Thoughts on managing complex geometry for simple calculations.

Andy Claughton, BSc CEng RINA SNAME.
Principal Research Engineer
Wolfson Unit MTIA
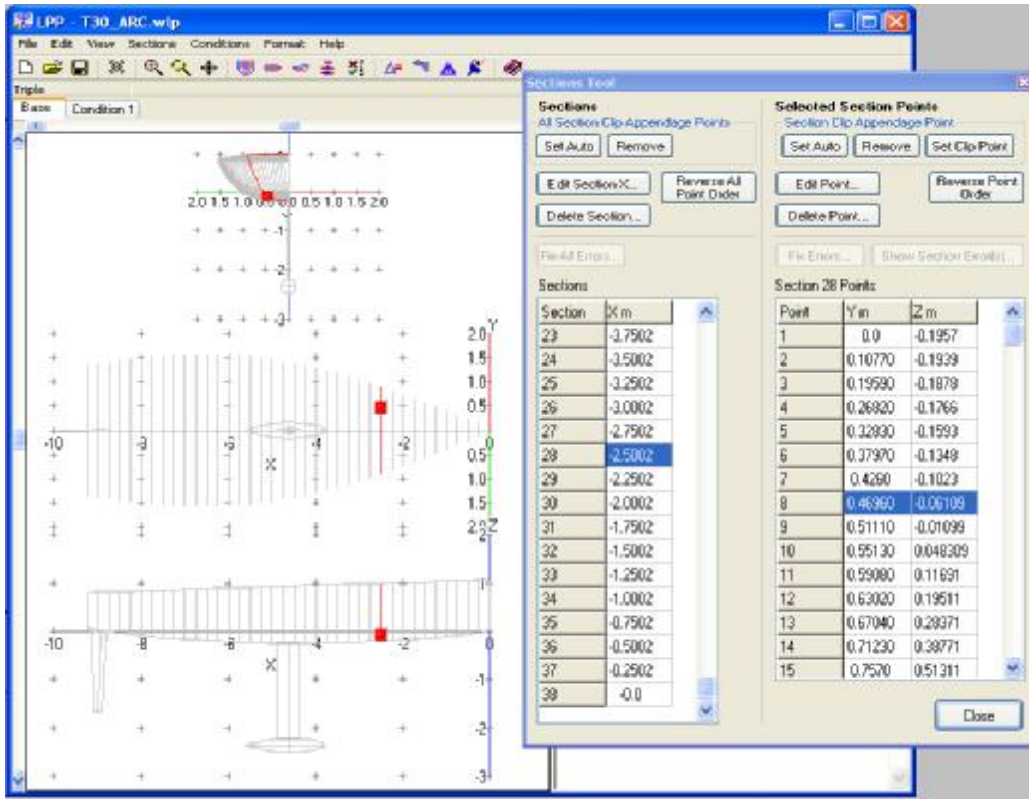University of Southampton

"Can I give you an IGS file?"   "Well actually no, I'd prefer you to give me something useful."

Modern design methods are now aimed at creating beautiful surfaces that can be rendered and displayed in a virtual world. This is a precursor to actually getting a client and then having to do the job. The picture below was created from the design surfaces.

1.   Pre production rendering of the KER 53.

Behind the scenes however many naval architects are still happily doing basic naval architecture calculations using data input files that have much more in common with a table of offsets than an igs file. Since Archimedes the principals of buoyancy and displacement have remained unchanged but our ability to create and manipulate shapes has moved ahead. There is a trend to work with files that define surfaces and solids which simple and reliable software packages do not have the ability to use. This is not a criticism of the older software, simple hull definitions of a boat as y & z coordinates at specified x (longitudinal positions) are easily defined and checked, and can be integrated accurately and quickly. Also volumes can be added and subtracted easily as the volume integration passes to and fro along the vessel. The screenshot below shows a typical interface for manipulating a point wise hull definition.

