

Using the right tools

At SARC, a consultancy and software house in The Netherlands, the drive to enhance and extend its *PIAS* and *Fairway* ship design software is permanent. Phd H.J Koelman, director, SARC explains some of the company's developments

The core subjects used by SARC are computer representations of the internal and external geometry of a ship, as well as the *modus operandi* they impose on the ship designer. Related subjects that are addressed in this article are 3D printing and developments in collaborative engineering.

Ship hull design and representation

In the early days of Computer Aided Ship Design (CASD) the first experiments were made with representations based on polynomials or transcendental functions, such as conics. Mostly in two dimensions, and as such, representing sections or waterlines. In the early eighties we saw the advancement of B-spline curves and surfaces, later generalised to non-uniform rational B-spline (NURBS) surfaces. This method has grown out to the de facto standard for the modelling of ship hull forms, although when applied in practice quite some disadvantages showed up. The strange contradiction is that in private communications with practical ship designers those drawbacks are commonly recognised and shared, while reports thereof in literature are only scarce. However, an early analysis of the problems was given by Koelman [1], while a recent evaluation is presented by Sharma, wan Kim, Storch, Hopman and Erikstad [2] where it is observed that NURBS surfaces suffer from a number of drawbacks, which are, summarised:

- NURBS are based on rectangular patches, which are basically not compatible with the non-rectangular topology of (parts of) a ship hull.
- In order to cope with this incompatibility, large numbers of control points are required, which leads to long computation times and limits the applicability of NURBS.
- For smoothing or fairing purposes the incorporation of physics-based or optimisation methods would be

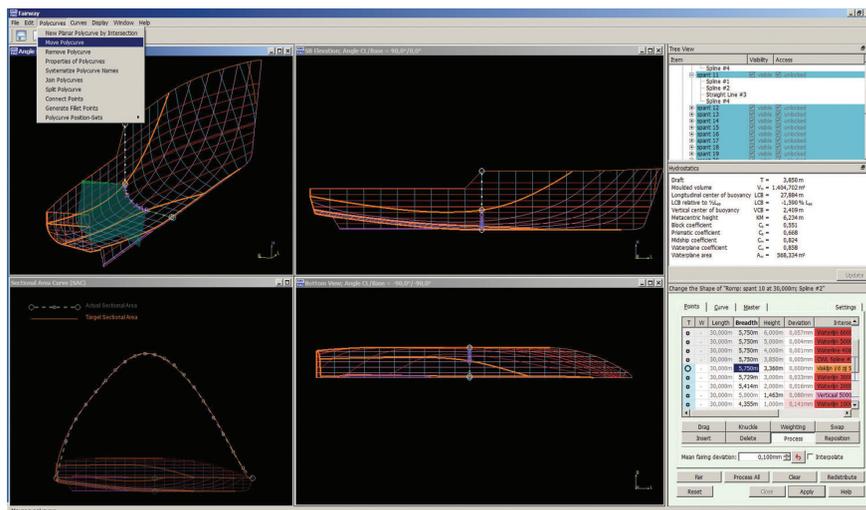


Figure 1: Screen shot of the redesigned GUI of Fairway, showing an angled view, two 2D views, the SAC curve as well as tabular detail information

preferable. Unfortunately, this leads to high computational costs.

However, alternatives for NURBS do exist. An overview is given by Koelman and Veelo [3] and is comprised of, for example, T-splines, subdivision surfaces and interpolating methods. In the latter a coherent network of user-defined curves is constructed and maintained, on which surfaces are interpolated, which fill the holes between the curves. To this category belongs the Fairway hull design module of the PIAS programme suite of SARC. This programme was developed in the 1990's, and was recently equipped with an entirely redesigned User-Interface - based on the latest GUI technologies - from which a screen shot is shown in figure 1. Fairway now combines a state-of-the-art GUI with the advantages that have always been implicit to its system design, such as:

- The user can work with an irregular network of connected curves and can choose exactly those ordinates, waterlines, buttocks or spatial curves that determine the particular hull shape at

hand. Also partial curves, which are not running over the complete hull surface, can be used.

- The user can either work with curve vertices or with points on the curve itself. Because the curves coincide with the surface this implies direct surface control. Furthermore, because each curve has its own independent geometric representation, the number of (NURBS) vertices can be different for each curve.
- Fairing methods are incorporated, as well as a library of elementary (conical) shapes.
- At any time a closed, curved surface is available, so additional curves can be generated easily.
- Design support by hydrostatics, sectional area curve (SAC), developable surfaces etc.

Tactile modelling

These days it is hard to read a serious newspaper without being flooded by articles on 3D printing (a.k.a. rapid prototyping, layered manufacturing or other fashionable terms). In order to chart the potential when used for ship hull design, some experimenting has been done with

the Ultimaker, which is a low-cost Do It Yourself (DIY) printer, printing Fairway hull models. In figure 2 an example print is shown, while more examples can be found on <http://www.sarc.nl/images/pdf/publications/dutch/2012/Ultimaker%20illustraties%20en%20links.pdf> and a movie of this printer in action, producing a cargo vessel demi model, on <http://youtu.be/L91vZ8iQQ50>

These experiments led to the following conclusions:

- A 3D print of the hull provides a distinct view of the hull shape. Strangely, even people with experience and background of reading lines plans or rendered views see things differently with a 3D print. And obviously more natural. But, especially for other stakeholders in the design process a tactile model, no matter how small, gives natural insight in the shape.
- With about 1/5mm the accuracy of the printer is more than sufficient to transfer the (subjective) notion of shape. A pity aspect is the shrinkage strain in the polymer which causes a slight deformation.
- DIY printing is cheap on investment and material. The downside is that the prints require some fine tuning and may sometimes fail, although with the latest modifications this appears to be much improved.
- So arbitrary lines drawings or a collection of unconnected surfaces cannot be used as basis for a 3D print. The printing software requires the representation to be a genuine solid model, exactly as is provided by Fairway.

