3D Digital Design of Cranes' Structures Based on Hybrid Software Architecture*

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Abstract: *3D digital design for cranes' structures based on hybrid software architecture of Client/Server and Browser/Server is introduced in this paper. Based on Pro/ENGINEER platform, 3D parametric model family is built to allow generation of feasible configurations of cranes' structures in Client/Server framework. Taking use of Visual C++, the second exploiting software kit provided by Pro/ENGINEER and ANSYS GUI/APDL modeling patterns, an integration method of 3D CAD and CAE is achieved, which includes regeneration of 3D parametric model, synchronous updating and analysis of FEA model. As in Browser/Server framework, the 3D CAD models of parts, components and the whole structure could also be displayed in the customer's browser in VRML format.*

Key words: *digital design; crane's structure; hybrid software architecture; CAD/CAE integration*

1 Introduction

Quayside container cranes are one of the main machinery used in ship transportation and increase rapidly all over the world in the recent years. The cranes are very large and complex machines. Their structures have various configurations and a lot of design parameters to meet the different natural, environmental and operating conditions of every harbor. In addition, the structures should be designed to conform to the requirements about strength, stability, bucking, cumulative damage and vibration frequency of the Standards and Specifications. So it is necessary to execute finite element analysis on the structures. As the structures are very large and complex, no finite element analysis procedure in commercial CAD soft wares could be adopted directly to fulfill the analysis task.

In this paper, the digital design method for the cranes' structures based on hybrid software architecture of Client/Server and Browser/Server is proposed. It is mainly based on the technologies of parametric 3D modeling, finite element analysis, integrated CAD/CAE technique, Pro/ENGINEER, ANSYS, MS Visual C++, Java, VRML (Virtual Reality Modeling Language) and EAI (External Authoring Interface). The method includes building CAD platform of 3D parametric model family for crane product, setting up FEA model, the second exploiting of 3D parametric model, the synchronous updating and analysis of FEA, dynamic display of 3D CAD models to the customer's web-browser in VRML format.

2 System Architecture Overview

The system architecture is showing in Fig. 1.

As in Client/Server architecture, a framework is presented to support 3D digital design. Desktop PCs running on CAD software platform such as Pro/ENGINEER etc. act as the clients, which request the values of design parameters of parts, components and the whole structure fromdatabase server. Then a parametric design approach is used to generalize the 3D CAD models. Other desktop PCs running on CAE software platform such as ANSYS also act as clients, on which FEA modeling and analyzing of the structure are realized. Based on integration method of CAD/CAE, when the 3D CAD models of parts, components and the structure are changed, the synchronous updating and analysis of FEA are also implemented.

As in Browser/Server architecture, a standard Internet Explore acts as the browser, which requests data from the web server. Queries are redirected to the database server by the web server, which displays the CAD model generated to the customer on his web-browser in VRML format.

Although such a structure may be a bottleneck for networks with low bandwidth, but it is a comparatively simple approach and whole volume of the system could be controlled as little as possible.

In the database server tier, data models are arranged according to their specialties. The system includes a

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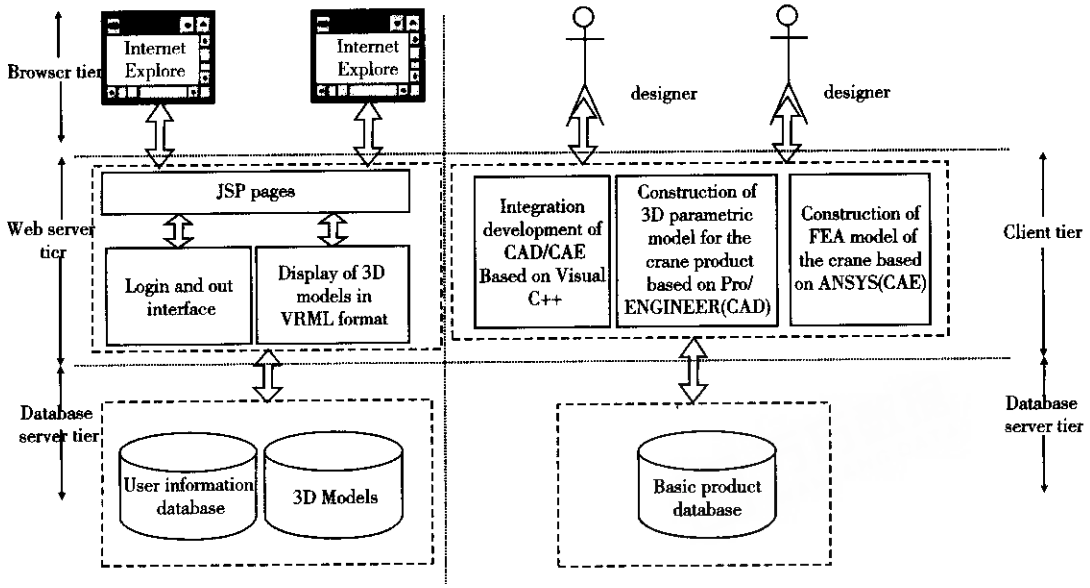

