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Reconstruction of existing hull shapes with PIAS-PhotoShip

Introduction

Reconstruction of existing hull shapes is a process that falls under the widely applied generic term 'Reverse Engineering', which is defined as follows: 'Recreating an existing geometry in form of a digital model'. Reverse engineering in naval architecture can serve many purposes, for instance repairs, duplication, extension, calculations or checking certain criteria. The need for reverse engineering is usually caused by a lack of proper documentation. SARC aimed to implement a measuring method in form of a PIAS-module, capable of reconstructing any hull shape possible, regardless its dimensions or the surroundings in which the ship is situated. Furthermore big investments in equipment were not desired. The result of our efforts to do so is PIAS-PhotoShip, a new module that meets all set conditions.

Photogrammetry

Of all measuring methods available, photogrammetry is the most suitable for our purposes. In photogrammetry 3D coordinates of several points on the hull are calculated , on basis of depictions of these points on multiple photos, and a certain number of reference points. While photographing, one is free in picking locations of the camera. The few conditions for taking photographs do not diminish the flexibility of the systems. Photogrammetry is a well-proven method, widely applied in the fields of architecture, medical and biological science, and industry. Other methods have a common disadvantage, related to the final processing of the measured data. They give no coherence whatsoever between the measured points. All they produce is a so called 'point cloud'. This problem can easily be overcome by using photogrammetry.

From point cloud to solid model

Our final goal is to obtain an unambiguous representation of the hull shape, in our case a solid model that can be imported in PIAS-Fairway, the hull shape modelling software developed by SARC [Ref 1], for further modelling. An object can be represented in different kind of ways (fig 1).

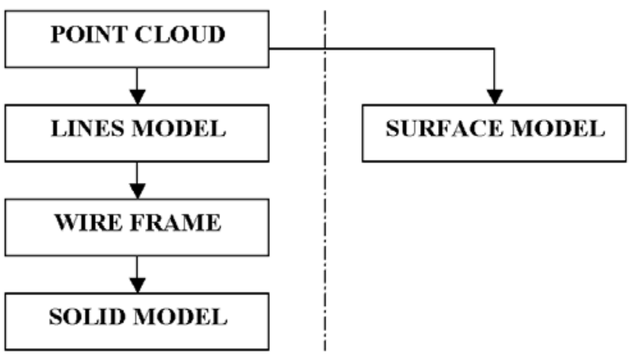

Fig.1. **From point cloud to solid model**

A point cloud is a set of points, without any implicit or explicit geometric information (the shape) concerning the object. A lines model or a surface model does hold such implicit geometric information. A wire frame also holds explicit information about intersections of its lines. On top of that the aimed representation form, the solid model, holds topological information (the 'coherence' of the shape).

It is not easy to obtain a solid model, when there is only a point cloud at hand. However, in the case of photogrammetry, with the support of the photos on which both the hull shape and the measuring points depicted, the user can easily define the coherence between the measuring points. As only few of the existing packages hold the possibility to define a coherence between measuring points, and the ones that do, do not work with a solid model, we chose to develop a new module that will give a solid model.

Principles of photogrammetry

The principle of photogrammetry is based on stereovision, see fig. 2. A comparison to man, that needs two eyes to see depth, can be drawn here.

