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Application of a photogrammetry-based system to measure and re-engineer ship hulls and ship parts: An industrial practices-based report

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ABSTRACT

In this paper, an industrial application of CAD is presented, which concerns the measurement and re-engineering of the shape of a complete ship hull and of ship's parts, which is a frequently recurring task in the shipbuilding and ship repair sector. In order to choose the most appropriate measurement method, several typical aspects of our object of measurement, such as its size, possible obstructions and poor accessibility, have to be taken into consideration, and we concluded that photogrammetry would be the most flexible method. One of the considerations in this respect was that with photogrammetry not only the 3D geometry can be measured, but that also topological properties will implicitly be taken into account, thanks to the fact that a human is interpreting and processing the photos. So a re-engineering system was developed, which consists of two major parts: the shape processing software and the photogrammetric measurement, which are tightly coupled. This system has proved to work fine for large-scale 3D objects, however, additionally, from the ship repair practice the question arose for the measurement of flat construction elements. For this purpose, an alternative and much simpler system was developed, strictly aimed at the measurement and further processing of flat steel parts.

For both methods, the practical applications and best practices are presented and discussed, and a tentative economical evaluation has been composed which shows that the proposed method is cost-effective. Finally, the general conclusion is drawn that the proposed photogrammetry-based system is quite versatile and applicable, although there are also points of concern or attention, such as the required space around the object, the aspect of sufficient light and visibility, camera calibration and the required skills of the users. The proposed method could benefit from further research in areas such as the optimal placement of a minimum number of landmarks and integration of laser-sensing and photogrammetry.

1. Introduction

Our company, a consultancy and software manufacturer for the maritime industry, is involved in ship design and engineering. For this purpose we have developed, and are intensively using, software for the modeling of the shape of the hull. Although this software was intended and is used for design activities, there is also a demand for alternative use, which is shape reverse engineering (re-engineering). Re-engineering may be required when no product information exists (anymore) or when such information is considered to be unreliable. Typical applications are, for example, post-building shape verification, shape retrieval for damage repairs, safety assessment (stability, strength) of ill-documented vessels and interior refurbishment.

For such purposes, conventional manual measurements are time-consuming, in the first place because the object may be rather large and may have a complicated freeform shape, and, secondly, because creating a virtual model out of the measured 3D coordinates is, in general, not a trivial task. So we have been looking for a more efficient measurement method, which is preferably integrated with, or at least linked to, a data processing and modeling tool. Although shape measurement and shape modeling methods are available in large varieties, there are some typical aspects of our application domain.

The first issue is the morphology of the shape, which may consist of a mixture of flat and curved regions, and may include sharp or gradual transitions between those regions. This aspect requires particular modeling capabilities, and if the object is also concave, not all measurement technologies are applicable. Secondly, the large size, with objects possibly larger than 200 m, may exceed some measurement limits, as well as environmental constraints or effects. A required accuracy of one millimeter is as such not extreme, but in relation to the object size it is also not trivial.

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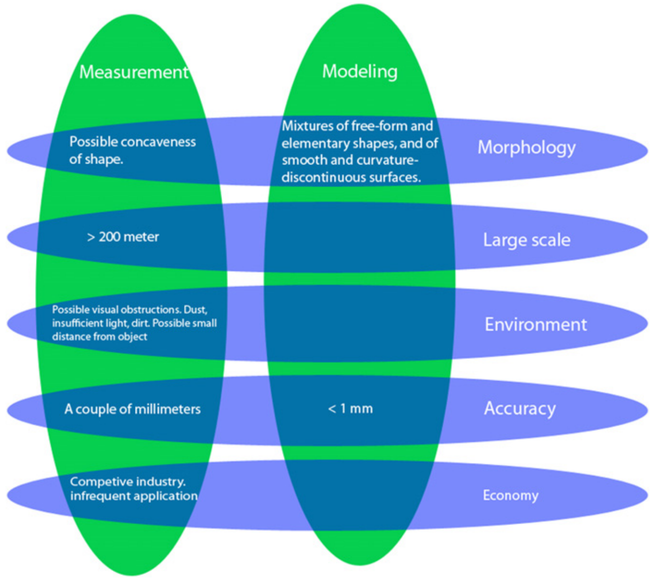

Fig. 1. Critical issues of ship hull re-engineering.

