Generation of Parameterized Models for Vessels Design

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ABSTRACT

This work proposes an integrated environment for modeling, and static and dynamic analysis of vessels. The main advantage of the proposed environment is that it is possible to automatically obtain variants of a specific model in order to achieve a desired configuration, not only in relation to geometry but also concerning the static stability aspect. This environment uses the Lua programming language and it is possible to define global variables to be used as parameters which retrieve or modify modeling values such as length, width, height, and so on. Any model can be parameterized, as a function of user chosen variables, which allows an automatic modeling with the variation of those parameters.

Keywords: Geometric Modeling, Computer Aided Geometric Design, Vessel Stability, Computational Geometry, Mesh Generation and Simplification, Lua.

1 INTRODUCTION

Many different engineering areas deal with complex geometry shapes such as compressors, turbines, vessel units, car, etc and relies on different kinds of modeling systems ([3], [19], [4], etc) that are capable to reproduce these shapes. Those systems can also define a finite element mesh in order to perform numeric simulations.

The area of Computer Aided Ship Hull Design (CASHD) is concerned with modeling systems that can generate different shapes and geometries of a vessel unit in an iterative or automatic manner.

The design and construction of an offshore vessel unit is not a simple task. Many aspects have to be be considered before building it, as in all engineering projects. The most used methodology to develop an offshore unit was proposed by Evans [11].

The designer of a vessel unit searches for a solution that best fits the operational requirements, while attending the economic and engineering constraints. During this search the designer will come up with several solutions that can be either unfeasible or do not fulfill the design criteria. Therefore, it is necessary a rational approach to guide the designer in this pursuit.

Bearing this scenario in mind, PETROBRAS (*the Brazilian oil Company*) has developed two softwares in collaboration with two research groups: CENPES (*Research Center of PETROBRAS*) and Tecgraf (*Computer Graphic Technology Group*) from PUC-Rio. These softwares are called MG (*Mesh Generator*) [8] and Sstab [7].

MG is used during the modeling phase in order to create the basic geometry of a vessel unit. The meshes for static and dynamic analysis are also generated and then in the phase of static stability analysis the Sstab software is used. The static stability evaluates the capacity of the vessel unit to restore its initial equilibrium after any perturbation. Finally, the Wamit [21] software is used to perform dynamic analysis in order to study the influence of the sea waves against the vessel unit structure.

2 RELATED WORK

Coelho [8] presented a modeling system based on patches (*MG-Mesh Geneator*), which makes use of a boundary representation model (*BRep*). Kassar [16] implemented an efficient solution to solve the surface mesh generation problem but representing the regions where the surface curvature changes using a reduced set of non uniform faces. This approach uses a modification of the space quadtree subdivision.

Regular meshes using NURBS surfaces are generated for simulation purposes and in some cases a technique that uses advancing front mesh generation with quadtrees is used where it is not possible to create a regular mesh [18]. Another work that uses NURBS surfaces in order to perform ship hull modeling is presented by Rasmussen [20], where the ship modeling is divided in several parts. Each part, like bow, stern, parallel middle body, etc is modeled by a NURBS surface and then this surfaces are merged into a global NURBS surface that represents the whole ship model.

An automatic parametric modeling approach was implemented by Oliveira [10] using the MG software in order to create the geometric model, but at the same time it is necessary to use another software to define the shape of the model. Therefore, it is possible to perform automatic modeling in order to generate many instances of the model, varying some form parameters. After the modeling phase these instances could be used to perform static and dynamic stability analysis.

Mendonça [9] allows the designer to perform a shape optimization of an offshore vessel unit by combining neural networks and a genetic algorithm that makes use of scripts written in Lua language [17].

Moreover, integrating the tools for modeling, analysis, simulation and assessment leads to faster processes and better products. So, Abt [2] proposed a tool integration system for simulation-driven design using XML(Extensible Markup Language) and COM(Component Object Model) interfaces into the FRIENDSHIP CAD environment for ship models. Abt [1] also proposed a new integration of FRIENDSHIP combining CAD and CFD, allowing rapid hydrodynamic evaluation in the ship design.

Birk [6] presented an hydrodynamic analysis optimization which uses a command language approach that interconnects the modeling phase with the hydrodynamic analysis. Harries et al [13] developed an integrated approach that simultaneously covers all relevant aspects of early ship design: main dimensions, hull form, hydrodynamics and safety including intact and damage stability; etc.

Other work for hull optimization is presented by Karri [15], where a simple interpolation scheme is used to generate panels for any conventional ship hull and the main objective is to design a ship hull that matches its operational conditions.

There is a strong tendency in searching an automatization process in the geometry phase modeling and also in the stability and dynamic phase analysis.

3 MODELING METHODOLOGY

The previous section presented some works that are concerned with automatic geometric modeling but also require an external software to perform this task.

The framework shown in Figure 1 provides to the project designer the necessary tools to create a set of instances of a model, by simply varying some chosen form parameters.