Internal ship modelling

Contrary to the outer hull, for the ship internals - such as compartments, bulkheads and decks - there is no prevailing methodology. In Ship compartment modeling based on a non-manifold polyhedron modeling kernel. Advances in Engineering Software, [4] an inventory was made where it is concluded that the methods applied so far fall in to two categories; either they model the spaces by their boundaries, or they use a wireframe model of boundaries, where essentially bulkheads and decks are modelled. However, neither of the two copes with

the fact that spaces and boundaries are mutually interrelated. In order to address this problem a new method was adopted, where this duality between spaces and planes is addressed. This method essentially splits the space recursively in two, and is consequently labelled the Binary Space Subdivision (BSP) method.

Actually the BSP as such has been known for quite some time - and applied in shooter games for example - but not used frequently for modelling purposes. It has been implemented in a new PIAS module for internal ship modelling, which is discussed in more detail in de Koningh, Koelman and Hopman [5], and from which figure 3 shows an output example. Some facilities of this program are:

- The user can either model spaces or planes, or any mixture. When modelling planes, all spaces in between are automatically created. On the other hand spaces can be converted to planes, if desired so.
- Output can be formatted to 2D drawings, e.g. to serve as tank plan or elementary general arrangement plan.
- Full-blown tank capacity calculations, tank sounding tables etc.
- Incorporated in the PIAS suite, so integrates seamlessly with e.g. probabilistic damage stability.
- Act as a server for internal geometry, as discussed in the next section.

An infrastructure for collaborative design

With ship design activities being more and more dispersed, both geographically as well as over specialised teams, the

need for tools that support co-design is compelling. From experiences gained in the Dutch joint-research project *Innovero* it was learned that the most promising software model for co-design is a collection of software tools which share each others facilities by means of an Application Programming Interface (API). This matter is further discussed by Koelman [6], but summarised in this fashion the software components work on a peer-to-peer basis, without the necessity of a central server.

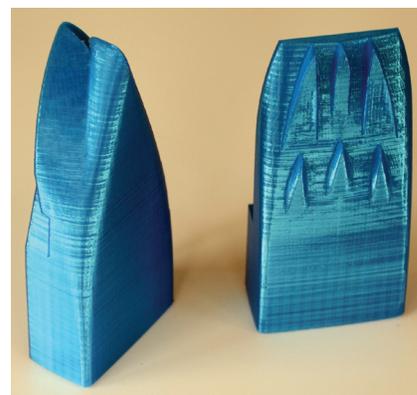
The internal geometry tool of PIAS was equipped with such an API, which enables partner software not only to request data and to push new data, but also to ask *services*, such as the computation of compartment shapes, deck shapes or compartment volumes. In cooperation between software developers and ship design offices two experimental co-design systems have been configured, each consisting of PIAS' internal geometry tool and a general-purpose CAD system. With the goal to *generate* general arrangement plans and tank plans in the CAD system on the basis of the information as requested from PIAS. One step further is to modify the plan in the CAD system - e.g. by adding a bulkhead and thus splitting a compartment in two - and inform PIAS correspondingly.

This system works instantaneously, without transferring files. Although these experiments have not yet led to commercial products, the results are so promising that the concept will be developed further in a new Dutch joint-research project. **NA**

References

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Figure 2: Fairway hull models printed by the Ultimaker 3D printer





Feature 2 | CAD/CAM

non-manifold polyhedron modeling kernel.
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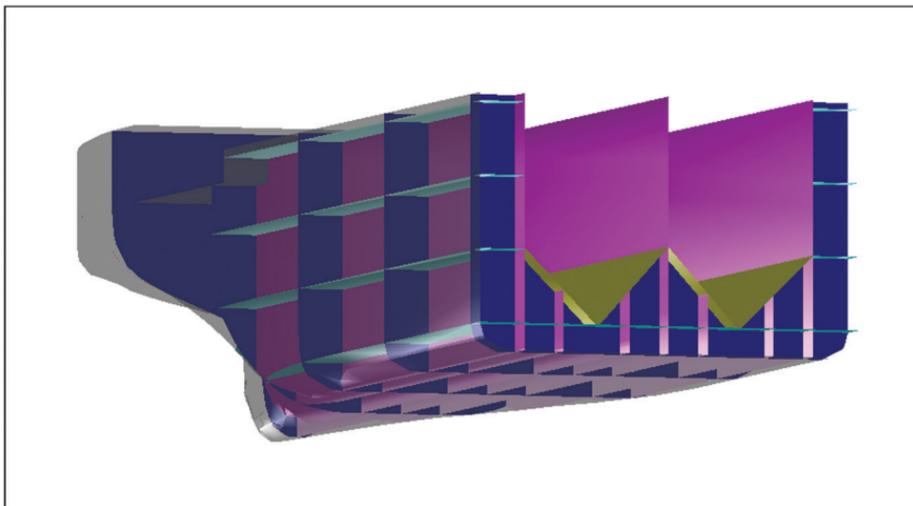


Figure 3: Internal ship layout modelled with the BSP-based PIAS module.