Discretization method of the ship hull cross sections

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Discretization method of the ship hull cross sections

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Abstract. The paper presents an original computer based method used for the discretization of the ship hull cross sections, activity which is a part of a larger project – the ship hull analytical model. We started the discretization process with the so called ‘typical sections’. The resulting ‘templates’ are useful because the parameterized analytical models may be reused for a particular frame which has particular dimensions, i.e. thickness of the side outer/inner shell plates. The section was divided into ‘simple’ shapes, i.e. rectangles, circles, half-circles, quarter-circles, polygons and bulb flats. A sign which may be either +1 or -1 is assigned to each ‘simple’ shape in order to create a Boolean algebra. The specific data which define the ‘simple’ shapes was stored in spreadsheet documents where it can be easily identified, filtered and saved in CSV format in order to be loaded in the upper-level data processing application. We already created an application which lists the data included in a selectable CSV file in order to test the header files already developed in the ‘calculus domains’ software development project and to verify the correctness of the cross section discretization. The results are used to compute the weighting forces which are used to develop the loads’ model. The discretization is also useful to compute the geometrical characteristics of the sections to be used in the calculus of the stresses and of the displacements.

1. Introduction
Ship strength problems are a distinct class of complex problems in engineering. Usually, a structural model consists of four submodels: a submodel regarding the geometry, other submodel regarding the material behaviour, the submodel of the loads and the submodel of the supports. Apart from the material behaviour model, all the other sub-models in ship strength problems are both, complex and interconnected. Design models were developed long time ago when the computer was not an automatic calculus instrument, many useful simplifying assumptions being conceived and used, in an age when the accuracy was not a very important objective. One can notice the influence of the calculation instrument upon the technological progress of a given period of history. At present, the tremendous progresses in computer science were used to conceive and develop software instruments for design and for structural calculi based on the finite element method. However, the computer science was not used to redesign the analytic knowledge, the computer being usually used as a data crunching tool, not as an advanced and intelligent instrument who offers huge creative resources.

2. Original basic solutions already considered
Elaborating structural studies based on original computer instruments was a constant direction of investigation and development of the authors. Identification of the sources of inaccuracy of the computer
based analytical models was an important issue, [1], in order to use to the best computers’ main features: accuracy and speed.

Other direction of study was the flexible modelling of the calculus domain’s geometry, which is important for the facile computing of the geometrical characteristics. In this way an initial solution was presented in [2], where a Boolean algebra based on ‘simple’ shapes was tested. The concept evolved, the latest approach being presented in [3].

The calculus of the geometrical characteristics was solved using a general method based on spline functions which approximate the domains’ boundary, [4], or using polygons, [5].

Regarding the marine engineering problems, we developed a software used to draw the free body diagrams for ship hull educational models, [6], and also for a model of a real ship, [7], figure 1.

![Free body diagrams](image-url)

**Figure 1.** Free body diagrams drawn using an original software application.

Being acquired a ‘critical mass’ in terms of theory and implemented solutions, there was accepted the challenge regarding the development of computer based analytical models of complex phenomena.

3. **New concepts based on computer science original analytical models**

The ship hull is a structure having an intricate geometry and which is loaded by a complex system of forces. Using the aforementioned specific instruments, a first step was to apply the so called ‘classical’ analytical methods in order to create an analytical model of the ship hull domain. As it is presented in [6] and [7], the ship hull is divided in several subdomains. In the mid region of the ship hull the sections have small variations, being possible to model a wide range of cross sections by developing a parameterized small set of models of the geometry. These geometric models are useful for two purposes: calculus of structure’s weighting forces and calculus of the geometrical characteristics. The weighting forces are further on used to develop the model of the loads, together with the buoyancy forces, as it was done for the model presented in figure 1.
Figure 2. Case study: a web frame that is widely used along the ship’s length.

The aforementioned ideas regarding the development of the model are used for a real structure, presented in the previous figure. The dimensions are intentionally blurred in order to protect the information of the according design. There are also some other sections in the class of the so called ‘typical’ cross sections, but we started with this section because it is widely used along the ship’s length and it has the most intricate geometry, therefore we are able to customize the geometry of this section in order to model other sections.

4. Model of the weighting forces and calculus of the geometrical characteristics

As it was mentioned before, the domain is divided in subdomains which have simple shapes. By simple shape we mean shapes for which we have direct calculus relations of their geometrical characteristics starting from the main dimensions which define each shape, together with its location inside the current cross section.

The simple shapes are used to create a ‘library’ of shapes which may be reused in other follow up projects. In order to have a user friendly interface during the data input process we use a spreadsheet application to store the data.
Figure 3. Input data in a spreadsheet application.

The information regarding a simple shape is stored on a line of the spreadsheet document. A specific colour is assigned to a given simple shape, in order to analyse the data in a readily way. All the columns, a.k.a. fields, used to define that simple shape use the specific colour specific to the current simple shape, so the fill in process is easier. In order to have a more precise identification of the components in which the section is discretized, we assign a ‘ShapeID’ parameter to each simple shape.

We use the ‘Info’ column in order to include detailed information regarding the designation, dimensions and location of the cross section’s component that is modelled by the current shape included in a given line.

