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A New Approach to Robustly Exchange Models in Heterogeneous CAD/CAE Environment and its Application

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Abstract

The model exchange from CAD system to CAE system in valid and effective manner is the major issue of automatic analysis modelling of ship structure. However, model exchange approaches based on the neutral CAD file have resulted in invalid model exchange that could not properly reflect the characteristics of CAD model and CAE model of ship structure. This paper presents the new approach of n-to-n mapping to exchange ship structure model in heterogeneous CAD/CAE environments. In this study, the common model called 'unified ship model for analysis' to directly extract proper information from different CAD systems for ship structural analysis is proposed. Moreover, a command language based model interfacing technique to construct an idealized model for analysis job is also proposed. The proposed approach has been actually implemented in DSME CAD/CAE environment of ship structure such as TRIBON system, PATRAN system and FLUENT system. The applicability and effectiveness of the proposed approach was verified by applying it to the real analysis project for fore-body of ship and block lifting. This application results show that the proposed approach can be effectively used for heterogeneous CAD/CAE environment.

Keywords: heterogeneous CAD/CAE environment, common model, command language based modelling method, FEM modeling

1 Introduction

1.1 Backgraounds

Nowadays, as CAD systems have been fully used in the detail ship design process, sufficient CAD model information can be used in analysis modelling job. Therefore, there is a growing need to reduce the analysis modelling time using CAD model information.

2.2 Differences between CAD model and CAE model in detail ship design stage

There are some different model representations between CAD model and model for CAE in detail ship design stage.

Firstly, a topological difference can be thought. In general, CAD model is defined as a solid model with thickness, while CAE model is defined as a surface model because of using shell elements in the analysis job. Figure. 1 shows the topological difference between CAD model and model for CAE.

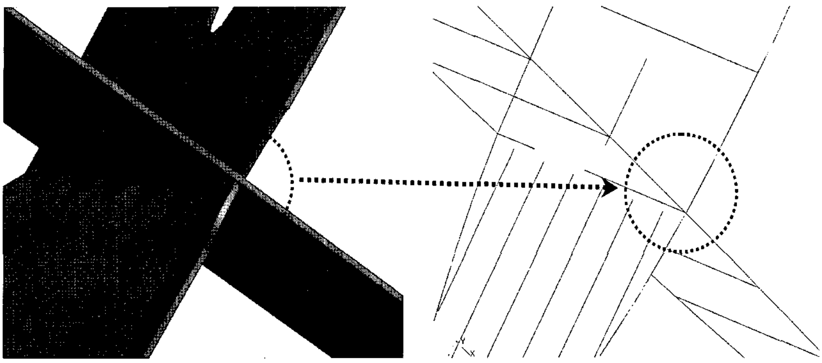


Figure 1: Topological difference between CAD model and model for analysis in detail design stage

Secondly, there is the difference of the level of detail between CAD model and model for CAE. Because CAD model represents all detailed features of product such as small holes, small brackets, notches, and so on. These detailed features, which are very small as compared with the size of mesh, hardly affect an analysis result and make the whole mesh quality lower. Therefore, these small parts must be ignored in model for CAE to perform analysis job in robust and fast manner. Figure. 2 shows the difference between CAD model and simplified model for analysis. It can be showed that CAD model has small brackets, small holes and notches, while these features are ignored in simplified model for analysis. Solving this problem is called as "idealization"

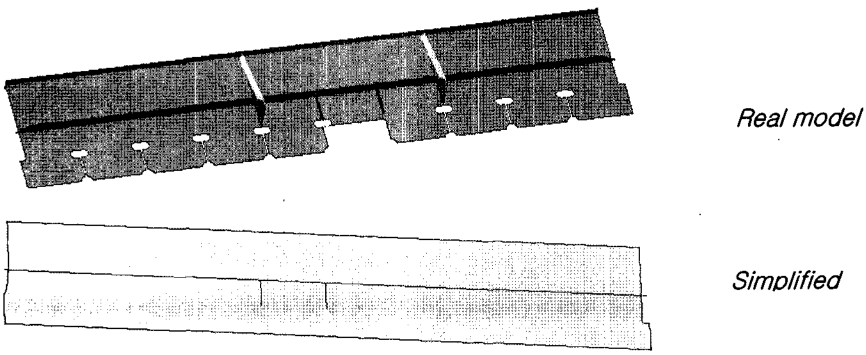


Figure 2: Difference in detail between CAD model and simplified model for analysis