Fig. 1 System architecture

basic product library maintained by designers and accessible only for designers. Other information such as user information, 3D models is also managed in this tier.

3 Integraion of CAD/CAE Based on Olient/Server

3.1 CAD Platform of 3D Parametric Model Family for Crane Product[1-6]

In order to support the designing crane family, CAD representations for product platform are developed to allow generation of feasible configurations of structure, component and part for each family member and then scaling them to the desired size. The framework of CAD model platform has to provide functions listed as follows.

● Decompose product into components and parts based on Top-Down hierarchical product structure

To be able to facilitate design tasks to the members of a development team, the crane structure to be designed has to be structured using the well-known hierarchical product structure. A product consists of a number of components. Each component can either consist of a number of subcomponents or be a part. The product structuring continues recursively in this way, until all components at the lowest level in the hierarchy are parts. So the product is structured in a top-down way, creating as many levels as desired by the designers. Fig. 2 shows a simplified hierarchical product structure of a quayside container crane 's structure.

● Construct 3D part model based on feature technology

Feature technology provided by CAD software platform such as Pro/ENGINEER includes: 1) Draft features which are fundamental geometry characters produced by drawing cross sections and stretching, rotating or scanning them; 2) Attachment features which are added to the fundamental characters include hole, round corner, collapse corner and so on.

According to the feature technology, the 3D models of all the parts of the crane 's structure are generated.

● Specify spatial constraint relationships of components to create product variety

The spatial relationships among the components and parts in the product family are represented using assembly constraint relationship. In the assembly module of CAD software such as Pro/ENGINEER, constraint relationships in assembling, for example, matching, aligning, inserting and tangential etc. are provided. Here, based on the hierarchical structure of the whole structure, relationships among parts and components are built using the assembly constraints provide by Pro/ENGINEER.

● Establishment of down to top size constraint relationship

In order to regenerate the new 3D model of part, component and whole structure when the values of design parameters are changed, a down to top size constraint relationships between size variables and design parameters in a part or component should be built.

Design parameters are established by designers according to the structure of part or component. Size variables, which are generated automatically when 3D models of parts or components are built, control the real geometrical size and topological relationship of a part or a component. Therefore, in order to regenerated the new