2. Screen capture from Wolfson Unit Lines Processing Program (LPP)

As consultants involved in physical and computer model testing, at the start of every job we are faced with the problem of getting drawings from the client and manipulating them into a form that a) we can use and b) doesn't lose important geometrical information. A request for information usually gets the reply "I've got an IGS file can you work from that"? This isn't an academic problem because every hour we spend working on the files is time that gets taken away from productive work. How can we easily say yes to that question? It will be several years before all software that works on simple hull definition files is abandoned, but creating the input files becomes more difficult as surface definitions become more complex and detailed.
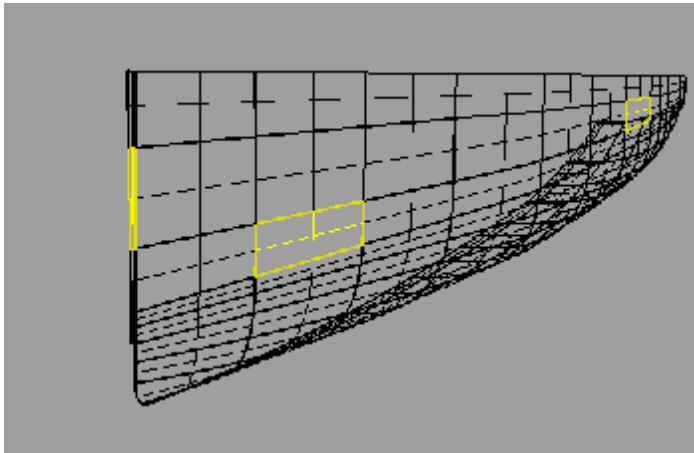
Working in the small craft industry I have run across the full gamut of design and analysis packages, a non exhaustive list of which are shown below.

High end CAD	Regular CAD	Freeware	Hand drawings
Catia SolidWorks Pro-Engineer ACAD Inventor Siemens NX7	Rhinocerous (Rhino) AutoCAD (Light) MaxSurf	Google Sketchup	

On the left hand side of the table these packages cost several thousands a year in licences, but they are complete parametric systems that large manufacturers demand to maintain product lifecycle management. A few design houses will support this kind of system, but it relies on having staff members entirely given over to using and managing the system. More

commonly small design houses will use regular CAD, with the SolidWorks system appearing more and more as a financially tolerable way of getting "parametric " CAD into the work place.

These packages will usually export an IGS file, but often an IGS file is composed of several tens of surfaces, when of course all we want is the shape of the hull as a continuous definition. Also some programs such as the lower end of MaxSurf restrict the number of surfaces you can view at any one time.

3.   Typical hull IGS file with multiple patches.

Fortunately Rhino comes to the rescue, it has become the lingua franca of groups trying to communicate shape information, it's very unusual for Rhino not to be able to at least open most files that you throw at it. That said its not an easy task to simplify complex assemblies that are not native to Rhino.
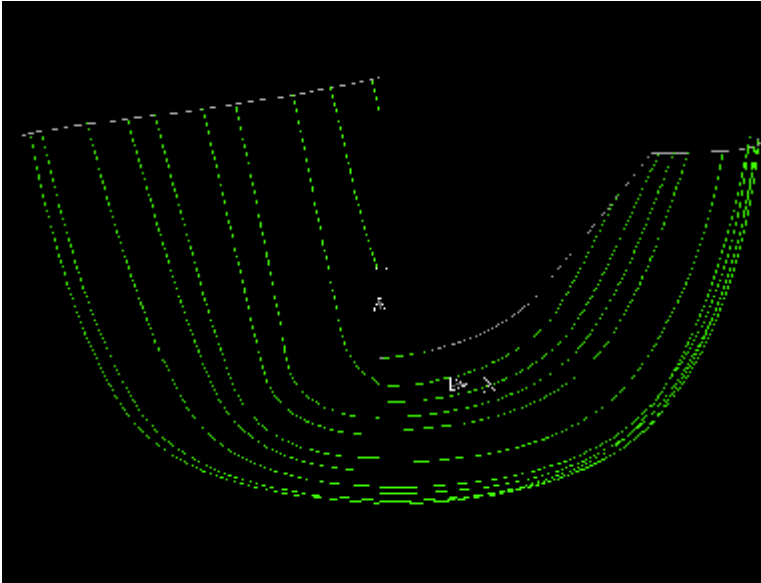
Once you have the file in Rhino the next step depends on what the task at hand is. For model construction we might need to get sections plotted at model scale or create a file for NC cutting of frames, or get a file to a 3D milling machine for small components.

