Experienced Marine Design and Data Use

A White Paper

Process, Power & Marine, a division of Intergraph

Table of Contents

1. Executive Summary

Numerous studies have determined that one of the major factors affecting global competitiveness in the marine industry is the ability of an organization to incorporate past experience into future products. Several terms are used to refer to this practice, such as “data reuse” or “experienced ship design.” Regardless of the terminology, the need to adapt past designs to new or changing market demands is paramount to winning new business and delivering quality products on time and within budget.

Data reuse can take many shapes and forms, beginning with basic capabilities in the areas of standardization of individual piece parts, uniformity of parts within an assembly, or symmetrical design consistency about the vessel’s centerline. More advanced design reuse capabilities are possible by extending this concept from “geometric” to “topological” similarity, where some aspect of the design basis is adaptively reapplied from one region of the vessel to another. The authors have been involved with the definition, development, and implementation of functionality in this area for more than three years. This paper presents an overview of the major functional areas that can benefit from this capability; compare and contrast the various technical solutions that have been implemented to address these requirements; and discuss in detail the power, flexibility, and potential of a highly advanced “Copy” functionality for similar structures.

2. Introduction

Data reuse and design reuse are terms that are often used interchangeably. While both are used for marine design and shipbuilding, they are, in fact, different concepts. In this paper, the scope of the analysis is the comparison of data reuse and design reuse for computer-aided design/computer-aided manufacturing (CAD/CAM) in the marine industry. After briefly discussing the differences between data reuse and design reuse and the means to achieve these in the CAD/CAM area, this paper will review in detail the concept and implementation of Copy Similar in SmartMarine™ 3D. We will also discuss how it is tied to a general concept of symmetry of engineering problems. Finally, we will briefly review some examples of the application of Copy Similar to design reuse in shipbuilding and offshore.

3. Data Reuse

In all industrial shipyards, electronic data reuse is now common at every step of the design and construction of a ship. This central concept allows shipyards to construct ships efficiently and manage the huge amount of data needed to build ships with a reasonable number of people and at an acceptable rate of error, while the complexity and sophistication of vessels being constructed increases. For example, reusing 3D data from multiple disciplines enables the building of ships directly from computerized designs without creating physical mock-ups. Some examples of electronic data reuse are:

- Use of a single database containing the design from all disciplines
- Transferring CAD files within or between tools using either the native file format or an industry-standard format such as STEP
- Automatic extraction of deliverables (such as drawings and bills of materials) from the models

This list by no means represents the complete scope of data reuse within CAD projects. Polini (2007) discusses an interesting application of integrated data reuse in the context of globally distributed design and data warehousing within the shipbuilding industry.

A few of the many key advantages of data reuse are:

- Reduction of errors
- Reduction of labor-hours
- Easier management of changes

4. Design Reuse

There is a fundamental difference between the design itself and the data resulting from the design. From an engineering perspective, a design is the application of the engineer's art to a particular engineering problem, the result of which might be an electronic mock-up. From a business perspective, the design is the intellectual property (IP) generated by the designers in the company, and thus its competitive advantage. While the ship is the property of the owner, the design usually remains the property of the yard or design office. The owner is handed a vast amount of data – paper or electronic drawings – but usually not the design knowledge itself (the thought process, rule application, trade-off analysis, and design decisions). That remains the IP of the company that created it.

Old-generation CAD tools are modeling tools that allow only a description of the geometrical and non-geometrical properties of the final product in 2D or 3D. In other words, the CAD database contains only data, not design information. However, the most modern product modeling (i.e. new CAD) tools embed more and more of the design intent within the database. The low-level details that can be inferred from the design are automatically computed by the software, making design changes considerably more efficient. This evolution has allowed designers to express their intent with a higher level of abstraction, thereby working faster and concentrating on the more creative tasks involved in the design process. It is, however, still a challenge to reuse the design to generate new projects or speed up the design process.

Design reuse is applicable between projects or within a project. The condition needed to reuse designs is that the same engineering problem occurs multiple times. The application of the same design may result in a different detailed model, since the boundary conditions may be different.