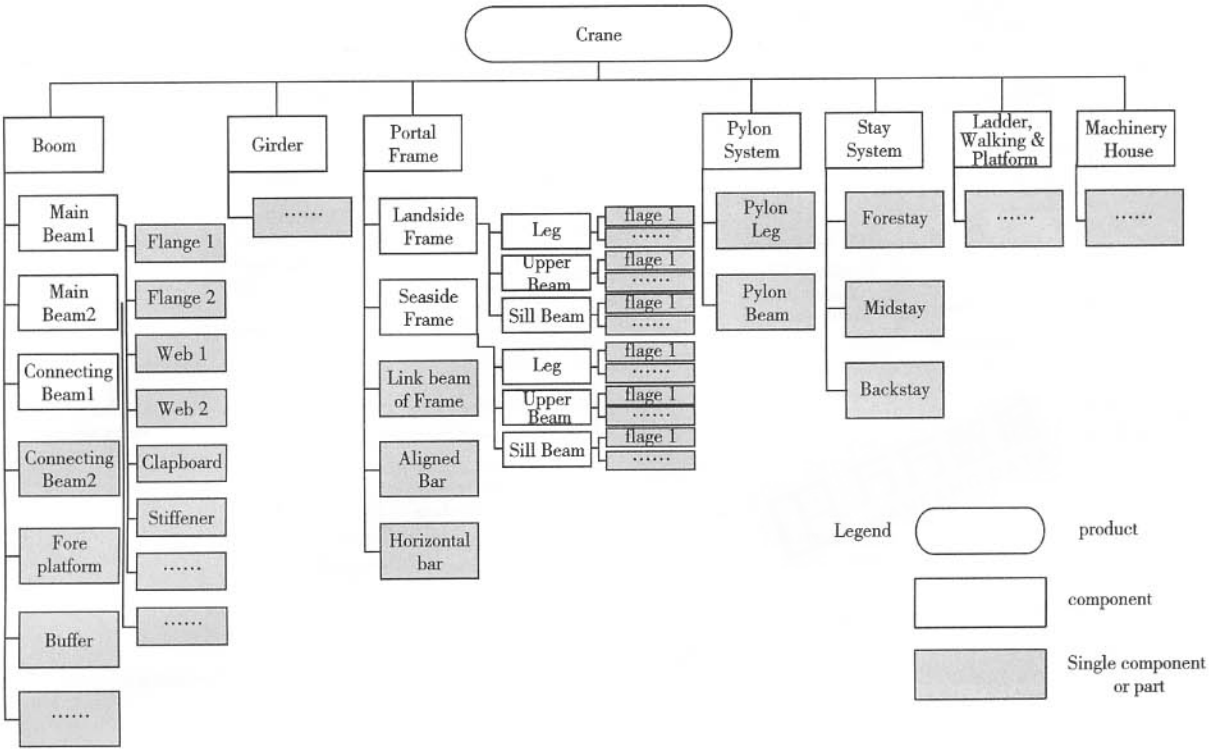

Fig. 2 Simplified hierarchical product structure of a crane

model of a part, component or the whole crane structure when the values of design parameters are changed, the relationship between design parameters and size variables should be constructed accurately.

Commercial CAD softwares such as Pro/ENGINEER have provided function to set up design parameters and build relationships between design parameters and size variables.

● Generation of component or product assembly model based on constraint relationships in bottom-up way

Based on the hierarchical structure of the structure, a designer can start building 3D model of a part as soon as the task has been assigned to him. On the other hand, 3D modeling of a component by a designer to whom it was assigned can only start when its subcomponents and parts have been created. So the actual modeling activity is bottom-up process, starting at the leaves of the hierarchical product structure.

According to the hierarchical product structure of the crane and assembly constraint relationships among components and parts, 3D models of a component desired are generated.

Fig. 3 shows 3D models of different portal frames based on assembly constraint relationships among parts and subcomponents.

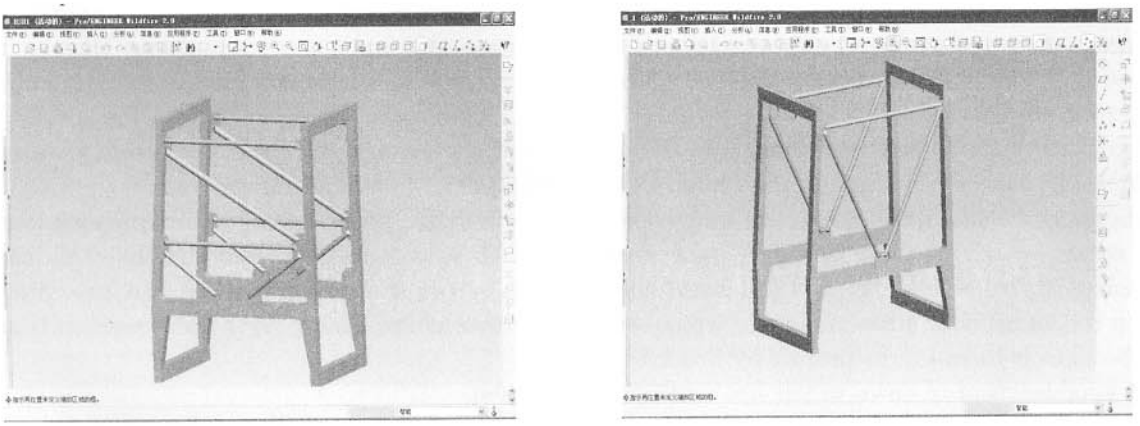

Fig. 3 3D assembly models of different portal frames

3.2 Generation of FEA Model for the Crane[7, 8]

In finite element analysis, the mathematical model shall simulate the real object as accurately as possible to get the reliable results. The FEA should usually be carried out on the whole crane structure.

