

Modeling Method and Application in Digital Mockup System towards Mechanical Product

Huaiyu Zhang

Abstract—The method of modeling is the key technology for digital mockup (DMU). Based upon the developing for mechanical product DMU, the theory, method and approach for virtual environment (VE) and virtual object (VO) were studied. This paper has expounded the design goal and architecture of DMU system, analyzed the method of DMU application, and researched the general process of physics modeling and behavior modeling.

Keywords—DMU, VR, virtual environment, virtual object, physics modeling, behavior modeling

I. INTRODUCTION

IN the last 20 years, the concept of CAX (CAD/CAE/CAM) by tradition has turned into a practicable technology, widely applied in automobile, aviation, general mechanism and weaponry etc. For example, from the year of 1995 to 1999, the fault rate of automobile part has been reduced about 40% meanwhile the cost of product design & manufacture has economized remarkably [1].

In recent years, the technology of digital mockup has rapidly developed on the basis of CAX, combining with technologies of information, advanced manufacture and advanced simulation, evolves into a new method of product design based upon virtual reality simulative model. In general, a typical application system of DMU comprises two elements: virtual environment and virtual object. The VE is 3D space and visual scene expressed by computer [2], the VO is the specified software entity, which could merely be graphics entity or part model containing physical attributes, assembly conditions and functional characteristics.

Fidelity is the most important virtue of DMU, because the main goal of DMU is to simplify or even to substitute for the actual product mockup, that means, DMU must be able to imitate the geometrical characteristics, physical characteristics, and behavioral characteristics of actual product mockup, makes real response like true product to exterior prompting [3].

Comparing with traditional CAX technology, DMU has an advantage because DMU is a method base upon systems engineering, which be compatible with the total processes of design and manufacture for complex product. Comparing with traditional experiment technology, DMU can reduce the amount of actual mockup, provide with more flexible methods for modification and configuration in the process of simulation. Comparing with traditional computer simulation technology, DMU has the advantage of UI functions which provide with real time interaction to support the immersion sensory perception.

H. Zhang is with the Institute of Structural Mechanics, China Academy of Engineering Physics, Mianyang City, Sichuan Province, China (e-mail: zhanghuaiyu2000@163.com).

For these reasons mentioned above, many institutions and enterprises have taken more and more interest in the research of DMU.

II. LITERATURE SURVEY

US DOD defined DMU as a modeling process using computer simulation to imitate the actual mockup, which can support the choice for optimal design plan by evaluating and testing of DMU. The DMU environment is an integrated system contains various models with different work principle, guides the designer to transform the product concept into prototype through comprehensive mockup testing [4]. Fan Dai etc. defined DMU as a rapid evaluation for product design, incorporating technologies of VR, computer simulation and CAD to build the digital prototype of actual product. The designer of product can manipulate and modify the model of DMU easily and exploit the reusable design data for emulational analysis [5]. Mikko Kerttula etc. considered DMU as a digital product model, which be a very close approximation to functionality and structure of the real product, can be put into a VR environment to perform the test for products in conceptual phase [6].

Ed P. Andert considered DMU as a virtual manufacture and simulation process from the point of view of mechanical engineering. The design model based on DMU stores all the information about mechanism, physics, appearance and functionality of actual mockup [7]. Mitchell M. Tseng indicated that DMU is a digital model which is able to substitute for real product model and check the geometry, function and manufacturability [8].

Bohu Li etc. indicated that DMU is a new design method based upon computer simulation model of product, provides with an integrated system of various models from different engineering domain. The basal theory of DMU involves in kinematics and kinetics of multi-body system [9], [10]. Wen Zhao etc. indicated that DMU is built on the theoretical basis of simulation modeling, which take the computer simulation, modern management, systems engineering, information modeling and software tools together. The technology of DMU supports the life circle of product design and evaluation to reduce cost and improve efficiency [11], [12].

III. THE DESIGN GOAL AND ARCHITECTURE OF DMU SYSTEM

DMU is a sort of general technology, needs to be applied in actual product design and pertinent problem solving. On the background of mechanical product design process, this paper presents the design goals of DMU system as three phases of development.

- 1) To introduce uniform CAD software platform for design modeling, the design model must conform to the product specification of parametric modeling and the accuracy of model must adequate for engineering drawing, be easy to modify and reuse.
- 2) Accomplish the definition of engineering elements in design model, including the physical attributes, multi-body mechanism elements, boundary conditions etc. The design model can be transformed into analysis model, fulfill the requirement for standardization, accuracy and integrality of product information in DMU.
- 3) Using the CAD/CAE/VR software programming approaches to establish the VE and VO of DMU gain the capabilities of engineering analysis and interactive simulation. DMU should be able to support the design validation on the level of part, and the performance analysis and simulation on the level of macrostructure of product.