The advantage of reusing a design translates into a major competitive advantage for the companies that are the most efficient at doing so. Benefits include:

- Standardization of design and construction planning
- Save skilled engineering and construction planning
- Faster design-cycle time
- Shorter time to market
- Early material estimates and deliverables
- Reduced risk
- Commercial proposals based on accurate cost and schedule information

Given the different nature of data and design reuse, the latter is usually more difficult to achieve and requires the use of a state-of-the-art product modeling or CAD system.

4.1 Known Approaches to Design Reuse

Several design reuse tools are already available to engineers. The following sections provide some examples of interest.

4.1.1 Rule-based Design and Automation

Several CAD systems allow each company to encode its specific design process directly into the software. Rule-based design can be used to generate the detailed model from the high-level design using the standards of a company, as Cochran (2007) illustrates. It can also be used to generate an initial design from a high-level set of requirements. This is different from a command replay system or macro language that speeds up the data input, but still requires the designer to apply the correct feature and manage changes manually.

4.1.2 Copy Similar/Copy from Catalog

Most state-of the-art CAD software allows creation of high-level design entities, storing them in a catalog and reusing them in a single model or across multiple models. This approach can be refined and sophistication added (Hiraki and Sonda, 2005).

The focus of the paper now turns to Copy Similar and its application to design reuse.

5. Copy Similar

As mentioned earlier, a prerequisite to reuse of a design is that the same engineering problem occurs multiple times, either between projects or within a project. This idea, very common in many scientific fields (such as math, physics, and engineering), is formalized using the more general concept of symmetry.

A definition of symmetry with respect to an operation is invariance by the given operation. In other words, when the operation is applied to the object, the object does not appear to be changed. While there are a vast number of symmetry operations that can be considered in general, the relevant ones in the marine world are the standard geometrical transformation – identity, mirror, translate, and rotate – but also more abstracted topological transformation that we will describe in more detail later.

The Copy Similar feature implemented in SmartMarine 3D allows the user to specify the symmetry of the engineering problem. From this high-level description of the symmetry of the problem, the software allows the user to design once, and reuse the design after the application of a transformation. It also allows controlled propagation and management of change between the instances of a similar design, as well as controlled management of the differences between the instances of a similar design.

5.1 Copy Similar Detail

We have seen that symmetry management is the fundamental concept that allows design reuse. CAD software that intends to provide some design reuse capability therefore needs to be a powerful tool to manage symmetry.

Copy Similar currently supports two types of symmetry operations (also referred to as “transformation”):

- A mirror operation whose application to shipbuilding is obvious
- Topological transformation of frames

Following are examples of topological transformation:

<table>
<tr><td>Frame x</td><td rowspan="3">Transformation</td><td>Frame u</td></tr>
<tr><td>Frame y</td><td>Frame v</td></tr>
<tr><td>Frame …</td><td>Frame …</td></tr>
</table>

This topological transformation of frames is a very powerful means of defining simple geometrical transformation such as translation, rotation, and a combination of translation and rotation, but also more complex non-linear transformation such as this:

F121		F151
F122	Transformation	F155
F123		F156

5.2 Family of Similar Groups

Group and family are the high-level concepts exposed to the user to define symmetry within a product model. The user defines a family of similar frames to define what structural objects are similar, and to maintain similarity relationships between the objects. See Figure 1.

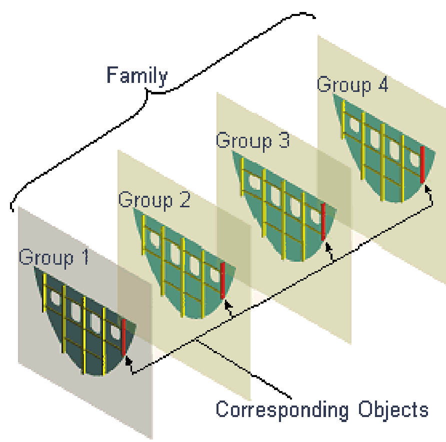

Figure 1: *This user can define a family of frames in a single- frame group.*

The definition of a group is not limited to a single frame; thus, a group can be made of multiple frames or frame systems. See Figure 2.