2 Related works

Recently, Many approaches to make analysis model from CAD model have been energetically studied in shipbuilding industry. These have mainly focused on the automatic generation of mesh model for analysis using the geometry information of CAD model. But owing to the differences of model characteristics, it actually spends almost the whole times not in generating mesh model but retouching the model from CAD system to make it suitable for analysis job. So, exchanging model information between CAD system and CAE system in a suitable form has been the main issue of the field of analysis automation. There are several techniques to address this issue. These techniques can be classified into four major approaches such as Translation & Healing, Discrete Representations Technique, Direct Geometry Access and Unified Topology Accessing Geometry.

Translation & Healing approach has historically been the most commonly used techniques. It has two phases. One is the translation phase to transfer the geometry information of CAD model to CAE system and the other is the healing phase to heal the transferred geometry for analysis job. Recently, many researches have evolved to attempt address the issues of Translation & Healing, but this approach is still not reliable or robust because of the differences in algorithms and tolerances between modelling engines.

Discrete Representations technique is based on the generation of a faceted model by CAD system and accessing the resulting faceted model for mesh generation. This is commonly done based on simple facets generated by CAD system faceter but may also use subdivision surface or higher order triangular patches. This technique has several drawbacks to lose the outer boundary information and the relationships between objects.

Direct Geometry Access is a technique that is growing in popularity based on accessing CAD geometry directly through CAD system toolkit such as CATIA CAA and Pro/Toolkit. Since many CAD systems use geometric modelling kernels, this approach can also be achieved by using the same geometric modelling kernel as the CAD system and accessing the geometry through the modelling kernel APIs. In this approach, some of the problems issued by the differences in algorithms and tolerances can be solved. However, it is hard to use multiple CAD parts in one system and it needs to develop the each CAE modeller for each CAD system because the CAE modeller is dependent on specific CAD system. Therefore, this approach is not suitable for exchanging models between heterogeneous CAD/CAE environments.

Unified Topology Accessing Geometry is a natural extension of the Direct Geometry Access technique with enhancements to overcome the shortfalls of that technique such as associated with multiple CAD sources etc. This technique proposed Unified Topology Model as common model to store model information from difference CAD systems.

3 Outline of work

In this study, the integrated framework, which can transfer model information from multiple CAD systems to multiple CAE systems, is proposed using Unified Ship Model for Analysis (USMA) and a command language based model interfacing technique. USMA is the common model for design and analysis of ship structure by applying the concept of Unified Topology Model for the analysis of general mechanical parts. The model information can be extracted and stored through a CAD system API. A common language based model interfacing technique can transfer model information between USMA and CAE system. This technique was made by adopting the concept of a macro parametric technique proposed by D.H. Moon et al. The overall configuration of proposed framework is shown in Figure. 3.