Lua language has been embedded into the MG and Sstab software in order to provide a single environment with the three softwares.

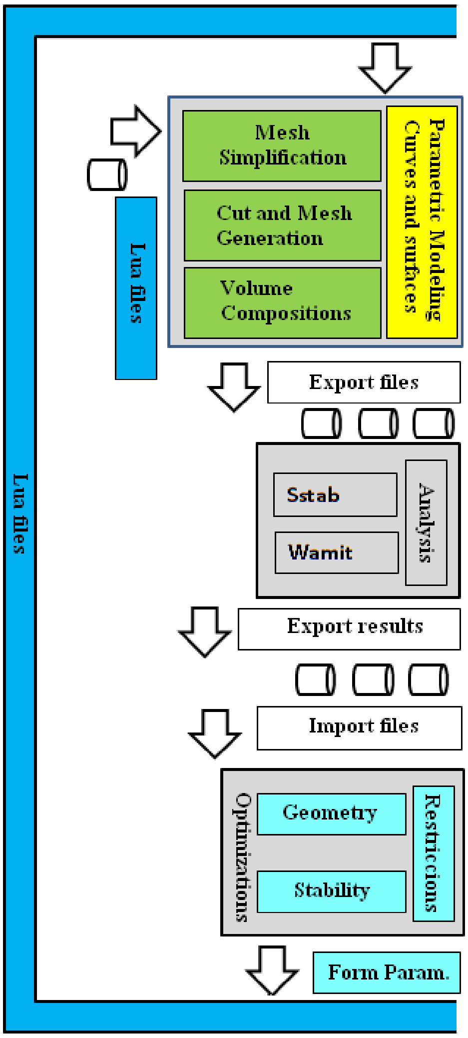


Figure 1: Modeling framework for vessel design

This work presents a methodology to create engineering vessel models using the MG (Mesh Generator) [8] and Sstab [7] software combined with automatic parametric geometry modeling. Scritps written in Lua [17] allow the project designer to obtain a set of different vessel units, according to constraints in the geometry and aspects of the static stability.

All the user actions (the creation or modification of vertices, curves, surfaces, volumes, etc.) during the geometric modeling phase are stored in a script history file and can be reproduced in an intuitive way. These scripts can also be parameterized in order to obtain different variations of the original model.

Geometric constraints are checked as well as static (Sstab) and dynamic (Wamit) stabilities. Once the static and dynamic analysis are performed the results can be exported to an optimization module. If the model does not comply with the geometric or stability restrictions some form parameters can be changed. These changes are achieved by Lua [17] scripts and MG generates a new model. This fact may reduce the process of re-visiting several times some cycles of the spiral methodology design process proposed by Evans [11]. This process goes on until a convergency appears in the simulations.

4 PARAMETRIC MODELING OF A SHIP HULL

One of the softwares used in this work, MG, is a shell modeler based on cross sections curves and it has been widely used in the design of several large offshore oil structures at Petrobras, the brazilian oil company. This software has an interactive modeling environment based on direct manipulation in 3D space, so it addresses several interesting user-interface issues, that have been discussed elsewhere [12]. Different types of meshes can be generated by the geometric modeler using trilinear, bilinear, planar, BSpline surfaces, etc.

In the next sections some modeling strategies using MG environment will be presented which could be used when designing a realistic engineering model. Some designing stages may be a hard task and some of these strategies presented here could be useful.

4.1 Volume Composition

Two schemes for representing a three-dimensional geometric model into a computer are used: a boundary scheme and a constructive scheme. In the boundary scheme, the geometry of an object is defined by its boundary elements, such as vertices, edges and surface patches, which may be created through an interactive graphics interface. The most common constructive scheme is constructive solid geometry (CSG) [5], in which the final object is obtained by a set of boolean operations applied to a set of primitive objects.

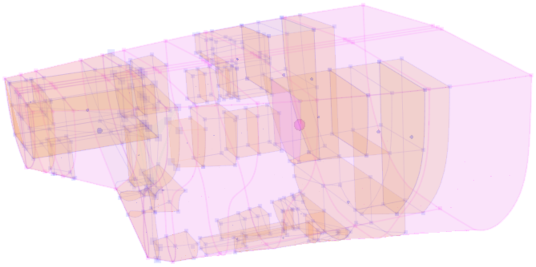
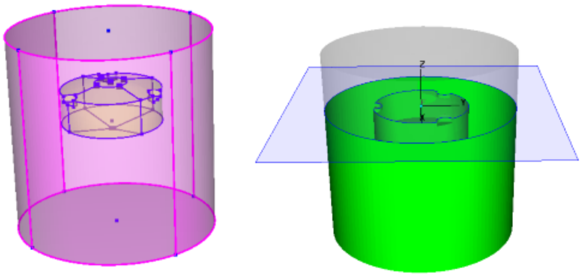


Figure 2: Example of volume composition

Realistic engineering model like vessel structures generally are composed by a hull volume and a set of internal compartments. Defining which mesh is internal or external is particularly important for finite element mesh generation and in this case could be a hard work when there is a lot of adjacent surfaces like it is shown in figure 2 where the stern of a ship has many internal compartments and empty spaces.