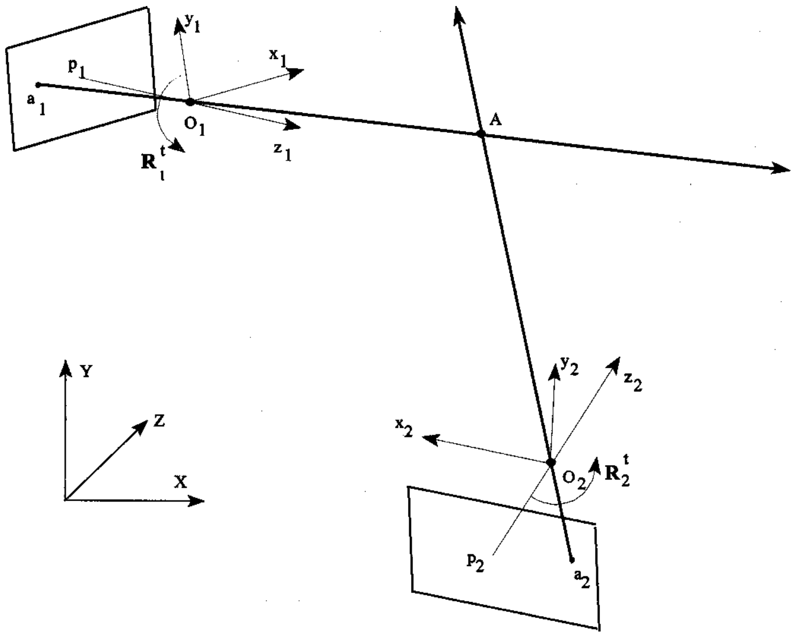

Fig.2. **Determination of the 3D coordinates of a measuring point with intersecting lines of sight**

Depictions of point A: a_1 and a_2 on two different photos are shown. Two lines of sight can be drawn from a_1 and a_2 through the foci O_1 and O_2. The intersection of these two lines defines the 3D coordinates of point A. The location and orientation of the camera at the time each photo was taken need to be known. These are calculated using reference points. Reference points are measuring points with known 3D coordinates. The coordinates are usually measured using conventional techniques. These points are also used to give the model its proper scale en orientation. Because all values used are measurements, the lines will not exactly intersect, so it is not possible to find an exact solution for the location of point A. So, the complete system of coordinates of measuring points and camera locations and orientations must be numerically optimised using the least squares method. The result of this process is the most accurate set 3D coordinates of the measuring points. This way complete objects are reconstructed using multiple photos and multiple measuring points.

Reconstruction of The "7 Provinciën" with Photoship

To prove the potential of PhotoShip and the practical feasibility of photogrammetry as a method for reconstruction, the "7 Provinciën" was reconstructed. This ship (fig 3) is a replica of the original that was built in 1665, measures (LxBxH) 46.14x12.14x4.74 m, and is still under construction at the Bataviawerf (Lelystad, Holland). More info on the ship itself can be found on www.bataviawerf.nl. The circumstances regarding reconstruction were less than ideal, because of all the scaffolding blocking the view. To test on symmetry of the hull, both starboard and portside were reconstructed separately.

Fig. 3. **The "7 Provinciën" under construction**

The sequence of actions in this process was as follows:

Data acquisition

1. Placing landmarks as reference points and obtain their world coordinates, fig 4.
   Three perpendiculars, all with three landmarks, were hanged up near the side of the ship. The 3D coordinates of the landmarks were determined using conventional measuring techniques. The coordinate system in which these coordinates are given, is the same system, in which the coordinates of the measuring points will be given. A minimum of four reference points is required.

***Fig.4.* Placing landmarks as reference points**

2. Placing landmarks on the ship to mark the measuring points, fig 5.
   Markings were placed on the hull surface by attaching discs (5 cm diameter), with the help of scaffolding and a crane. The number of landmarks required depends on the size and geometry of the ship. For this project, a total of over 600 landmarks were used. In addition to the artificial markers, naturally distinguishable points such as corners or visible intersections of seams between hull planking were used as well.

Fig.5. Placing landmarks as measuring points

3. Taking photos from different positions, fig 6.
   Each landmark has to be depicted on at least two photos. The photos were taken with a digital metric camera. Such a camera has little lens deviations and is calibrated, so that deviations can be corrected for. Using a non-metric camera (digital or film) is also possible, but results will be less accurate. An excess of photos was taken, so that later on in the process the most appropriate ones could be selected.