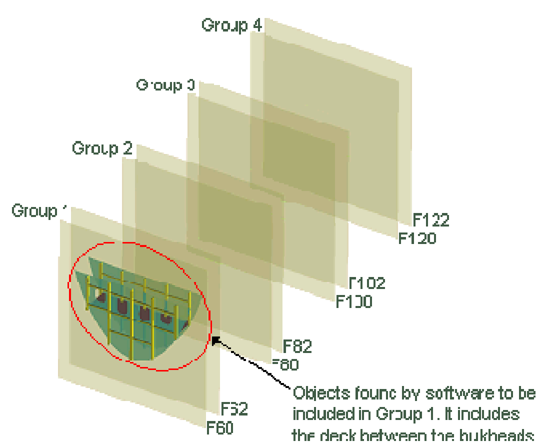

Figure 2: *The user can define a multi-frame group.*

The behavior of similar groups can be further specified. The following types are relevant and easily controlled through the user interface. See Figure 3.

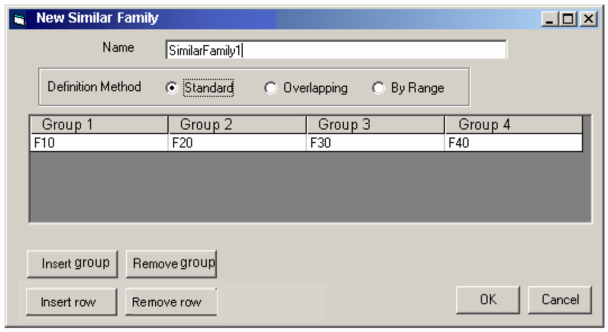

Figure 3: *This image illustrates a copy behavior interface.*

5.2.1 Standard/Overlapping

The overlapping family ignores the structure that overlaps from one group to the next. For example, in the Standard case where F60-F61 is similar to F61-F62, a transverse bulkhead could be at the end of the F60-F61 range, but would also be at the beginning of the F61-F62 range. The Overlapping option prevents the F61 bulkhead from being created twice.

The concept of group and family is dynamic, and families and groups can be created, deleted, and modified at any time during the design process to suit the user's intentions. It is important to note that groups and families can be defined after the model has been created. This enables a flexible reconfiguration of the system to propagate design changes effectively late in the design process.

Two groups of the same family need to be topologically identical, but do not need to be geometrically identical. Therefore, a family can be created with group F60-F61 similar to group F80-F85.

5.2.2 Mirror

Symmetry by a mirror plane is very important for many engineering problems. SmartMarine 3D's implementation of Copy Similar allows the user to define a family of type mirror. In SmartMarine 3D, port and starboard symmetry, sometimes referred to as "copy mirror" or "copy symmetry," is handled as one or several families of similar items.

6. Operation on Groups

Once a family and group are specified, several operations are available to perform on the groups belonging to the family. When group operations are introduced, the notion of source and target need to be introduced as well. There is always a single source group, but there can be one or several target groups. It is important to note that the source and target groups are dynamically defined by the user for a given operation, and are not embedded in the family definition. SmartMarine 3D supports four operations on groups:

- Find
- Copy
- Modify
- Delete

6.1 Find Operation (Similar Item Identification)

The Find operation explores the source group and the target group, and similar relationships are created between similar items (systems, parts, features, welds, etc.). The identification of similar items is primarily based on the topology of the groups. Geometrical transformation, as well as user override, can be used to make clear the topology in complex cases, or where it is necessary to customize the behavior. The similar item hierarchies are exposed to the user graphically (graphic view) or logically (tree view).

The Find operation makes it possible to configure or reconfigure the families and groups at any time during the design. When a family of similar groups is defined, the software identifies all similar items between these groups.

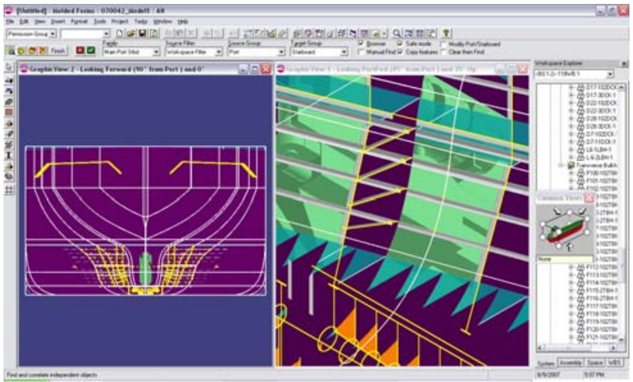

Figure 4: *The Find operation allows the user to configure or reconfigure families and groups.*

6.2 Copy Operation

The Copy operation explores all the objects present in the source group, and copies those that do not have similar items in the target group over to that group. The system establishes a similar relationship between the source item and the target item.