In order to define a new volume or an internal compartment that could fit in all empty spaces shown in figure 2 it is necessary to perform addition or subtraction operations, and to make sure that the created volume will be topologically correct. Volume contribution for each face will be positive and negative respectively.

A less complicated model than the one presented in figure 2 is a cylinder with one internal compartment (figure 3a). Sstab software uses the mesh exported by MG for static analysis by computing the volume contribution below a draft plane. Considering the new faces orientation defined (External or Internal) it is possible to see an empty space relative to the smaller compartment defined inside the cylinder where no volume contribution is considered for the final volume computation (figure 3b).



(a) Volume modeling (b) Volume considered below a draft plane

Figure 3: Volume contribution for composed volumes

The new created volume will fit into the empty space left by the other existing volumes. All volumes are modeled individually and then composed into a new one.

This approach is similar to the constructive scheme called CSG where a set of operations is also applied but in this case is more simplified with only two operations, so it was called of Pseudo-CSG because makes easy to create new volume considering a set of existing volumes.

4.2 Virtual Entities

Mirror symmetry is another important feature of an object being modeled from a set of curves and surfaces. Generally a ship hull contains symmetry properties in one or more planes relative to the cross section curves. Models that contain for example 30 surfaces could be modeled by half of the surfaces and curves by just applying mirror transformations.

An inportant task when defining a ship hull surface is to achieve a faired surface or a set of surfaces that are created using some specific points that belong to the cross section curves of the ship hull (figure 4).

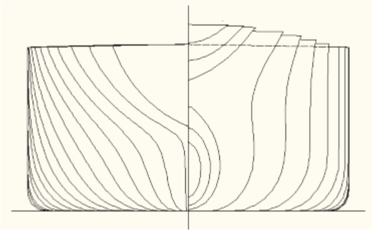
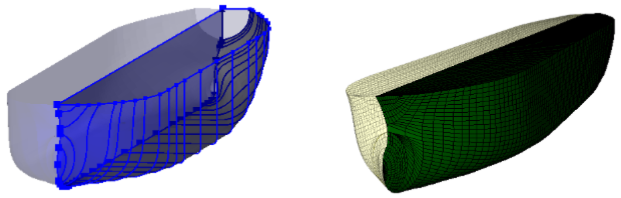


Figure 4: Cross sections of a ship hull.

This section proposes an approach to model an object that has some similar properties using virtual entities. Each virtual entity created is defined as an OpenGL matrix transformation that will be applied to the original surface in order to get the final position of each surface, curve, etc.

Virtual entities may contain any kind of transformation such as: mirror, shear, scale, translation etc. These type of entities could be very useful when designing an engineering model holding a lot of surfaces that have some properties in common. Due this the final model can contain a minimal set of curves and surfaces that represents the whole geometry itself. It is used an OpenGl optimization technique called Display List in order to avoid repeating a set of transformation operations. Display list is just a group of compiled function calls stored for subsequent execution. Once a display list is created it could be called as many times as needed by the final application.

FEM meshes that will be generated considering a model with symmetry properties need to orient its faces according to the mirror operation applied. Figures 5a and 5b show a model containing a set of virtual surfaces and its corresponding created FEM mesh. Meshes containing virtual entities with no symmetry do not need to re-orient their internal faces. This operation is only performed for mirror transformation.

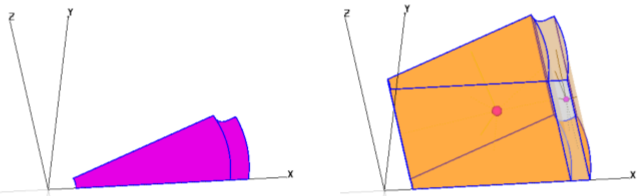


(a) Model with virtual entities (b) FEM mesh exported

Figure 5: Virtual Entities.

4.3 Volume Sweeps

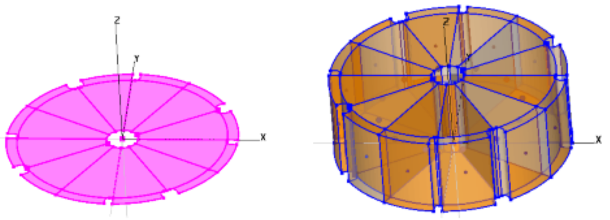
The sweep volume of a 3D object is a powerful tool that makes possible to transform a surface into a volume. It has been proved to be an excellent aid when planning and designing a 3D model (shell) that contains internal compartments like a 3D vessel structure. Volume sweep is a solid bounded by parametric surfaces undergoing an arbitrary direction. The direction chosen in this work is the normal direction of each parametric surface. Figure 6 shows creation of volumes considering a set of initial selected surfaces and a chosen direction. In the example shown below the chosen direction was along Z axis.