At this stage it's important to address the question of accuracy vs. fairness of the surface. For hull models I like the model to be fair, durable and easily handled rather than accurate to within a fraction of a mm, but heavy, or delicate or both. For appendages, of course these must be super accurate as our ability to calculate viscous drag relies on knowing the section shapes. Also when exporting a hull surface from Rhino and Maxsurf into higher end packages beware that the surface that looks OK in one program may have idiosyncrasies that make it hard to manipulate when doing offset surfaces to create moulds and build frames. Most commonly we will need to extract a DXF file that captures only the features we want to model.

For hydrostatics we need an LFH file, for ORCi yacht race handicapping (IMS as was) we need a OFF file, both these are simple definitions of y and z coordinates at fixed x. How do we get from an IGS to an LFH file?.

Both Rhino and MaxSurf will export a 3 dimensional DXF file of the display they have on the screen. Both programs let you define cross sections at predefined longitudinal positions. In

MaxSurf it's hard to clutter up the picture, but turn off grids and labels before exporting, you don't need the station numbers in the DXF file.
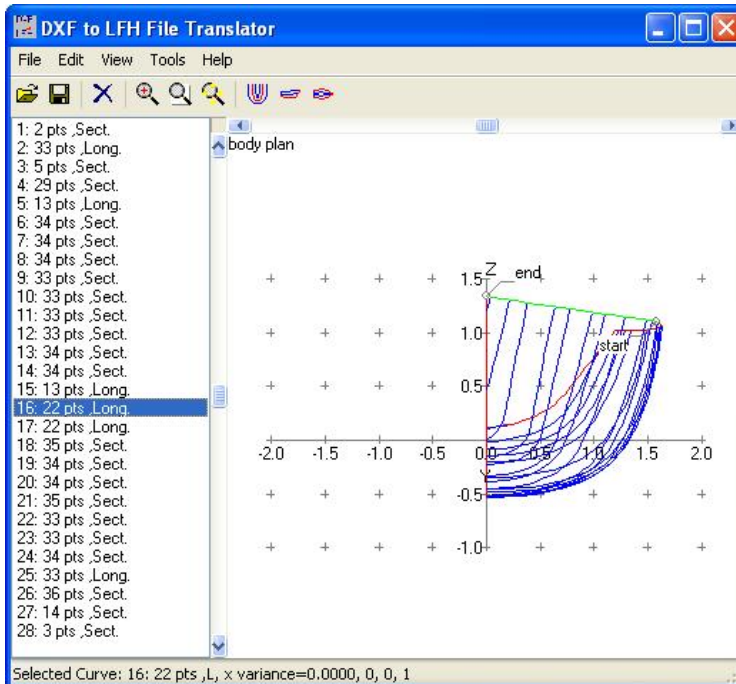

4. Screen capture of a MaxSurf Body plan ready for export to DXF

In Rhino its easier just put all you want to export on a single layer and hide the rest when time comes to export. Increasingly Rhino plug ins are seen as the way forward for software developers wanting to get an accessible front end to other programs that require geometry definition.

Once you have a DXF file that looks like a simple body plan it's likely that the DXF file may not define the hull sections as continuous curves if the sections have been created from a multi surfaced parent. Also it can be hard to coincide the x,y,z orientations of the input and output.