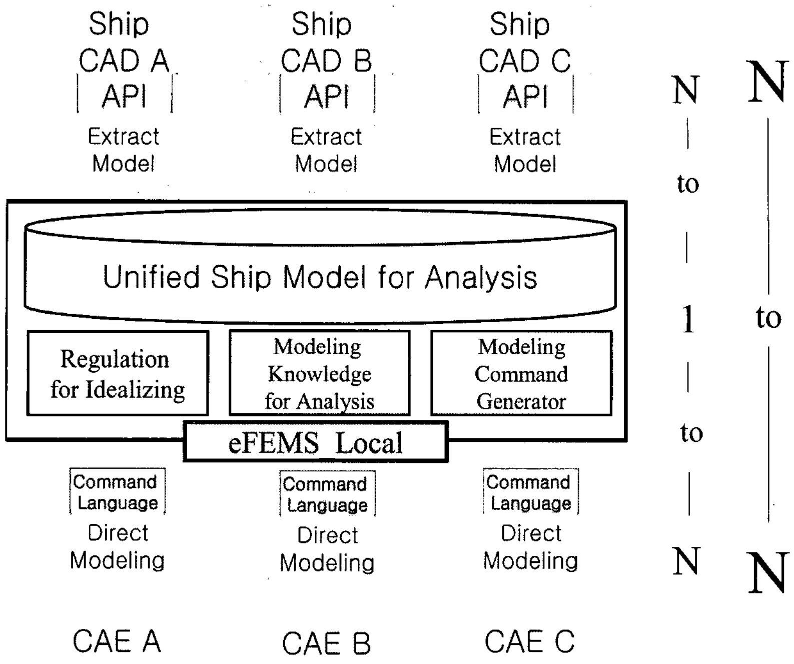


Figure3: The overall configuration of proposed framework.

The ship CAD model created by arbitrary CAD systems is stored in USMA and this stored model information is transferred to CAE system through a set of the modelling commands created by post-processor. The relationship between CAD systems and USMA is N - to - 1 and that between USMA and CAE systems is 1 - to - N. After all, the N – to – N relationship is made between CAD systems and CAE systems. For example, if one builds up one adaptor from one CAD system to USMA and one adaptor from USMA to one CAE system, this framework can be thought as one – to – one. However, if one builds up an additional adapter from USMA and other CAE system, this framework becomes one – to – two in a very short time. To be sure, opposite direction is same. If one builds up an additional adaptor from other CAD system to USMA, this framework becomes two – to – two.

4 Unified Ship Model for Analysis(USMA)

Tautges(Tautges T.J 2000) and Shepard(Shepard M.S. 2000) each proposed the Unified Topology Accessing Geometry in order to effectively use the geometry information of CAD model in CAE system. This has Unified Topology Model as the common model with non-manifold solid data structure for mesh generation. Figure 4 shows the configuration of the mesh generation tool using Unified Topology Accessing Geometry technique and its Unified Topology Model. With this concept and common model, they can effectively generate the mesh model for general mechanical parts.

Unified Topology Accessing Geometry technique can be applied to the case of the coincidence of topology information between CAD model and CAE model. However, in the case of ship structure at detail design stage, the topology of CAD model is different from that of CAE model. CAD model is the solid model with thickness, while CAE model is the surface model as shown in Figure 1. Besides, ship structure includes stiffeners and they are represented as line segments in CAE model. Consequently, there is big topology difference between CAD model and CAE model at detail ship design stage.

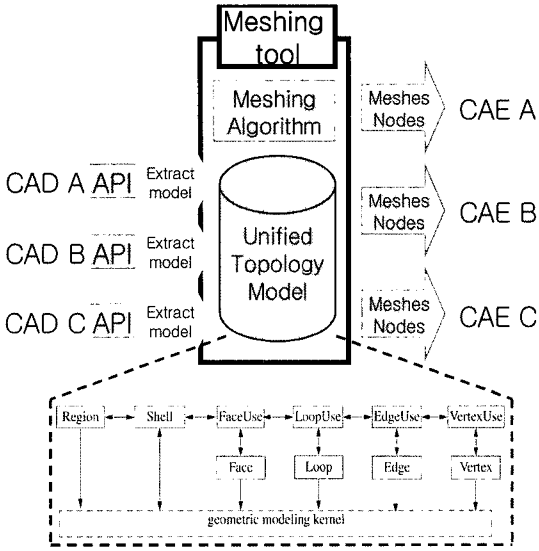


Figure 4: The configuration of the mesh generation tool with Unified Topology Accessing Geometry(upper region) and the data structure of Unified Topology Model(dashed box)

Because Unified Topology Model is the geometry model to effectively generate mesh, it is hard to handle the properties and the connecting relation of the parts of CAD model needed in analysis job. In order to effectively use CAD model information in analysis job, it is necessary to handle this information.

In this study, Unified Ship Model for Analysis (USMA) is proposed as a common model for the detail ship design and analysis by applying the concept of Unified Topology Model to it. Figure 5 shows the class diagram of USMA.