(a) Initial surfaces selected (b) Volume sweep creation for each surface

Figure 6: Volume sweep creation.

The building approach shown here leads to model a 3D volume or internal compartments of a vessel structure much more easy as shown in figure 7 where all internal compartments of a cylindrical vessel structure have been modeled using this approach.



(a) Initial surfaces selected (b) Volume sweep creation for each surface

Figure 7: Internal compartments of a cylindrical vessel using sweep volume creation.

Internal compartments in a vessel structure are very important to be modeled in order to simulate a damage situation for example where one or more internal compartments can be flooded. Figure 8 shows the mesh used to perform some simulation according its hydrodynamic or static properties defined by a current situation. Symmetry properties are automatically detected when a mesh is generated to perform simulations. The mesh is generated only in part of the model and then transformed to its symmetrical parts relative to XZ and YZ planes.

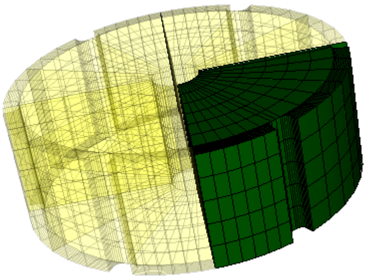


Figure 8: Mesh compartments of a cylinder

4.4 Lua Language Programming

Many different engineering areas deal with complex geometry shapes and the environment used to reproduce this models are adopting extension language or scripts as a way to increase flexibility and modeling facilities.

Parametric modeling allows to describe properties of a model by using geometric descriptors known as form parameters. This descriptors can be used in order to increase a wide range of facilities in the early modeling phase of a CAD model.

It is shown in figure 9 an example of MG capabilities where a ship hull is modelled using different type of surfaces (bilinear, trilinear, Bspline) with their corresponding geometric support and mesh discretization. It is also possible to model sweep surfaces defined by a translational, rotational or generic direction.

The main dimensions of a ship hull, as the one shown in Figure 9, are LBP, Breadth and Depth. LBP specifies the size of the ship hull between perpendiculars relative to X axis. Breadth specifies the size of the ship relative to Y axis and Depth is the height of the ship, relative to Z axis.

It is shown in table 1 values of the parameters LBP, Breadth and Depth that were set to 319, 56 and 30,2 respectively. The value of 165 refers to the middle section of the ship.

Lua scripts have been written that are able to modify the shape of the ship hull but keeping the model always centered in relation to its middle section. Therefore, the Lua function TransformLBP shown in Figure 10, is used to parameterize the ship in relation to the LBP parameter.

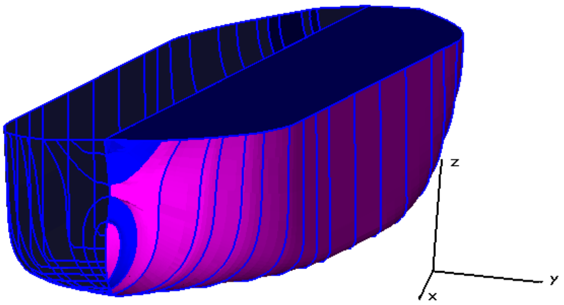


Figure 9: Ship hull modelled by Bspline surfaces, bilinear and trilinear mappings.

Description	**Value**
Mid Ship with respect to (wrt) Keel	165,00
Length Between Perpendiculars wrt Mid Ship	319,00
Molded Breadth wrt Mid Ship	56,00
Molded Depth wrt Mid Ship	30,20

Table 1: Initial dimensions of the ship hull.

```
function TransformLBP(idv1,idv2,NLBP)
    // get the vertex positions of idv1 and idv2
    a=mgGetVertex(idv1)
    b=mgGetVertex(idv2)
    // compute LBP distance
    LBP = a:Distance(b)
    // get factor scale relative to the new value of LBP
    factor = NLBP/LBP
    // get the midsection point
    LBPMx=(a.x+b.x)*0.5
    LBPMy=(a.y+b.y)*0.5
    LBPMz=(a.z+b.z)*0.5
    mgSelect(”all”)
    mgTranslateXYZ(LBPMx,LBPMy,LBPMz)
    mgScaleXYZ(factor,1,1)
    mgTranslateXYZ(-LBPMx,-LBPMy,-LBPMz)
    return factor,LBPMx,LBPMy,LBPMz
fim
```

Figure 10: Lua script to parameterize the ship with relation to LBP parameter

The function TransformLBP computes a scale factor between the current *LBP* value and the new value *NLBP*, passed as a parameter. The current *LBP* value is computed using the reference points passed to the function by *idv*1 and *idv*2 parameters. After the scale factor is computed, all entities of the model (vertex, surfaces, volumes, etc) are selected and then the appropriated transformations are applied.

The translation is performed in relation to the middle point of LBP, in order to keep the model centered with its midship section, and then the scale factor is applied. The function to transform the Breadth ship parameter is similar to the TransformLBP but all transformations must be applied relative to Y axis.