To get over this problem the Wolfson Unit wrote a small freeware application that takes a 3D DXF file and creates a manageable LFH file. It allows you to map the DXF file to the most appropriate orientation and also it can stitch sections into continuous curves and isolate longitudinal curves so that they can be removed from the file, leaving only cross sectional curves. All of this is made much easier if you keep the exported DXF file AS SIMPLE AS POSSIBLE.

5. Screen shot of the DXF to LFH converter showing longitudinal and sectional curves.

Once you have an LFH we can read it into the Wolfson HST and LPP programs that pre-process the data for stability and VPP calculations. The LPP will also calculate IMS offset files and write those out, but in truth the LFH file is pretty similar to an OFF file and a few minutes work with Excel will sort it out.
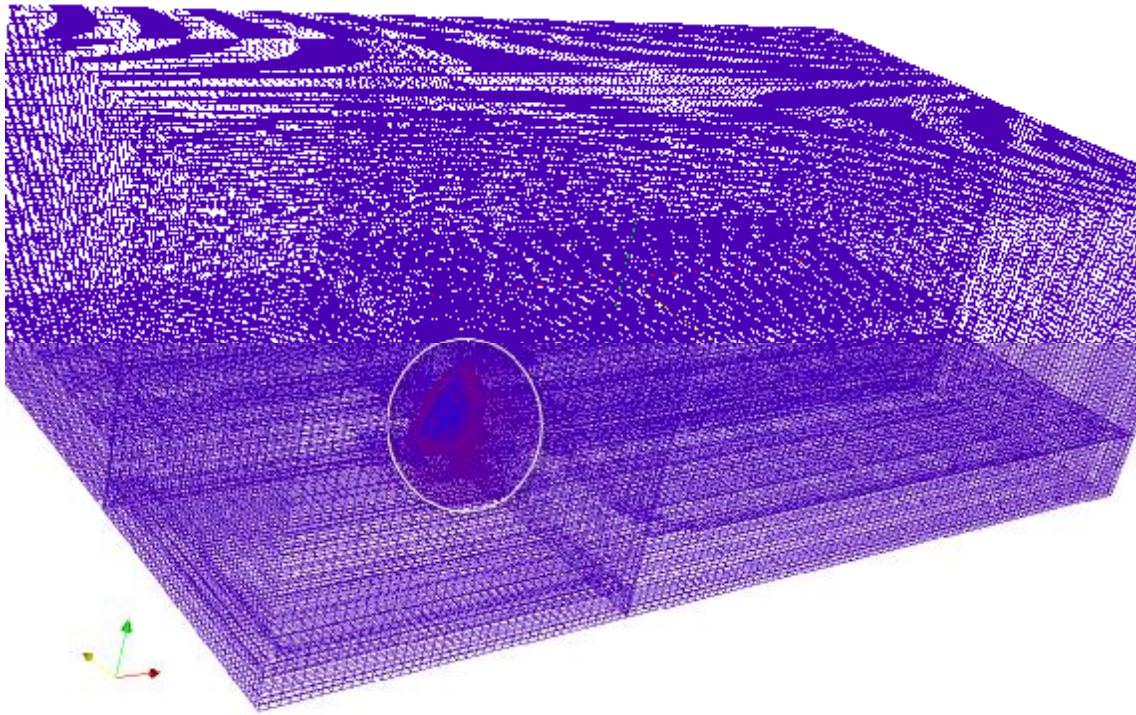
The old IMS offset file format is commonly used to capture simple sailing yacht hull definitions, the format is described in the ORC VPP Documentation. (http://www.orc.org/rules/ORC%20VPP%20Documentation%202009.pdf)

Similar issues arise when trying to move in the opposite direction up the file food chain, from simple offset files and surfaces into CFD (Computational Fluid Dynamics) or FEA programs. Moving from an offset file to CAD, you can get point files into Rhino and SolidWorks very easily using a text file of x, y, & z coordinates. With other packages you may hear the phrase "it's easy, just write a small macro". My advice at that point is to seek an alternative solution, or ask your children for help.