USMA is defined by referencing the data structure of TRIBON planar hull. This includes all of the information necessary for analysis job. This information can be directly acquired from CAD system. This is also designed as a convenient model for idealization with consideration on the characteristics of ship structure. The surface comprising the ship structure is classified into planar surface and curved surface. Each surface has an outer contour, inner contours and thickness information. Thickness information is defined as a property and an outer contour consists of several boundaries to have the relation to refer to other surfaces. Such relation between surfaces can maintain the connecting relation of meshes created on these surfaces. Each boundary is designed to have curve information as the set of segment objects or one spline object in order to cover the all of the boundary information from arbitrary CAD systems. Each surface is designed to have the trace curve and the profile information of stiffener.

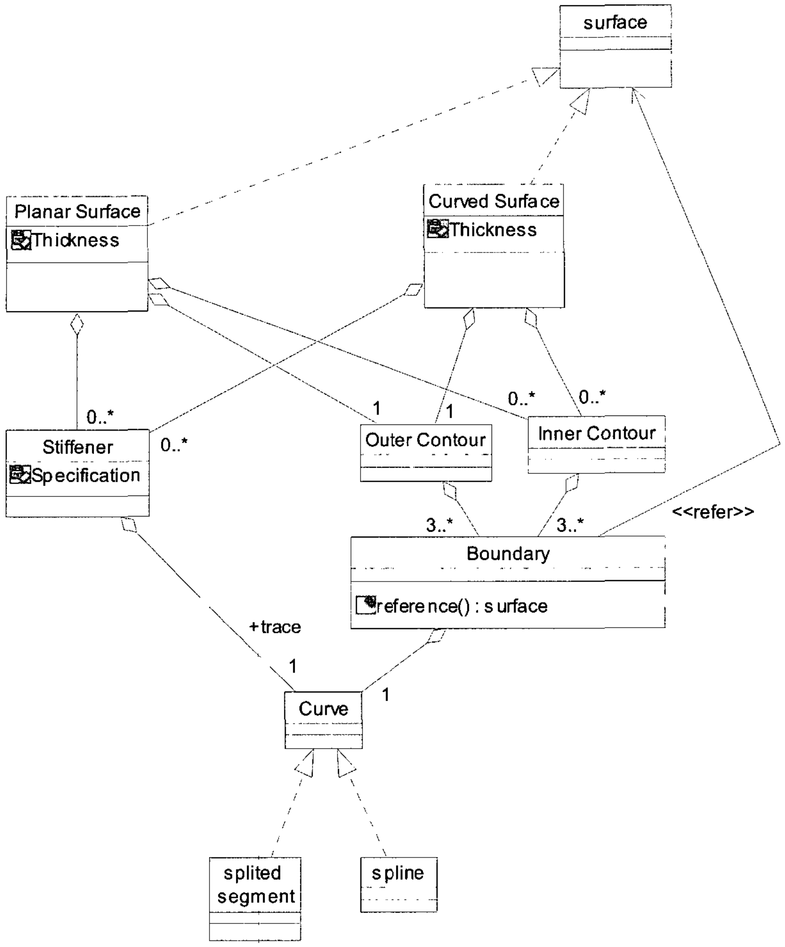


Figure 5: The class diagram of Unified Ship Model for Analysis (USMA) is proposed as a common model for the detail ship design and analysis

The proposed USMA is the common model for detail ship analysis. As shown in Figure 6, the model information from various CAD systems such as TRIBON, Intelliship, FORAN, Ship Constructor and CATIA can be extracted and stored in USMA model directly, using own API (Application Programming Interface) of CAD systems. In the case of Shipbuilding oriented CAD system, CAD model has to be defined with ship design and production process. Therefore, the boundary information of surface and the trace curve of stiffener must be extracted in ship design and production process. Consequently, if shipbuilding oriented CAD system is used, it is expected that the information can be easily extracted as a USMA data structure from the CAD system through its own API.