As the structures are very large and complex, the number of element will be several million to get an acceptable solution. It is impossible to use any FEA procedures in commercial CAD soft wares to fulfill the task. The ANSYS is selected because of its powerful structural analysis functions. As the same reason, the plate elements in ANSYS will not be adopted. The beam188 elements are used to build the FEA model.

In ANSYS, two modeling patterns are provided to build the FEA model, i.e. the human-machine interactive pattern also called GUI pattern and the command stream flow input pattern also known as APDL pattern. Two patterns have also advantages and shortcomings which are described in reference literature. With a sum up of background knowledge of GUI and APDL patterns of ANSYS, the FEA model of the crane structure is realized based on composite pattern. First, FEA model of the structure can be built through ANSYS GUI pattern. Second, CAE analyses of the structure are realized, and corresponding log file is also generated. Then the log file can be modified by using parametric design language APDL provide by ANSYS. Last, the APDL file of the structure including generation of model, imposing of load and constrain, solving and post treatment is built. Generation of model consists of parameter definition, node/unit/section establishment etc. New FEA model of the crane structure is constructed by running the APDL file. Fig. 4 shows the FEA model of the structure and its stress analysis chart.

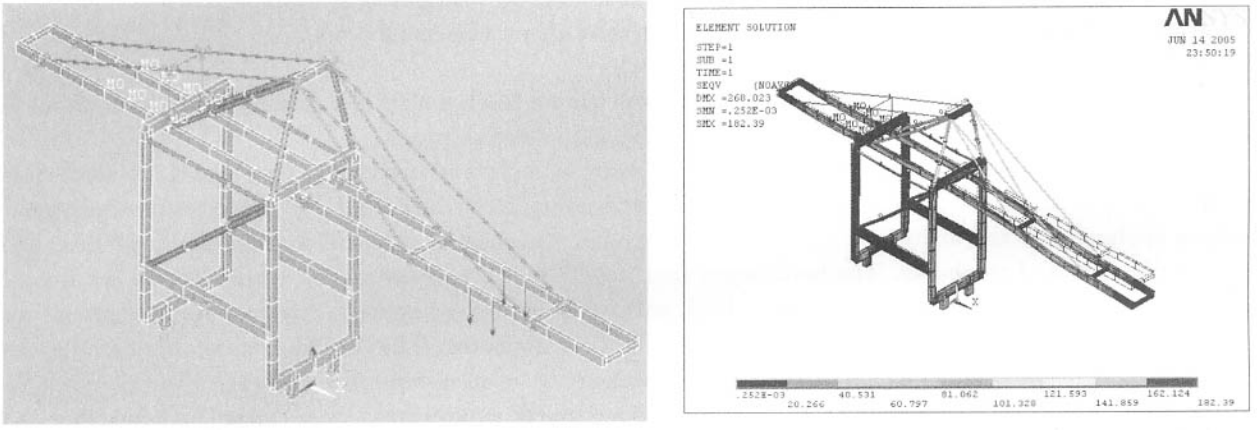

Fig. 4 FEA model and stress analysis chart

3.3 Integration of CAD/CAE based on Visual C++ [7, 8]

● Establishment of integration development environment of CAD/CAE

The integration development of CAD/CAE can be realized using Visual C++ and Pro/TOOLKIT. The latter is a second exploiting software kit provided by Pro/ENGINEER. File path and library file path of Pro/TOOLKIT, file path of APDL are set up in Visual C++, so the integration development environment of CAD/CAE is established.

● Foundation of integration design dialog of CAD/CAE

In Visual C++ development environment, CAD/CAE integration design dialogs of parts, components and whole structure are established through design tools provided by Visual C++.

● CAD/CAE integration process

First, parameter values for design which are acquired through COM database connection are displayed in textbox of CAD/CAE integration design dialog of the boom.