In aerodynamics and hydrodynamics we are used to seeing beautifully sculpted shapes, and these are well suited to NURBS type representations and so they tend to get used as the basis for creating meshes for input to CFD software. Here, as always it's helpful to have a clear idea what the surface will be used for. For example to run CFD on a yacht's sails the computer model is set in a flow domain or "virtual wind tunnel" For a modern racing yacht this would be 60m high and wide and 100m long, i.e. a volume of 360,000 m^3. The picture below shows the cell outlines of a typical domain, the sails are circled in white.
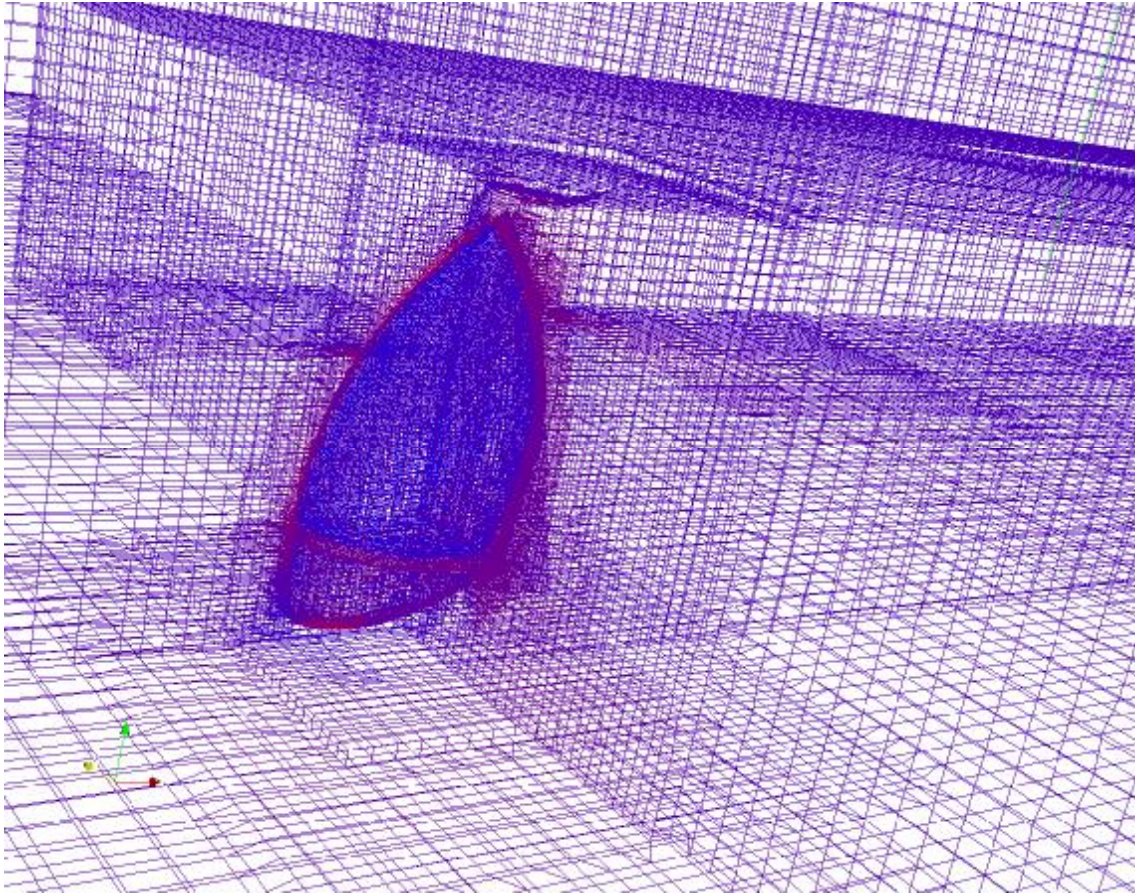
The computer program attempts to predict the flow around the solid object by dividing the domain into small interconnected cells and calculating the flow through the domain and around the shapes in it by calculating a flow velocity and direction at the centre of each cell.
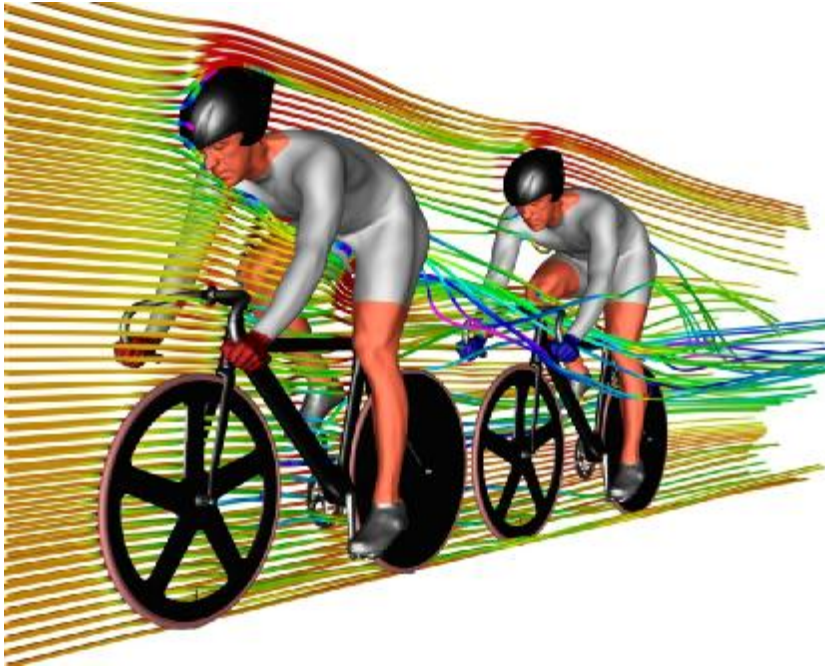
6. Typical CFD domain.