***Fig.6.* Taking photos**

Processing the measured data

1. Reading in the measured data.
   The best photos were selected and read into PhotoShip. Because photographing was difficult due to the scaffolding surrounding the whole ship, a relatively large number of photos had to be used: 86 in total. The 3D coordinates of the reference points and camera parameters (focal length, dimensions of the CCD-chip and deviation parameters) were defined in PhotoShip.
2. Allocation of depictions of landmarks, fig 7.
   The user pointed out the depictions and subsequently the software calculated its coordinates in the on the photo and places a red circle on the spot. Using a dedicated algorithm, these coordinates were established very accurately.

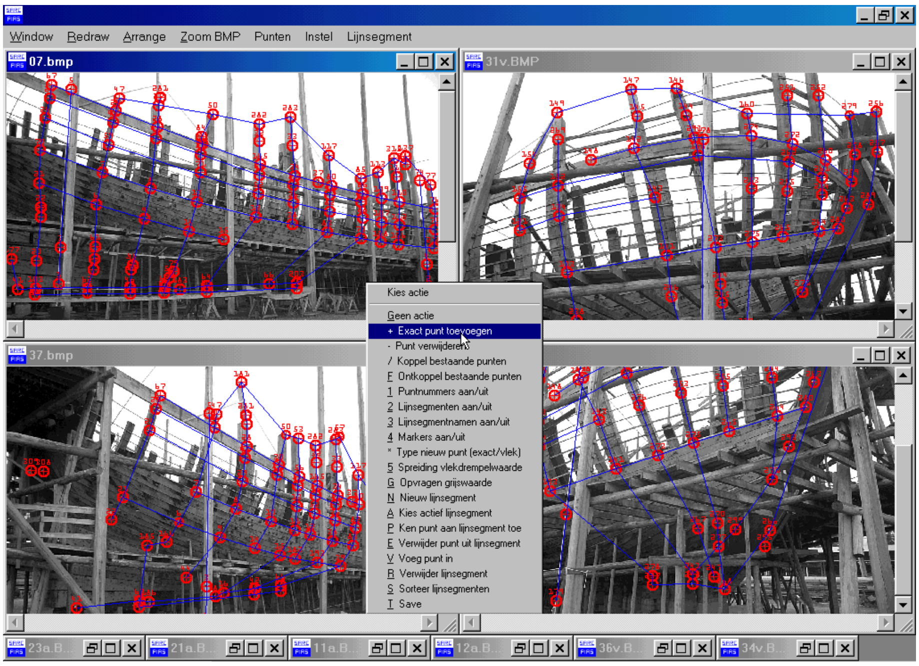

***Fig.7.* The main part of the PhotoShip user-interface**

3. Linking measuring points.
   Depictions of equal measuring points on different photos were identified by hand.
4. Defining the coherence between the measuring points.
   In conjunction with further processing of the model of the ship, measuring points were set in order by use of imaginary lines. This activity was also being performed by hand. The lines are shown in blue in figure 7.
5. Calculation of camera location and orientation.
   These calculations are made on basis of the reference points, with an algorithm based on conventional photogrammetric techniques [Ref. 2].
6. Calculation of 3D coordinates of measuring points with the least squares method.
7. Conversion of the wireframe into a solid model by PIAS-To_Fair.
8. Import of the solid model in Fairway [Ref. 1].

Final processing
After completing these steps, final processing in Fairway could begin. At first there was only the rough model, without a proper deckline (yet to be constructed) and with still undulating lines (because knuckles were not yet defined), fig 8. After final processing, chosen cross-sections were generated (fig. 9), and the model could be rendered (fig. 10). The result of this project is the linesplan shown in fig. 11.