The function TransformDepth, shown in Figure 11, applies transformations in relation to the Depth parameter of the ship hull. The same transformations of TransformLBP are also applied in this function, but it is necessary to apply an extra transformation according to the scale factor value.

```
function TransformDepth(idv1,idv2,NDepth)
  // get the vertex positions of idv1 and idv2
  a=mgGetVertex(idv1)
  b=mgGetVertex(idv2)
  // compute Depth distance
  DEPTH = a:Distance(b)
  // get factor scale relative to the new value of NDEPTH
  factor=NDEPTH/DEPTH
  // get the midsection point
  DEPTHMx=(a.x+b.x)*0.5
  DEPTHMy=(a.y+b.y)*0.5
  DEPTHMz=(a.z+b.z)*0.5
  mgSelect(”all”)
  mgTranslateXYZ(DEPTHMx,DEPTHMy,DEPTHMz)
  mgScaleXYZ(1,1,factor)
  mgTranslateXYZ(-DEPTHMx,-DEPTHMy,-DEPTHMz)
  // keep keel ship at original point relative to Z axis
  if (factor>1) then
   mgTranslateZ((NDEPTH*0.5)-DEPTHMz)
  end
  if (factor<1) then
   mgTranslateZ(-(DEPTHMz-(NDEPTH*0.5)))
  return factor,DEPTHMx,DEPTHMy,DEPTHMz
  end
fim
```

Figure 11: Lua script to parameterize the ship with relation to Depth parameter

Each parameter LBP, Breadth or Detph of the ship hull can be individually modified or the three modifications can be done at the same time.

Figure 12 shows the modified hull of Figure 9. In case that the hull vessel has internal (hull, ballast, diesel, void spaces, etc) or external compartments (super structure, etc), all of them will be also transformed in order to fit the new model geometry. The transformations of the ship hull internal compartments are important in order to guarrantee the consistency of the generated model.

In other words, there are geometric correlations between the internal tanks and the ship hull. This correlation is attended by Lua scripts implemented in this work.

Once the geometric modeler automatically modifies the hull shape, it is exported to Sstab software in order to analyze its static stability. If the model is symmetric in relation to the diametral plane, then the generated meshes should also be symmetric. In order to avoid the occurrence of trim and heel, due to an inconsistent mesh generation, only half of the model is stored.

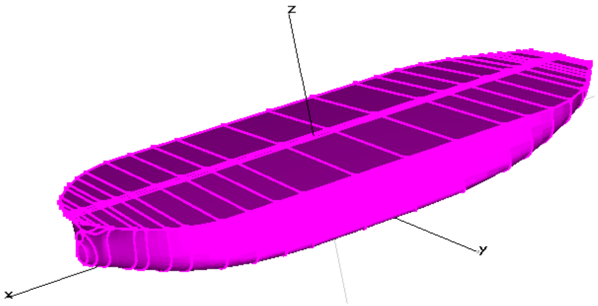


Figure 12: Ship hull parameterized by Lua function TransformShip.

5 FORM SHAPE STABILITY ANALYSIS

The behavior of an offshore unit is evaluated in two different situations:

- The static intact stability considering wind actions;
- The static stability in a damaged condition.

These situations are regulated by international organizations such as IMO (*International Maritime Organization*) [14], NMD (*Norwegian Maritime Directorate*), etc

In this work, an offshore ship unit (Figure 9) has been studied to evaluate its behavior when submitted to an overweight with the intention to simulate a damaged condition.

In the design project of a vessel unit, the weight conditions are organized in classes that usually separate the intact conditions from the damaged conditions, according to IMO. In order to test a damaged condition, an intact condition must be simulated beforehand.

The stability requirements after a damaged condition, according the MARPOL 73/78 rules, are listed below and are shown in Figure 13.

- In the final stage of flooding, the absolute angle equilibrium shall not exceed 25 degrees.
- The stability in the final stage of flooding shall be investigated and may be regarded as sufficient if the righting lever curve has at least a range of 20 degrees beyond the position of equilibrium.
- The maximum residual righting lever shall not exceed 0.1 meters within the 20 degrees range indicated above.
- The area under the curve within this range shall not be less than 0.0175 meters radians.

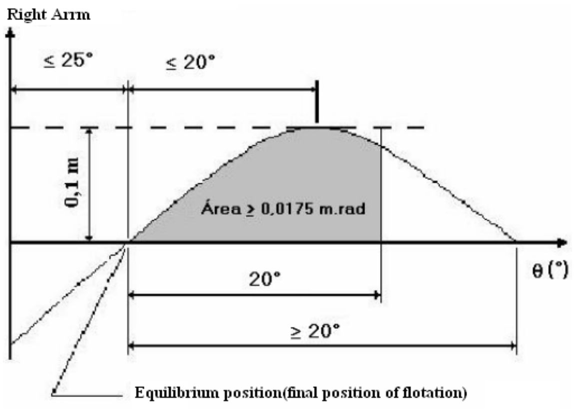


Figure 13: Stability damage rules

Initial Damage Conditions The damaged condition considered in this example is the bulkhead's ship vessel collision that causes the flooding of two stern compartments and the moorings storehouse. Figure 14 shows the same ship presented in Figure 9 but considering all its internal compartments. Damaged tanks are indicated by a black circle.