Second, new design parameter values are input through design dialog and saved also through database connection, corresponding design parameter values in APDL file of the crane are also modified automatically. Some modification of the APDL file for the crane would merely result in the change of some parameters such as the nodes' ordinates of the FEA model. Some modification would change the characters of the elements' cross sections, the values and directions of loads etc.

Next, new 3D CAD models of the boom and crane structure are built automatically.

Then, new APDL file is executed and new FEA model of the crane is regenerated in ANSYS software environment.

Last, based on modified FEA model, FEA analysis and calculation are undertaken to justify whether new

parameter values are satisfied with design demand.

4 Product Database Structure

In order to set up the 3D scenes in the presentation, designers have to instantiate a file of the design parameter value for each part, component and the structure. The result is huge amount of files. Since the development of such complex system, several designers have to work close to each other. Even with strong restrictions in the file naming, the overview is soon lost. To guarantee data integrity and correct relations among parts or components, a data management system has to be used. The typical solution is a database. The basic product library, which consists of design parameter information, configuration of the structure, is maintained by designers and accessible only for designers. With the use of database, some general problems would be addressed:

● Data integrity

On a file system, the changes of the designer who saves the file first are then deleted by the designer who saves the same file afterward. But a CAD model can not be modified by two designers at the same time by using the transaction mechanism of database.

● Direct relations

With direct relations of data entities of models, technical dependencies among 3D models can be easily found. Direct relations give the designer a hint to which models must also be changed after making the changes in a model.

● Center data management

The central data pool offers several advantages for backup and versioning.

● Data clustering

The data clustering speeds up the data access, since each designer can get the desired information on his local PC. This is quite important for distributed and collaborative design projects.

The Entity-Relationship (ER) model, which is a popular high-level conceptual data model, is used to design basic product database. This model and its variations are frequently used for the conceptual design of database applications, and many database design tools employ its concepts. The ER model describes data as entities, relationships and attributes. The basic object that the ER model represents is an entity, which is a thing in the real world with an independent existence. Each entity has attributes, namely, the particular properties that describe it. A particular entity will have a value for each of its attributes. The attribute values that describe each entity become a major part of the data stored in the database. A relationship type R among n entity types E1, E2, ..., En defines set of associations or a relationship set among entities from these types. As entity types and entity sets, a relationship type and its corresponding relationship set are customarily referred to by the same name R.

The database has entities according to the hierarchical product structure of the crane. Each part, component and the structure can be represented as an entity which has attributes described by its design parameters. Spatial relationships among the components and parts in the crane products are represented as relationship set R. The database is constructed using Microsoft SQL Server and Component Object Model (COM) components are used for database connectivity from CAD/CAE integration design interface.

5 Display of 3D Models based on Broswer/Server[9, 10]

The Browser/Server architecture is used to display 3D CAD models of parts, components and the whole structure on customer's web-browser in VRML format. A standard Internet Explore forms the basis of the browser. The application server programs are implemented in Java for several reasons. The most important one is that standard browser technology in combination with Java offers a good independence platform. On top of that, the Java Virtual Machine is supplied with most of the standard browser products.

The 3D CAD models created by Pro/ENGINEER are saved as VRML format. The converted VRML files from CAD software platform tend to be very big because VRML uses polygons instead of nonlinear free-formed surfaces to describe 3D objects. The more accurate the model, the more polygons have to be used. On the other hand, the system aims at to be available on ordinary desktop PCs through Internet without using special high-capability hardware. As a result, a compromise between realistic fidelity and rendering speed has to be made. In this case, the VRML files are exported to 3DS Max, where they are edited and optimized further through such methods as reducing the polygon number, simplifying less important parts of components or the whole structure and compressing the VRML file etc.

For the display of 3D CAD models, the Cosmo Player plug-in is chosen because it can display models in both

the VRML 1.0 and VRML 2.0 versions. As a channel between the Cosmo Player and the Java applets, EAI is used to connect the VRML world with HTML pages through Java applets that control the VRML scene dynamically.

6 Conclusions

The 3D digital design of quayside container cranes' structures based on hybrid pattern of Client/Server and Browser/Server is introduced in this paper.