6.3 Modify Operation

The Modify operation explores all similar items. Objects that are different between the source and target are exposed to the user. The user can then propagate the properties of the source objects to the similar target objects. The system considers the difference in the design characteristic of the objects, as well as the attribution differences. (The geometrical differences are irrelevant.) The user can specify whether the target object should be updated to match the source object, or if the difference is intentional and should be retained. The system automatically updates the target objects.

6.4 Delete Operation

The Delete operation deletes all items that are present in the target group and not in the source group. As with the other operations, the user can decide to override the delete that the system proposes.

6.5 Copy Similar and CAD Data Model

This type of approach can be implemented only if the CAD data model embeds the designer's intent in the model.

In order to generate the correct model in a similar group, the data model needs to capture the topological relationship between the entities, and then needs to compute the adequate geometry of the group from the topological entities. The topological relationships are not limited to the bounding relationships, but also include the interdependencies between high-level design entities (such as plate system) and lower-level design entities (such as part).

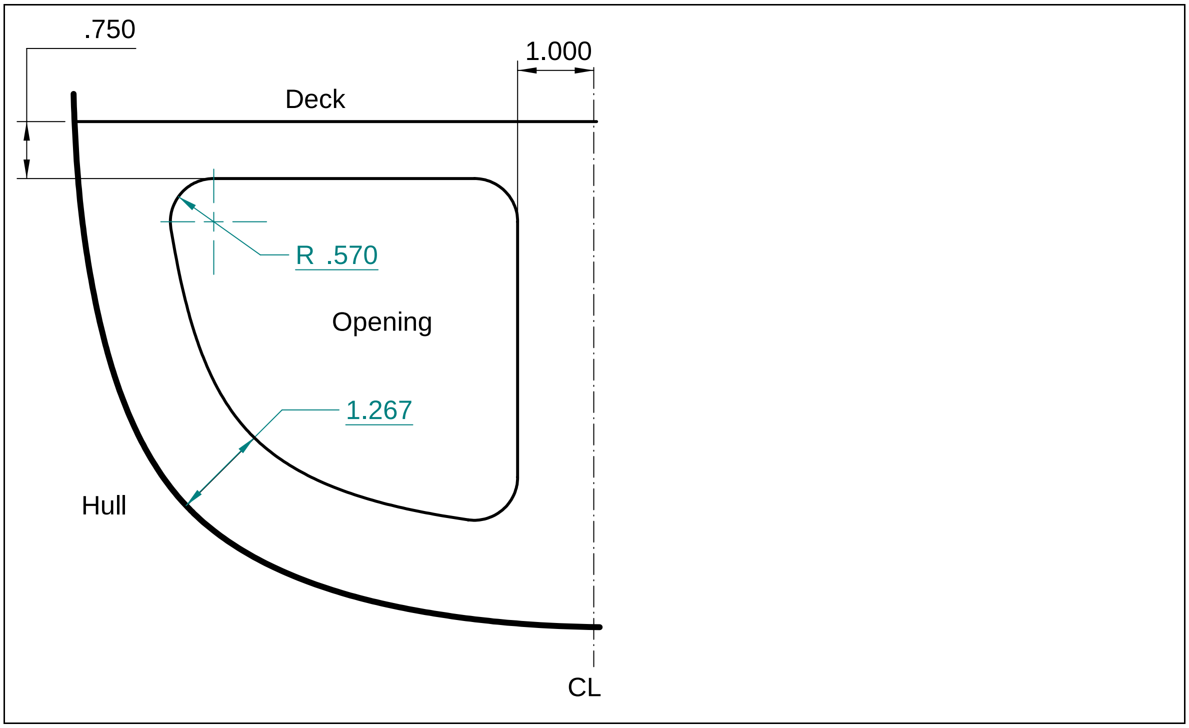

Figure 5: *Geometrical dimensions are needed to capture the design in the model and reapply it on similar groups.*

While topological relationships are necessary, they are not sufficient to accurately reuse the design from one group to the other. For some type of objects (such as opening, plate unsupported or “free edges”) there are typically multiple solutions that fulfill the topological constraints. Geometrical dimensions are then needed to capture the design in the model and re-apply it on similar groups, as shown in Figure 5. SmartMarine 3D allows the user to capture geometrical dimensions and reapply them on similar groups. When no dimension is provided, the system applies a default transformation (such as a mirror transformation for port and starboard similar groups).