Finally, there are some economical issues, such as the competitive nature and fragmented structure of the naval industry, which inhibit expensive solutions. These aspects are depicted in Fig. 1, which expresses the idea of merging measurement and modeling, a trend which was signalled in e.g. [1]. In general, there will exist dimension-dependent relationships between the different entities in this figure. A large-scale object, for example, will in general result in a lower absolute accuracy, while a complex morphology may affect the accuracy, and will certainly have its effects on the economy. For this reason some reference properties or target values which are typical for our objects of measurement have been inserted in Fig. 1. The different element in the figure will be further discussed in Section 2.3.

For the measurement of a large-scale object, such as a ship, four methods are applicable:

- Conventional manual measurement, with measurement tape or a laser distance meter. This method is rather flexible, it does not rely on expensive equipment or special skills, but is not very efficient. Furthermore, the size of an object which can be measured accurately is limited to an order of magnitude of tens of meters.
- With a mechanical device, also called a *contact scanner* or a *coordinate measuring machine*. An example of an apparatus intended to measure yachts, is a 2D triangulation device where a rod is attached to two running wires, and on the basis of the lengths of the two wires by means of triangulation the 2D coordinates of the end of the rod can be derived. The advantages of this method are its modest costs and the fact that measured coordinates are directly available in electronic form. The disadvantages are its 2D nature, as well as the limited size of objects (which in case of the 2D device can more or less be as large as the rod).
- With laser scanning, which functions on the basis of the time delay of a radiated and captured laser beam, which scans the environment in a high density.
- With photogrammetry, a method which for many decades has been applied in areal surveying and architecture, but which finds application in many fields where it is required to determine the spatial shape of an existing object. Photogrammetry belongs to the category of image-based modeling, a group to which also belong some more exotic technologies, such as *shape from shading*, *shape from silhouette* and *shape from texture*.

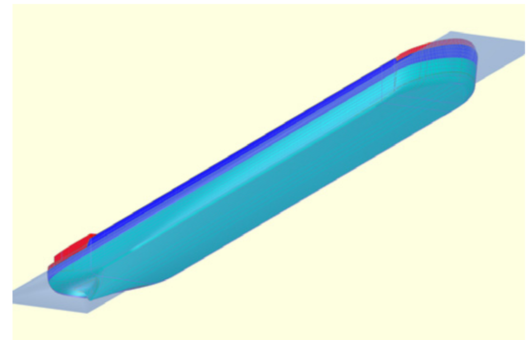

Fig. 2. Quite simple inland waterway vessel.

Summarized, with photogrammetry multiple photos of an object are made, and subsequently identical points of the object are identified on different photos, thus leading to a solvable system of equations.

The basic claim in this paper is the viability of an integrated measurement-modeling system for the re-engineering of large objects such as ships, in conditions as encountered in practice. The research goals of this paper are:

- Propose a framework which assists in the selection of the most appropriate measurement technology;
- select measurement and modeling technologies, and merge them into one combined re-engineering tool;
- evaluate practical experiences, reflect on the proposed methods, and conclude upon the applicability of the proposed method.

The structure of this paper is as follows: in Section 2 the related work on ship hull modeling as well as on measurement technologies are discussed, while at the end a number of open issues are addressed. In Section 3 our re-engineering method is presented and in Section 4 the application in practice is discussed. Finally, a qualitative validation is made, limits and constraints are discussed, suggestions for further research are made and the conclusion is drawn.

2. Related work

2.1. Ship hull shape modeling

In some respects the shape of the hull of a ship is hard to qualify. Some authors have proposed a taxonomy of shapes and singularities, e.g. [2], where first-order discontinuities as spikes and crests play a role in the division of a surface in more or less distinct regions. Although ships may also have knuckles, or regions of sudden change of curvature, *in general*, they tend to be rather smooth, see Fig. 2 for a simple example. However, the hull surface is strictly not free-form, in general the fore and aft regions are smoothly curved, but in the middle part the side and bottom of the vessel are exactly flat, with a cylindrical circular arc in between. Such a feature is quite common in our profession, but of course also more complex shapes can be encountered, as shown in Figs. 3 and 4.

For the representation and design of ship hulls, a number of methods has been proposed and applied, which can be categorized as *wireframe*, *curved polygon*, *parametric surface* and *hybrid* methods. The *wireframe* modeling method has been applied for applications where a complete hull surface model is not required, e.g. in the field of the analysis of technical properties of a ship, such as stability or seakeeping behaviour. In the method as proposed by [3], surface patches are defined on the wireframe to extend it to a polyhedral representation. This may be considered as one of the first implementations of a hybrid representation system.