5 A common language based model-interfacing technique

D.H.Moon et al.(D.H. Moon et al 2003) proposed a macro parametric technique to exchange models between heterogeneous CAD systems with maintaining parameter information. With this technique, they can solve some of the problems that can occur in exchanging models with neutral files such as IGES, STEP etc. Because macro parametric technique is for exchanging models between CAD systems, it is focused on exact conversion of model information including parameter information. However, the shape and topology information of CAE model is often different from that of CAD model. In this study, applying the concept of the macro parametric technique, a common language based model interface technique is proposed to transfer model information from USMA to CAE systems with non-identical model information. Figure. 7 shows the differences between the procedures of a common language based model interfacing technique and the procedures of macro parametric technique.

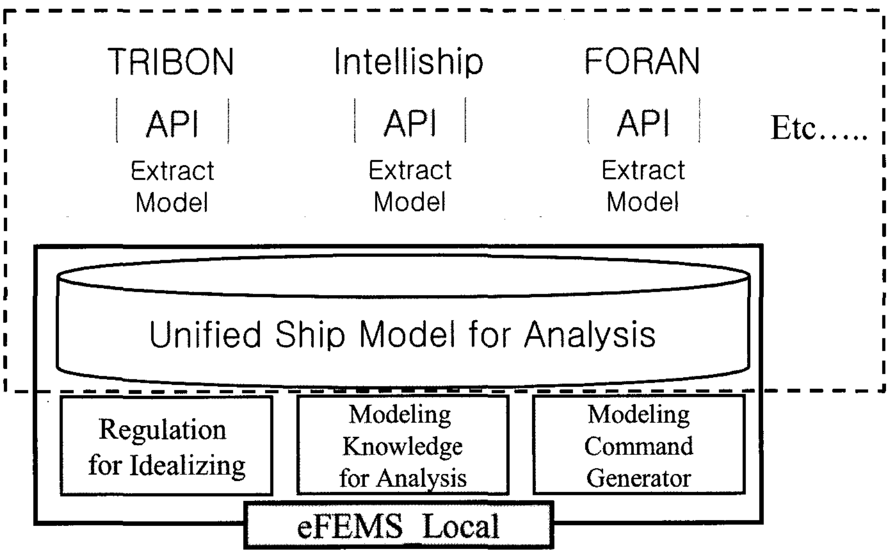
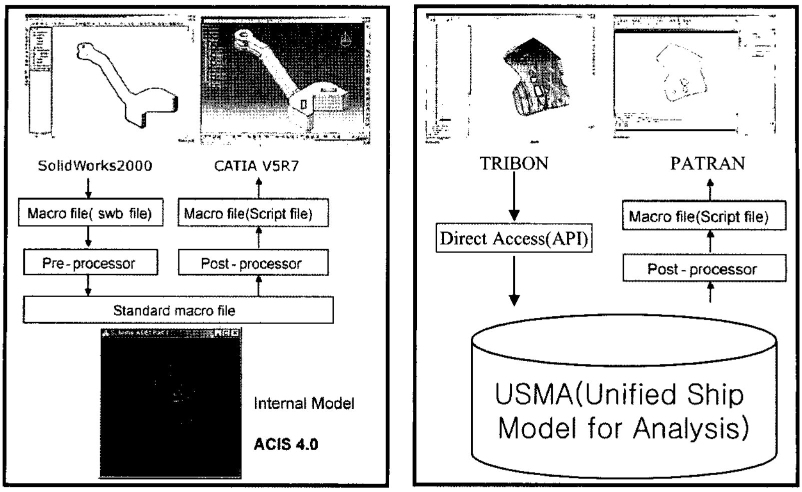


Figure 6: Dashed area shows the part of data exchange from various ship CAD systems using their own API.

The model information in USMA directly extracted from CAD system using CAD system API is transferred to CAE systems using the command language of each CAE system. Through this approach, the drawbacks appearing in exchanging model information using neutral files can be overcome and the model information can be transferred in suitable form for CAE process.

The post-processor of a macro parametric technique has the mapping rules between macros in standard macro file and those in the macro file of target CAD system in order to transfer the model information identically. On the other hand, the post-processor of a command language based model interfacing technique has the knowledge of modelling procedure and rules for idealization. With this knowledge, the post-processor creates the macro file including a set of modelling command to generate proper model in CAE system concerning the characteristic of each CAE procedure and CAE system. The post processor consists of three parts as shown in the dashed box of Figure. 8.