7. Copy Similar Application

This section reviews some typical applications of Copy Similar as implemented in SmartMarine 3D. We will not go deeply into the detailed design issues; instead, the intent is to provide an overview of what can be done in the context of various classes of vessels.

7.1 Monohull

A commercial ship presents many intrinsic symmetry operations. The relevant symmetries strongly depend on the type of ship being considered; however, this paper does not address that level of detail. The most obvious symmetry is the port and starboard mirror plane going through the centerline. There are, however, many more symmetries. The inner bottom, as well as the cargo hold, tanks, engine room, and other areas present many instances of symmetry that can be exploited.

Copy similar allows the user to define many families, including overlapping families. In Figure 6, the centerline mirror overlaps all other families defined. Figure 6 also contains a list of the translation transformation symmetry families (Copy Similar), as well as the single mirror transformation family (copy symmetry). The Copy Similar families each contain a portion of the design that is repeated along the length of the ship.

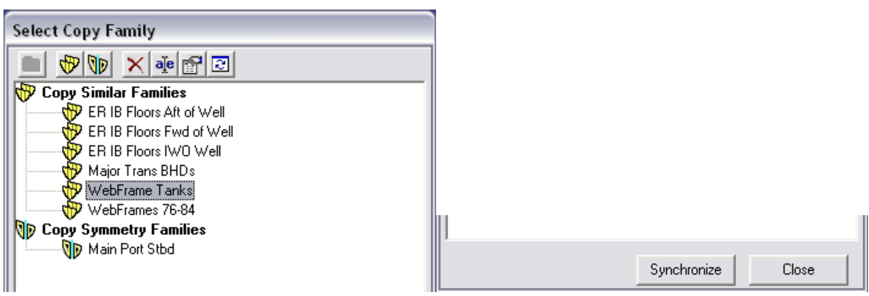

Figure 6: *This image shows an example of Copy Similar translation families.*

Figure 7 provides an example definition of the "Webframe Tanks" family. The definition states there is similar structure between groups of frames 76-84, 86-94, 96-104, and so on. The Webframe family overlaps with the "Main Port Stbd" family in the sense that the Web frames exist along the longitudinal axis, as well as on both sides of the centerline. Therefore, the software must be careful not to create duplicate Web frames.

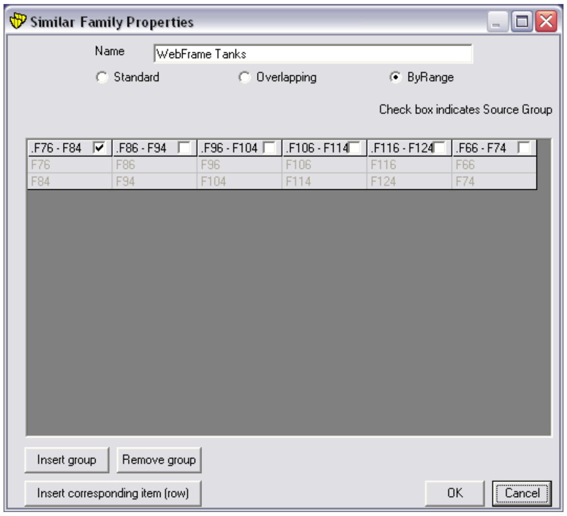

Figure 7: *This figure illustrates a single Web frame group definition.*

Figure 8 illustrates the design for the major transverse bulkheads and frames, and Figure 9 shows the design of the engine room inner bottom structure.