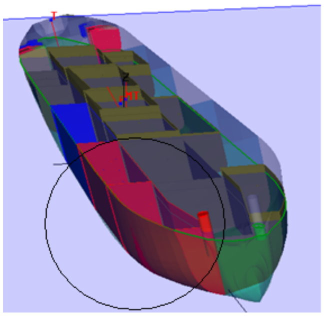


Figure 14: Initial damaged conditions

Table 2 presents the results of the static equilibrium analysis and their corresponding stability diagram for the current damaged condition. The initial dimensions of the ship hull are the same listed in table 1, and the VCG (*Vertical Center of Gravity*) of the light weight within the ship vessel structure is located in 33 meters.

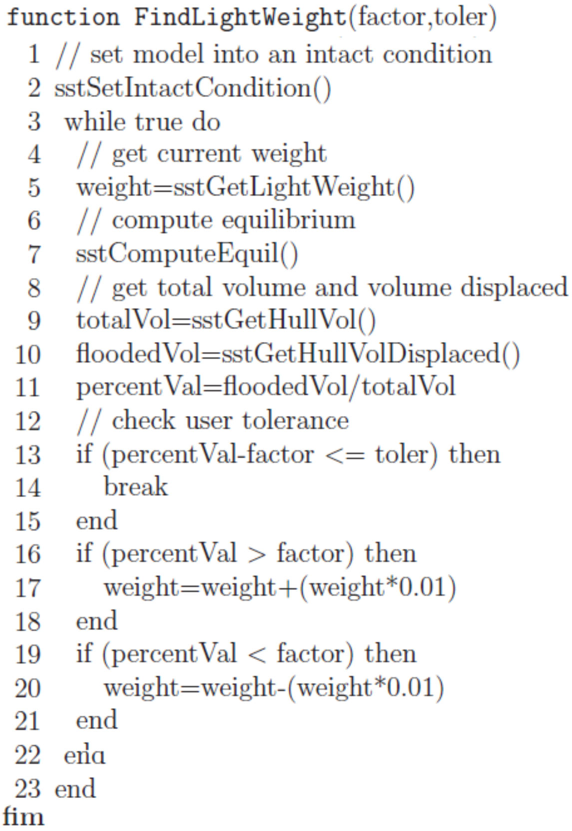
All the restrictions imposed by the MARPOL 73/78 regulations are being accepted but one restriction concerning to the minimal range of stability angles of 20 degrees is currently rejected. This result can be seen in table 2 where the range angle is highlighted in red text.

The next section of this work will present an approach to overcome this damaged situation by testing different variations of the ship model until all MARPOL 73/78 restrictions rules are being accepted.

Automatic Weight Estimation In order the ship meets all the requirements imposed by MARPOL 73/78, it's geometry must be changed by varying the light weight of the vessel structure and the draft equilibrium in order get all MARPOL 73/78 requisites to be approved.

Criterion	**Value**	**Eval**
Equilibrium free-board (lowest flooding point height)	5,554 > 0,000	OK
Angle of deck edge immersion	18,392	Ok
Equilibrium heel angle	14,297 < 25,000	OK
Equilibrium trim angle	0,648	-
Stability range (beyond equil. position with 0.1m level)	18,627 > 20,000	NO
Area under GZ curve in Stability range	0,204 > 0,018	OK
Maximum GZ in Stability range	1,009 > 0,100	OK
Theta WE > Theta 0	27,949 > 14,297	OK

Table 2: Marpol Damaged Condition Stability Table Results



```
function FindLightWeight(factor,toler)
  // set model into an intact condition
  sstSetIntactCondition()
  while true do
    // get current weight
    weight=sstGetLightWeight()
    // compute equilibrium
    sstComputeEquil()
    // get total volume and volume displaced
    totalVol=sstGetHullVol()
    floodedVol=sstGetHullVolDisplaced()
    percentVal=floodedVol/totalVol
    // check user tolerance
    if (percentVal-factor <= toler) then
      break
    end
    if (percentVal > factor) then
      weight=weight+(weight*0.01)
    end
    if (percentVal < factor) then
      weight=weight-(weight*0.01)
    end
  end
end
fim
```

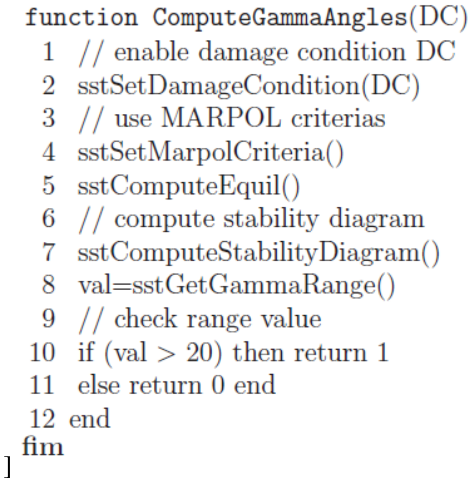
Figure 15: Lua script to find light weight proportional to 63% of the vessel.