Model exchange from One CAD system to the other CAD system

Model exchange from One CAD system to CAE system (**proposed in this study**)

Figure 7: Model exchange from one CAD system to another CAD system by macro parametric technique(left: D.H.Moon et al[16]) and Proposed technique, a common language based model interfacing technique, to transfer model from USMA to CAE system using the concept of macro parametric technique(right: Proposed in this study)

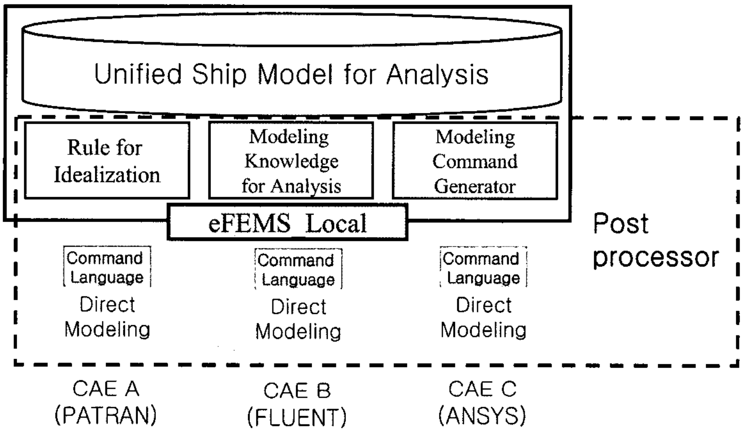


Figure 8: The configuration of post processor

The Rule for model idealization and modelling knowledge for analysis can create a set of modelling commands in right order just as how the user of CAE system make its CAE model from reading the drafting. That is, the set of modelling commands created by these rules can generate the proper model in CAE system, which user wants to make. Figure 9 shows the example of transferring model information from USMA to PATRAN through a set of modelling commands with satisfying users' intents and carrying out model idealization. Following modelling knowledge for analysis, it can be seen that the segmented boundary information in USMA is changed to one curve. In addition, following rule for idealization, it can be seen that the end of stiffener trace line meets the other stiffener trace line and the gap between adjacent stiffeners is removed.