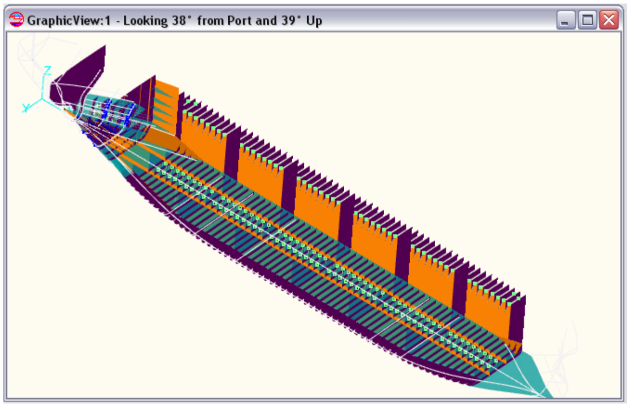

Figure 8: *This image shows the design for the major transverse bulkheads and Web frames.*

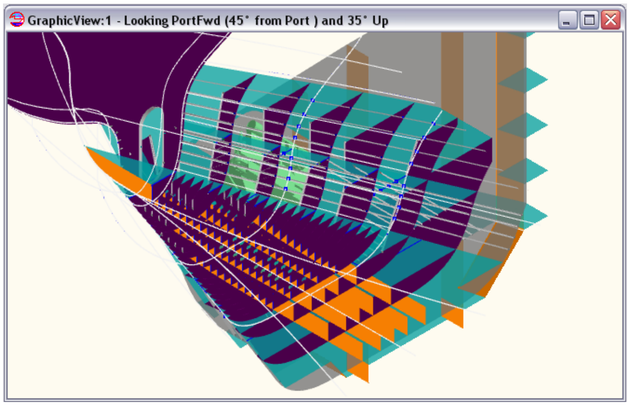

Figure 9*: This image depicts an engine room inner bottom group definition.*

7.2 Other Marine Structure

Other types of marine structures, such as multi-hull systems (for example, catamarans, SWATHs, and semi-submersibles), present different symmetry characteristics that can be exploited by Copy Similar. In the SWATH example in Figure 10, there are several mirror planes that can be used.

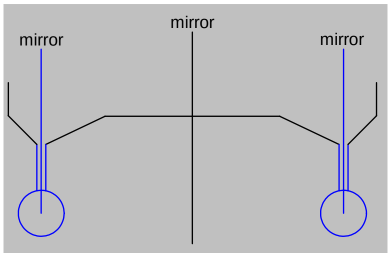

Figure 10: *This image illustrates SWATH symmetry planes.*

A cell spar is another example of an offshore marine structure that will present very different symmetry characteristics from those of a ship. The example below is a cell spar made of seven spar tubes. For such a system, it is common practice to define a cylindrical coordinate system for each tube. The frame system is made of standard frames along the Z-axis, and radial frames as well as cylindrical frames. Each tube can be obtained by a topological transformation of these frames. Furthermore, the system has many mirror symmetry planes that are useful to model the structure connecting the tubes, as well as the mooring deck and the top side. See Figure 11.

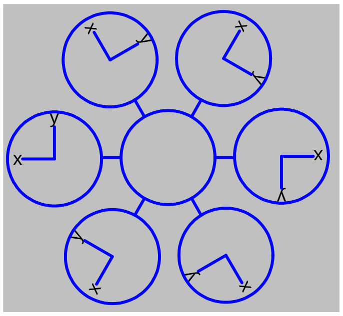

Figure 11: *SPAR symmetrical planes are different from those associated with a ship.*

Designing the legs of a “jackup” type marine platform presents the same type of symmetry as the cell spar, while the top side will be more like a ship. The structure connecting the legs to the topside will be an area of transition where several types of symmetry can be used. See Figure 12.

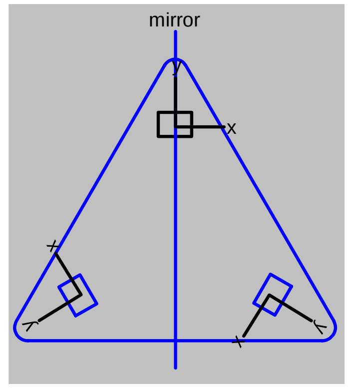

Figure 12: *Jackup symmetrical planes present the same type of symmetry as cell spars.*

An offshore semi-submersible vessel, as shown in Figure 13, offers the potential to take advantage of several Copy Similar operations. The fore and aft columns are similar by region, while all three columns and the pontoon structure are similar by mirror about the centerline plane. See Figure 13.