A parameter considered to redefine the hull shape is the breadth, but resizing the hull structure does not guaranty a significant gain in the stability range because it is directly linked with the initial GM (distance between the mass center and the metacenter) computed in its intact equilibrium condition.

Once the ship geometric model have been exported into Sstab software, it was decided to keep constant the relation between submersed volume by total volume in about 63% taking as reference the intact condition. This way, the light weight increases proportional the variation of the submersed volume.

The function *FindLightWeight* (Figure 15) developed in Lua language searches for the light weight that reaches the 63% of flooded volume, according of the input geometric model. This process is done iteratively adding and subtracting weights until a determined tolerance that defines the correct light weight of the vessel is reached, where the total flooded volume must be proportional to 63% equal to the intact condition. At each search step of the *FindLightWeight* function the vessel equilibrium is computed in order to check the flooded volume percentage.

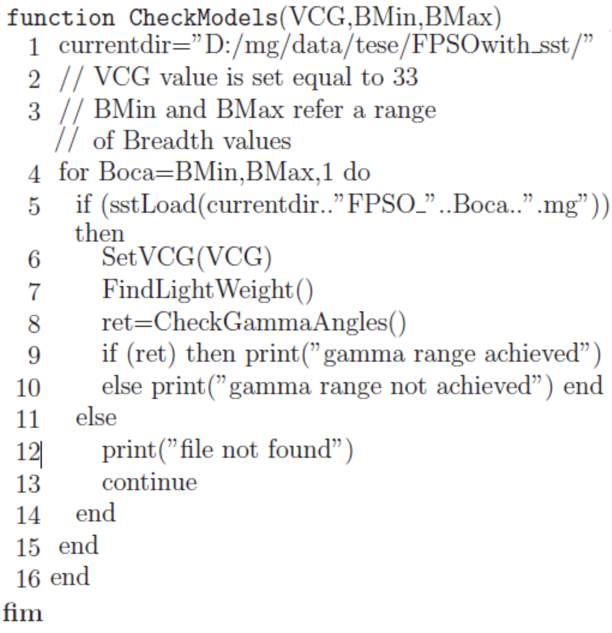
The Lua function *ComputGammaAngles* shown in Figure 16 checks if the current damage condition is approved by the MARPOL 73/78 requirements. Each damage condition computes the currente static stability diagram, and the minimal range angle value is evaluated. This value must be greater than 20 degrees.



```
function ComputeGammaAngles(DC)
 // enable damage condition DC
 sstSetDamageCondition(DC)
 // use MARPOL criterias
 sstSetMarpolCriteria()
 sstComputeEquil()
 // compute stability diagram
 sstComputeStabilityDiagram()
 val=sstGetGammaRange()
 // check range value
 if (val > 20) then return 1
 else return 0 end
end
fim
]
```

Figure 16: Lua script to compute stability range.

In order to find the ship that meets all the requirements imposed by MARPOL 73/78, considering a set of ship models that have their breadth parameters varying between 56 and 70 meters. The function *CheckModels* (Figure 17) were developed using the functions *FindLightWeight* and *ComputGammaAngles* presented above. This function loads a file that has stored the intact and damage condition for each breadth value and then sets the VCG in 33 meters (function *FindLightWeight*) and then checks the minimal range angles of stability for both conditions (function *ComputGammaAngles*).



```
function CheckModels(VCG,BMin,BMax)
 currentdir="D:/mg/data/tese/FPSOwith_sst/"
 // VCG value is set equal to 33
 // BMin and BMax refer a range
 // of Breadth values
 for Boca=BMin,BMax,1 do
  if (sstLoad(currentdir.."FPSO_"..Boca..".mg"))
  then
    SetVCG(VCG)
    FindLightWeight()
    ret=CheckGammaAngles()
    if (ret) then print("gamma range achieved")
    else print("gamma range not achieved") end
  else
    print("file not found")
    continue
  end
 end
end
fim
```

Figure 17: Lua generic script to compute stability range of a set of ship models.

6 RESULTS

Different variations of the model shown in Figure 9 were generated varying the breadth parameter and using Lua functions to perform this process in an automatic way. The geometry variation doest not changes the value of the block coefficient that stand in around 0.70 meters. So, it could be say that fluctuation characteristic of the vessel was kept intact.

The static stability properties results with the tested models according to the breadth and weight variation parameters are presented in Table 3.

The model reference or initial condition is highlighted with horizontal lines that forms a box. Therefore it can see that the breadth parameter (B) was modified up and down the breadth reference that is 56 so only three models from Table 3 (bold data) achieved the minimal range stability for the current damage condition.