The complete solution satisfies flow continuity (what goes in must come out) through the domain, and through each individual cell. Once you have the flow velocity at each cell position you can calculate the force on each surface cell and integrate the total force on the "model", plus you get colourful plots by the million to inspect what is going on throughout the domain.

Typically with a modern computer you can think of using 25-50million cells to fill the domain, i.e. 25-50 million individual data points of flow velocity. This means that if the domain was divided up evenly each cell would be a cube about 15mm on each edge. Clearly that's too big if you are trying to predict boundary layer flow, where you need cell sizes less than a mm. To get around this the meshes are generated so that close to the model the cells are small, and further away they can be allowed to grow substantially larger. In this way flow details are captured and the global flows are more simply calculated.

7. Close up of the cells around the sails.

Meshing is a fine field of research and all sorts of tools are available, but in the engineering world where deadlines are fixed you have to find solutions that work, reliably, consistently and cheaply. Consequently, we are moving towards using STL files for defining geometries, this file format basically covers your shape with tiny planar triangles, and was developed for use in rapid prototyping systems as an easy way to represent complex geometries. This is an anathema to those who see the purity of their sculpted curved surfaces being made out of plane facets. Truth is though the facets are small, and it's a versatile format, it works for sails, but also for more irregular geometries, such as cyclists and skiers.

8. CFD calculations on track cyclists using STL solid geometry.
(Photo courtesy of UK Sport & TotalSim)

Also it is a gateway to automated meshing software, which will automatically create robust CFD meshes according to simple rules about cell subdivision based on the closeness to the surface being meshed, and its local curvature. Once again Rhino can export STL files.

In essence there are not many problems that can't be solved with Rhino and the DXF to LFH converter.