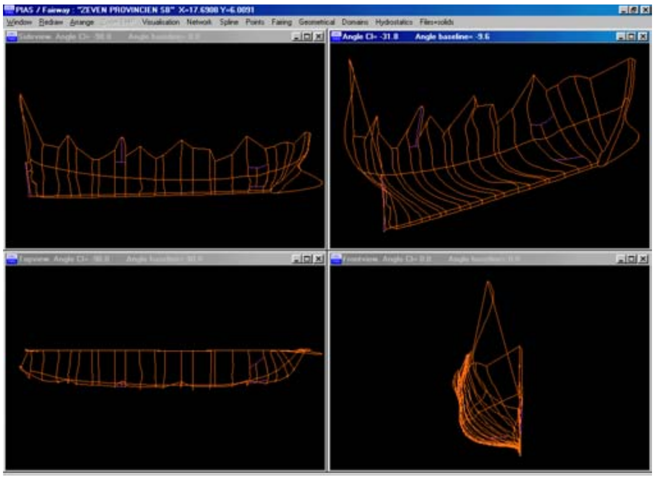

Fig.8. **Rough model of the "7 Provinciën" in Fairway**

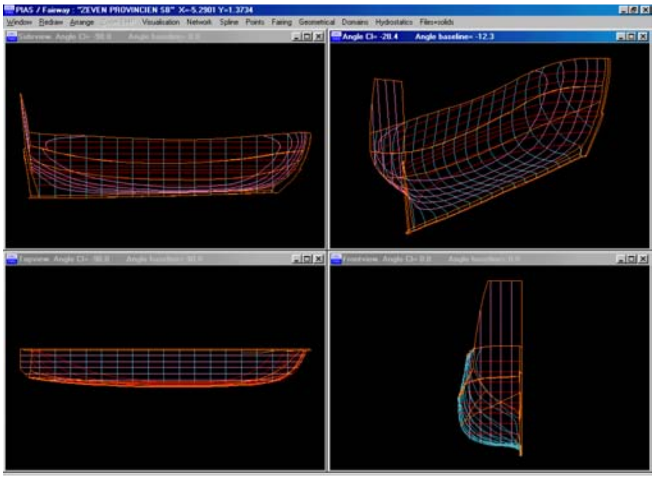

Fig.9. **Model of the" 7 Provinciën" after final processing**

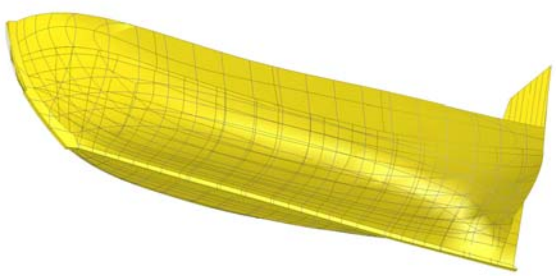

Fig.10. **Rendered model of the "7 Provinciën'**

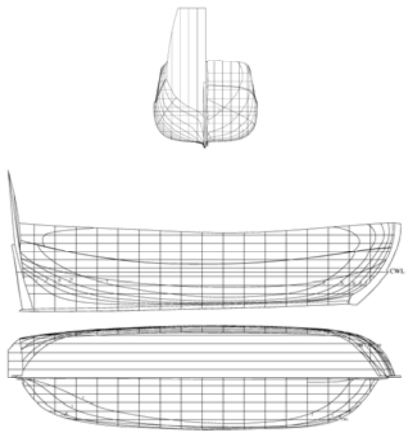

Fig.11. **Linesplan of the "7 Provinciën"**

References

[1] Soede, W.B., "Efficient design tools for complex shapes", Shipyard Technology News, April May 2002, pp. 34-35.

[2] Kraus, K., "Photogrammetry", Vol. 1, 2000, and Vol. 2, 1997.

About SARC: SARC is a Dutch consultancy and software house, which specialises in software for naval architectural calculations and hull design. The company's calculation software includes intact- and damage stability, probabilistic damage stability, speed and power predictions, and propeller calculations. SARC claims to have a unique approach to CAD software for ship hull design.