The partial volume shown in the table is the total flooded volume with relation to the added weight. The column Displacement indicates the total displace weight of the vessel. The data in columns 1 to 7 were extracted with reference to its intact condition, so there is no damage being considered. Data from columns 8 to 10 were extracted considering the damage condition.

Considering the models that were approved by the MARPOL 73/78 restrictions in its damage condition, in case that the vessel needs to supports the current weight loading, the most indicated geometry to be adopted as

B	Draft	Displacement	Total vol	Parcial vol	Vol.%	Weight	KG	GM	Range
50	**20,45**	**272501,4**	**420870,8**	**265836**	**0,63**	**25000**	**15,75**	**5,20**	**20,26**
52	20,48	284098,8	437712,1	277152	0,63	35000	16,01	5,79	19,04
53	20,51	290179,0	446125,0	283084	0,63	41000	16,17	6,07	18,71
54	20,48	295194,3	454540,0	287977	0,63	46000	16,26	6,42	18,80
56	20,52	306998,8	471375,4	299499	0,63	57806	16,56	7,02	18,62
57	20,44	311197,3	479798,9	303591	0,63	62000	16,62	7,44	19,09
58	20,37	315391,4	488215,5	307684	0,63	66194	16,69	7,86	19,54
58,2	20,37	316715,3	489893,6	308976	0,63	67518	16,72	7,92	19,49
58,5	**20,35**	**318701,2**	**492418,8**	**310913**	**0,63**	**69503**	**16,78**	**8,00**	**22,46**
59	20,38	321197,6	496631,4	313349	0,63	72000	16,84	8,19	19,53
60	20,39	327003,8	505044,1	319014	0,63	77806	16,98	8,54	19,52
62	20,42	338616,3	521879,8	330343	0,63	89418	17,30	9,24	19,48
70	20,39	382199,5	589219,1	372867	0,63	133000	18,30	12,6	19,81
72	**20,41**	**393831,4**	**606054.0**	**384215**	**0,63**	**144632**	**18,60**	**13,49**	**34,10**

Table 3: Breadth parameter variations of a ship hull.

reference would be the model whose breadth parameter is 58.5 meters because this model could have the least economical cost to be considered.

The implemented Lua scripts for searching the optimal geometry of the vessel that supports the current weight loading and the damage condition may consider or not all the restrictions imposed by MARPOL 73/78 (minimal stability ranges angles, right arm, etc).

In this work the minimal stability ranges angles were only considered because it was the only condition that was not satisfied for the damage condition simulated considering a hull vessel with breadth equal to 56 meters.

The varying process modifies the breadth parameter up and down considering the reference model (breadth equal to 56) does not mean that the minimal range stability angles (column 10) will have a proportional variation. This fact could be seen in the Table 3 where the breadth variation parameter can get a gain or loss in the minimal range stability angles.

Hence, the current problem is to look up for the local minimum that minimizes a certain objective function that project designer wants to achieve and at the same time all the restrictions requirements by the classifying societies (IMO, DNV, etc) must be approved.

Criterion	**Value**	**Eval**
Equilibrium free-board (lowest flooding point height)	$7{,}226 > 0{,}000$	Ok
Angle of deck edge immersion	19,795	Ok
Equilibrium heel angle	$14{,}144 < 25{,}000$	Ok
Equilibrium trim angle	0,520	-
Stability range (beyond equil. position with 0.1m level)	**$22{,}456 > 20{,}000$**	**Ok**
Area under GZ curve in Stability range	$0{,}398 > 0{,}018$	Ok
Maximum GZ in Stability range	$1{,}662 > 0{,}100$	Ok
Theta WE > Theta 0	$29{,}636 > 12{,}144$	Ok

Table 4: Approved Marpol Damaged Condition Stability Table Results

Table 4 show the corresponding numeric table resume of all MARPOL 73/78 restrictions that were considered after the equilibrium computation of the vessel and can be appreciated an stability range of 22.456 value.

7 CONCLUSIONS

This work has as principal contribution the building of an embedded scripting language inside a well known softwares that are actually been used at PETROBRAS, the Brazilian oil company for modeling shells of vessel unit based on cross sections and for static stability analysis. Lua language was chosen because is freely available for both academic and commercial purposes and is a general-purpose embedded programming language designed to support procedural programming with data-description facilities and the most important is that Lua was born at PUC-Rio.

The embedded Lua language let the user to define variables in Lua. This variables can be used as input parameters for parametric modeling functions that sintetize data as: length, hight, etc of any kind model.

A set of Lua languages commands was defined in order to perform automatic modeling in MG. The Lua language was also embedded into the Sstab software in order to be able to write all the Lua functions shown in this section. The Lua language enables that many iterative process to be done in an automatic way.

This command sets sintetize the process of creating any kind of basic geometric entities (vertices, curves, surfaces, etc). A set o Lua language commands was also create for the Sstab software in order to perform automatic analysis as the scripts shown in the section Form Shape Stability Analysis.

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