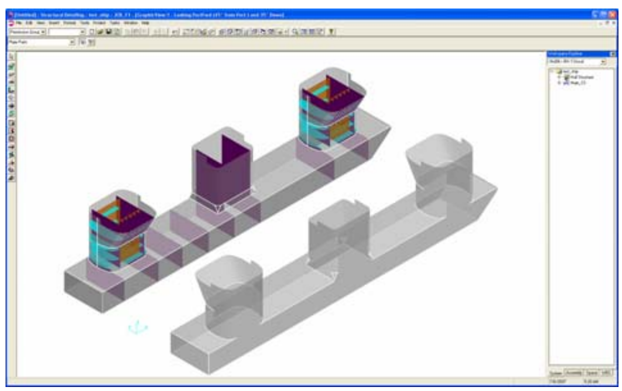

Figure 13: *An offshore semi-submersible vessel can take advantage of several Copy Similar operations.*

8. Modular Design

The ultimate goal is to support a completely modular design system based on Copy Similar, where complete modules from experienced design can be brought together into a new design. See Figure 14.

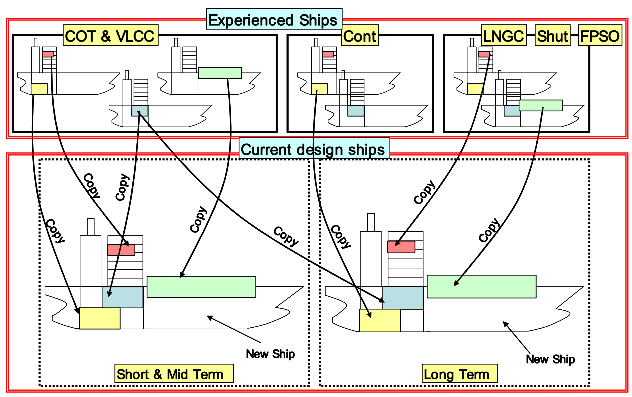

Figure 14: *The illustration represents the ideal data reuse vision.*

9. Conclusion

Modern state-of-the-art product modeling and CAD systems embed a high-level, abstract definition of the design that not only captures the geometric result, but the design intent. When this feature is combined with powerful tools to describe the symmetry of the product model, it results in and permits reuse of the design within the model. This process can result in a marked benefit to the enterprise or organization through improved efficiency and effective use of resources. Properly applied efficiencies gained can result in significant competitive advantage.

10. Authors' Biographies

Yann Limon Duparcmeur is currently Vice President of Development for Marine and Structure at Intergraph Corporation, Process, Power & Marine (PP&M). He is responsible for all development related to structural functions and features across marine and plant applications. He leads a globally distributed development organization composed of teams in France, the United States, and India. He resides in Hampton, Virginia.

Robert Patience is the Founder and Principle Technologist for Engineering Knowledge Models Pty Ltd., AU. He is responsible for the design and implementation of the Copy Similar/Mirror functionality in SmartMarine 3D. Previously, as Vice President for Product Development for Intergraph Corporation, he led the development of several relational-based shipbuilding and process plant software systems.

Jim Butler is currently a Senior Consultant at Intergraph Corporation. He is responsible for the collection and analysis of use cases depicting users' requirements from a functional and business perspective, and synthesizing these into concept documents and specifications to support the software development and certification process. He holds a B.S.E and M.S.E. in Naval Architecture and Marine Engineering from the University of Michigan.

11. References

Cochran, K. “Rule-based Product Development.” *ICCAS* 2007, Sept. 2007.

Hiraki, Tokimasa and Masahiro Sonda, “Study on Advanced Hull Designing Systems based on Structural Pattern Concepts,” *ICCAS* 2005.

Polini, M., “Integrated Product Development using Global Workshare,” *ICCAS* 2007, Sept. 2007.

Headquarters
Intergraph Corporation
170 Graphics Drive
Madison, AL 35758

For more information about Intergraph, visit our Web site at www.intergraph.com.