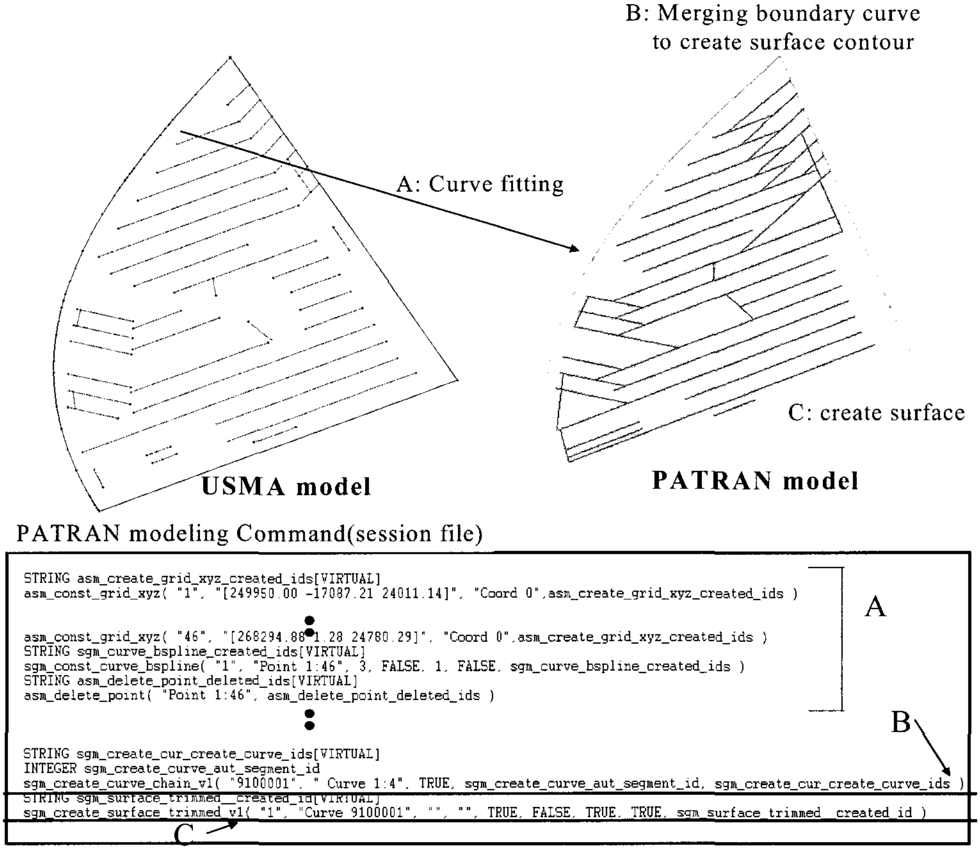


Figure 9: The example of transferring model information from USMA to PATRAN using a set of modelling commands with satisfying user's intents and carrying out model idealization

As a result of using this proposed model interfacing technique, a common language based model interfacing technique, the following can be expected.

- The problems that can occur in exchanging different CAD model information through neutral file with different tolerance and algorithms can be solved.
- Model information can be regenerated in various geometry and topology forms for the objective of CAE job and the characteristic of CAE system.
- The additional information for CAE job such as properties, model relationship, and so on., can be transferred.
- As the procedure like as the CAE user makes model from the drafting is included in the post-processor, the CAE model satisfying the users' intents can be acquired.
- The modelling commands in CAE system are so intuitive that the post-processor can be very simply developed. In addition, one post-processor can cover the information from various CAD systems. It means that once CAD model information from various ship CAD systems is stored in USMA, pre-developed

post-processor can do the transfer of this information to one CAE system without any additional implementation of post- processor. This is shown in Figure 10.

- Using the commands of CAE system directly, it is possible to automate the jobs of CAE system such as creating nodes, meshes, boundary conditions, and load cases so on.

6 Implementation and examples

The proposed approach in this paper is implemented for TRIBON, PATRAN and FLUENT system. PATRAN is the pre-processor for structural analysis and FLUENT is the CFD analysis system. Figure. 10 shows the whole configuration of real implementation and the example of exchanging models from TRIBON to CAE systems (PATRAN, FLUENT). TRIBON model information is extracted using TRIBON API and stored in USMA. After extracting, the model information is transferred to each CAE system using a command language based model interfacing technique. Transferred model is in suitable form to perform analysis job. Firstly, TRIBON model extraction module and PATRAN post-processor were developed. It can be thought then that this is a one–to–one system. Through simple implementation of post-processor in FLUENT, the model exchanging between TRIBON and FLUENT can be also accomplished. Consequently, a one–to–two system can be made in a very short time. In the same way, if extraction module for other CAD systems such as Intelliship, Foran, CATIA, and so on. Is developed, two–to–two system can be constructed in a very short time. From this, it can be verified that the proposed framework based on USMA and common language based model interfacing technique is very flexible.

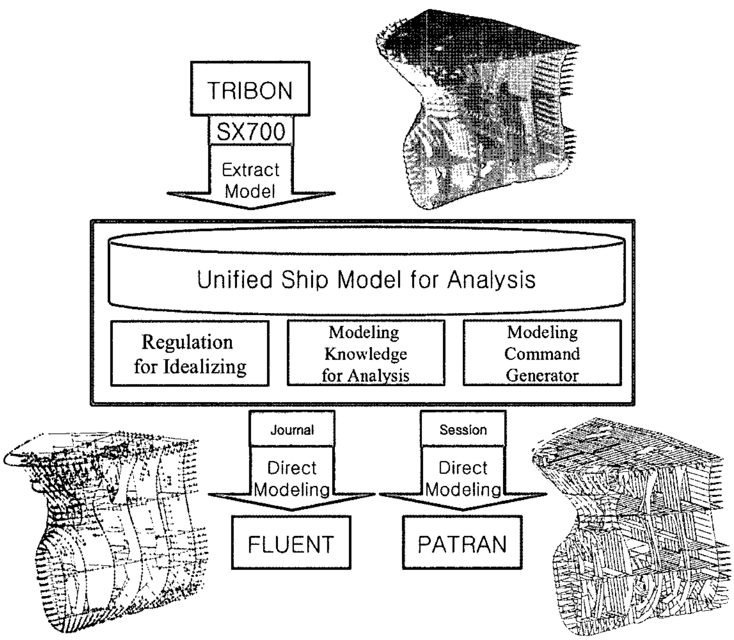


Figure 10: The real implementation of proposed approach for DSME CAD/CAE environment & examples.