Based on the Top-Down hierarchical product structure, feature technology, assembly constraint relationship, bottom-up assembly process and down-to-top dimension relationship provided by Pro/ENGINEER, a CAD platform of 3D parametric model family is built to allow generation of feasible configurations of crane structures.

With a sum up of background knowledge of GUI and APDL patterns of ANSYS platform, the finite element model of the crane structure is realized based on composite pattern.

With the help of MS Visual C++, the integration development method of CAD/CAE which consists of regeneration of 3D parametric CAD model, synchronous updating and analysis of finite element model is achieved.

Based on the technologies of JAVA, VRML, EAI and Cosmo Player, dynamic display of the newest 3D models on customer's browser is realized.

The basic product and user information are constructed using Microsoft SQL Server 2000.

The system can improve greatly the design efficiency of the quayside container cranes' structures.

References

[1] Siddique, Z., and Rosen, D. W.. On Discrete Design Spaces for the Configuration Design of Product Families[J]. AI EDAM., 2001,15(2):91-108.

[2] Martin, M. V., and Ishii, K.,Design for Variety:Developing Standardized and Modularized Product Platform Architectures [J]. Res. Eng. Des.,2002,13(4):213-235.

[3] Claesson, A., Johannesson, H., and Gedell, S.,Platform Product Development:Product Model a System Structure Composed of Configurable Components, Proc. 2001 ASME DETC/CIE Conference, Pittsburgh, ASME, New York, ASME Paper No. DETC2001/DTM-21714. No. DETC2001/CIE-21291.

[4] Simpson, T. W., Maier, J. R. A., and Mistree, F., Product Platform Design:Method and Application Res. Eng. Des., 2001,13(1):2-22.

[5] Meyer, M. H., and Utterback, J. M., The Product Family and the Dynamics of Core Capability, Sloan Manage. Rev., 1993,34(3):29-47.

[6] Siddique, Z., and Rosen, D. W., Product Platform Design:A Graph Grammar Approach, Proc. 1999 ASME DETC/CIE Conference, Las Vegas, ASME, New York, ASME Paper No. DETC99/DTM-8762.

[7] Peak, R. S., Characterizing Fine-Grained Associatively Gaps:A Preliminary Study of CAD-CAE Model Inter-operability, Paper number CIE48,232, ASME DETC/CIE Conference, Chicago, September, 2003.

[8] ANSYS User's Manual:Procedures, Vol. I, II, III, Swanson Analysis Systems Inc.

[9] VRML Consortium. The Virtual Reality Modeling Language:International Standard ISO/IEC 14772-1,1997.

[10] Silicon Graphics, Inc., The External Authoring Interface EAI, http://cosmosoftware.com/developer/eai.html.

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参考文献(10条)

1. Siddique Z. Rosen D W On Discrete Design Spaces for the Configuration Design of Product Families 2001(2)

2. Martin M V. Ishii K Design for Variety:Developing Standardized and Modularized Product Platform Architectures 2002(4)

3. Claesson A. Johannesson H. Gedell S Platform Product Development:Product Model a System Structure Composed of Configurable Components[ASME Paper No.DETC2001/DTM-21714.No.DETC2001/CIE-21291]

4. Simpson T W. Maier J R A. Mistree F Product Platform Design:Method and Application 2001(1)

5. Meyer M H. Utterback J M The Product Family and the Dynamics of Core Capability 1993(3)

6. Siddique Z. Rosen D W Product Platform Design:A Graph Grammar Approach[ASME Paper No.DETC99/DTM-8762]

7. Peak R S Characterizing Fine-Grained Associatively Gaps:A Preliminary Study of CAD-CAE Model Inter-operability[Paper number CIE48,232] 2003

8. ANSYS User's Manual:Procedures

9. VRML Consortium ISO/IEC 14772-1.The Virtual Reality Modeling Language:International Standard 1997

10. Silicon Graphics Inc The External Authoring Interface EAI

相似文献(2条)

1. 外文会议 WANG Chonghua. LI Hua 3D Digital Design of Cranes' Structures Based on Hybrid Software Architecture

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2. 外文会议 Wang Chonghua. Li Hua. ; 3D Digital Design of Cranes' Structures Based on Hybrid Software Architecture

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