The simple shapes considered by us are: rectangles, circles, half-circles (4 types: ‘N’, ‘E’, ‘S’ and ‘W’), quarter-circles (4 types: ‘NE’, ‘SE’, ‘SW’ and ‘NW’), polygons and bulb flats.

Each component in which the section is divided has a sign, that is either +1, in this way the component being added to the section, or -1, in this way the component being subtracted from the section. These signs are used to define a Boolean algebra useful to define the composite section similar to a Lego object. The -1 sign is used to define holes in the section’s plates. If the sign is 0, the current line is disregarded, this means that we are able to use several dimensions/versions of a given component in order to evaluate its influence.

Beside the dimensions in the cross section, each component has a certain depth, the direction of this dimension stored in the ‘Thickness/Depth’ field being symbolized by the ‘Depth_flag’ parameter. We use the following rule regarding the values of this parameter: ‘s’ symmetry, ‘f’ to the fore/bow, ‘a’ to the stern/aft, according to the position of the current section with respect to the ship’s midsection. The ‘Thickness/Depth’ field is useful to compute the volume of the current simple shape which is multiplied by the specific weight of its material in order to have the weight of the current component.

The information stored in the spreadsheet file are also useful to visualise the section. In this way, there were conceived some visualisation rules according to which a certain side of the current simple shape is either visible, in this case the visualisation flag is ‘v’, or not visible, the according flag being ‘n’. For instance, in figure 3 yellow lines store the data of the rectangular components (ID=1) for which we have the ‘Visibility’ field ‘nnnv’. Each character regards the top/right/bottom/left side of the current rectangle. In the lines 99 and 104 there are stored the data of a half-circle, ‘Circle Downward’ ID=4, for which the sign is -1 and the visualisation field is ‘vn’. This means that this shape is used to define a hole.
and the arc is visible (first character of the ‘vn’ string) while the diameter is not visible, because the second character of the ‘vn’ string is ‘n’. Moreover, figure 4 presents the information stored in line number 107 of the spreadsheet document which defines a polygon, ID=5, having 4 vertices (nodes). After each set of coordinates which define a vertex it follows a visualisation code regarding the current line segment. For bulb flats, ID=1001, we consider that all the sides are visible, except the welded side.

![Figure 4. Input data in a spreadsheet application.](image)

We have also defined rules regarding the angle of the bulb flats and the position of its ‘nose’, in order to use the correct geometrical characteristics. Because some of the bulb flats could not be found in the manufacturers’ brochures, an analytical model was developed, in this way being available reliable values of their geometrical characteristics.

The spreadsheet file is useful for the data input process because it allows us to input formulae used to compute coordinates, not only numbers. Moreover, we are allowed to set filters in order to verify the data. Once the data input process is completed, the according spreadsheet file which stores the data is saved in the comma-separated-value format. It results a text file where the simple shapes are identified by their ID codes, not by colours as it was presented in figure 3. The text file may be read by any programming language and in any operating system.

Starting from the general definitions of a domain presented in [3], we developed a set of header files used to implement the principal operations with domains and subdomains. The development is still in progress, so far being solved the geometrical characteristics problem only for polygons. However, any simple shape may be approximated using polygons. The development of the implementation based on header files allow us to reuse the software in other projects, fact which lead to the readily and rapidly development of computer based models, [8].
The previous figure presents the input data report, using as input file the aforementioned CSV file. A ‘timestamp’ information is added in the last section of the output file name, in order to identify the versions of the report. In this way the input data may be tightly controlled, aspect which is very important if a huge volume of data must be processed. Once the data visualisation processor will be completed, the data will be visually verified.

![Excel spreadsheet](image)

**Figure 5.** Dimensions of some components depending on the web frame number.

The structure of the input data allows us to consider parameters in the upper level software. In this way, a component identified using the ‘Info’ field may have the dimensions set according to a given criterion. For instance, the thickness of the side outer / inner plating may be defined with respect to the web frame number. In this way a more accurate geometric model may be defined. Moreover, in the definition of the components of a cross section we may use a local system of axes which simplifies the data input process, the coordinates being updated according to ‘standard’ system of axes when the CSV data file is read in the upper-level application.

5. **Conclusions**

The analytical definition of a ship hull seemed to be an impossible task in an age when the computer was not available as a current calculus instrument. At present, we explore the possibility to define a computer based analytical model of a ship hull, which has a series of strengths: the theoretical background is simple, there are no issues regarding the convergence of the solution, once it is created and implemented it may be used in various situations, some of the input data being possible to be acquired from sensors.

The accuracy of the results depends on the accuracy of the cross sections’ discretization, being possible to update the data in the input file by considering a larger number of simple shapes, which enhances the precision of the approximation.

Being a large volume of input data to be defined, we started with the ‘typical cross sections’. In the following stages we’ll also consider the sections from the fore and stern of the ship hull, in order to reach a higher accuracy of the weighting forces which influence the accuracy of the loads’ model. Moreover, having more accurate values of the geometrical characteristics we may have more accurate results of the stresses and of the displacements.
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