Figure. 11 shows the example of idealized model for detail ship structure analysis. Figure. 11 (a) shows the example that solid panel with thickness is simplified as surface panel without thickness and the boundary information of surfaces is conformed. Figure 11 (b) shows that the node information of two panels is also identical one. The command language created by post–processor includes rule for idealization.

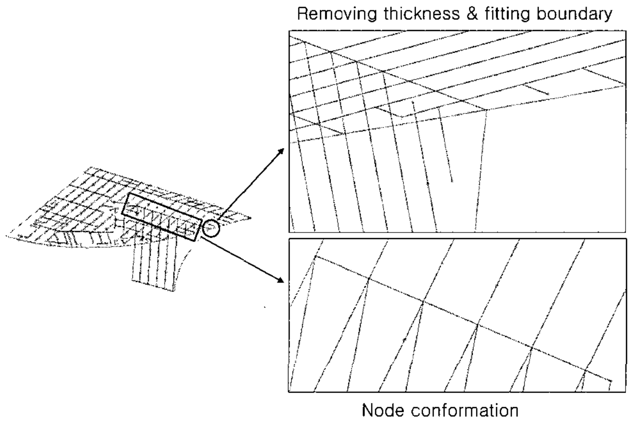


Figure 11: The example of idealization

Figure 12 shows the example to apply proposed approach to real analysis project for crane lifting simulation (S.H. Kim et al 2005). Figure 12 (a) shows TRIBON model, (b) shows the model created in PATRAN through proposed approach, (c) shows the finite element model created by using model in (b) and (d) shows the one of analysis results-shear stress distribution. As suitable model to analysis job is acquired from TRIBON through proposed approach, analysis time can be reduced below the half of current time. Apart from this, it can be shown that a better analysis result is acquired as more precise model information is used for analysis job.

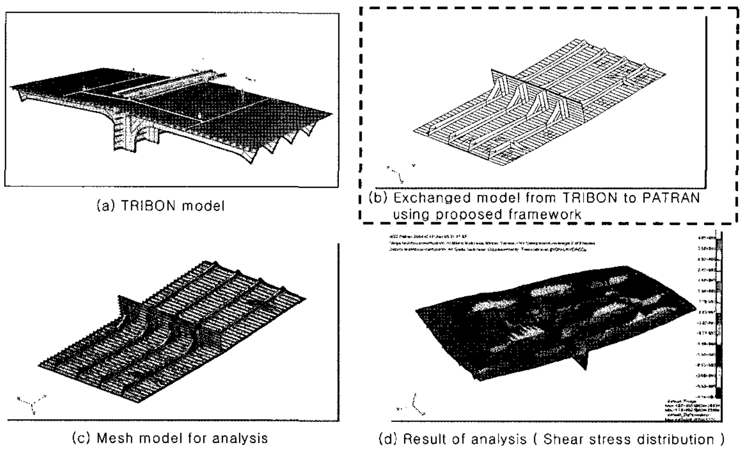


Figure 12: The example to apply proposed framework to real analysis project for crane lifting simulation

7 Conclusion

This paper proposes the new approach of n-to-n mapping to exchange ship structure model in heterogeneous CAD/CAE environments. In this study, the common model called 'unified model for ship structural analysis' to directly extract proper information from different CAD systems for ship structural analysis is proposed. Moreover, a command language based model interfacing technique to construct an idealized model for analysis job is also proposed. The proposed approach has been implemented in DSME CAD/CAE environment of ship structure such as TRIBON system, PATRAN system and FLUENT system. Through this implementation, it can be verified that analysis time can be reduced below half of current time and a better analysis result is acquired.

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