 75 0.55
"6" 6 60 0.6
"7" 7 55 0.8
"8" 8 65 0.75
"9" 9 72 0.6
"10" 10 80 0.56|
```



The LEASQ interpolation function now returns an average `GM` value in meters for a certain `Lpp`. The syntax `TEXTITEM$(nr)` is often used in Quaestor, and refers to a template, text item or TeLiTab in the Data slot of the Expression Editor. In this way, data that is not included in the knowledgebase but is only used in a particular function (as in our relation) can be used.

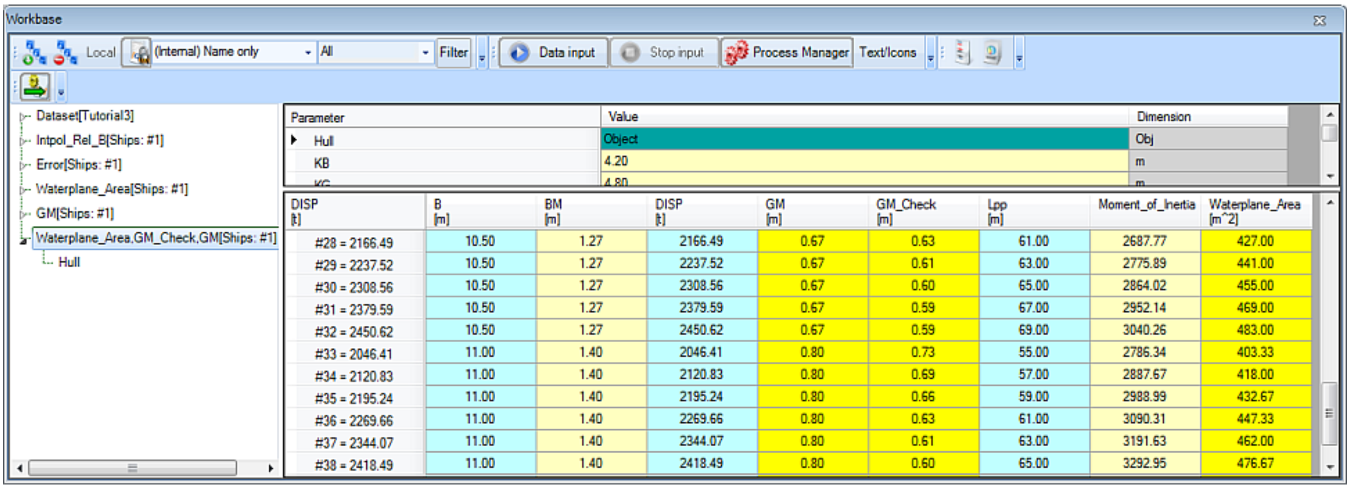
Note that the syntax of the relation uses `TEXTITEM$(nr)`, but in the data slot the syntax `TEXTITEM1=` is used. The TeLiTab is written between two | characters. Multiple textitems can be available in a relation `(TEXTITEM$(1), TEXTITEM$(2) .. TEXTITEM$(n))`.

> ⚠ Please note that "the devil is in the detail". Small errors in your syntax will always be a problem for software such as Quaestor. Therefore, keep checking the correctness of your syntax.

- Run a solution using the Process Manager. Select `Waterplane_Area`, `GM` and `GM_Check` as goals. Again, press *Next* until the solution is completed.

> ⓘ You can select several goals at once!

To browse through results, it might be convenient to maximize the workbase window. The result of the last solution should look like this:



7 Check

You can verify your results by comparing it to [Tutorial 3 Finished]

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