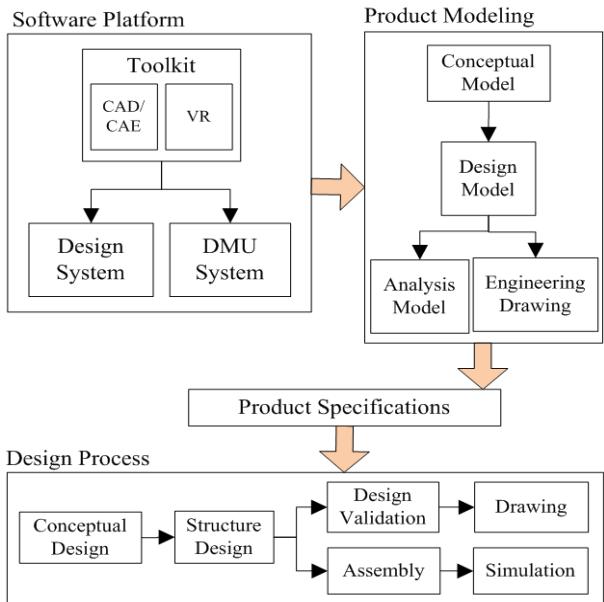


Fig. 1 The architecture of DMU system

Generally, there are four factors which are pertinent to product design, i.e. platform, specification, model and process. The platform applies to system function development and the specification applies to standardization of modeling, these two factors denote the general characteristics of product design. The model represents design data stored in computer and the process represents various application instances of product design, these two factors denote the particularities of product design. The architecture of DMU system is shown in Fig.1.

IV. THE METHOD OF DMU APPLICATION

The product design could be formulated as a series of phases, i.e. conceptual design → structure design → design validation → assembly design → performance simulation → actual mockup test.

In those phases, the design plan becomes more and more clear, the designer or manager will focus their mind on detailed work, and the tools, models, arithmetic used by them will be more and more complex. At the end of the series of phases, the product model maybe brings hundreds of files and thousands of design parameters [13]. For various application instances of product design, developers have to make the choice and confirm the type, content and granularity of model, sometimes need to select different software platforms and product specifications. Using appropriate software programming approaches, developers are able to employ potential capacities of computer to improve the efficiency of DMU.

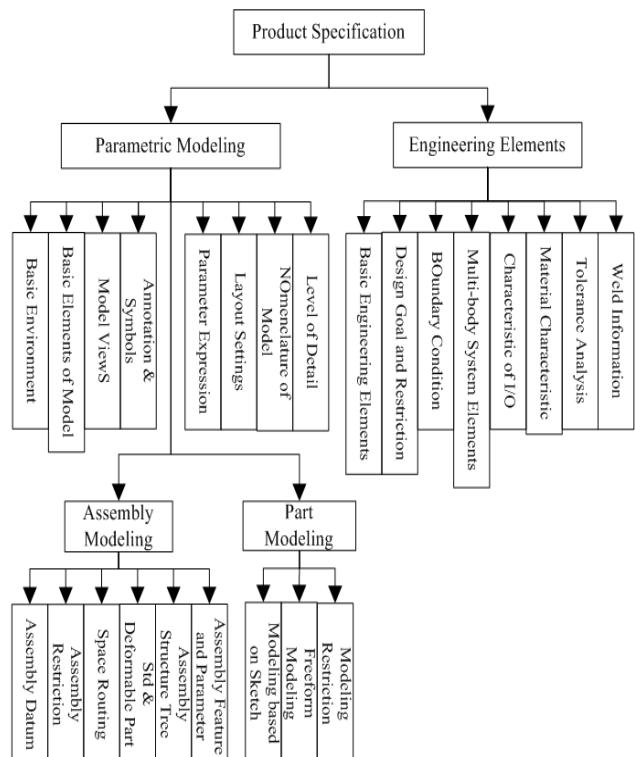


Fig. 2 The product specification

In the phases of conceptual and structure design, the emphases of DMU application are establishing product specifications to standardize the modeling process (geometrical, physics and behavior modeling), insure the accuracy and reusability of model in the multidisciplinary collaborative design mode. The product specifications are shown in Fig.2.

The specification of parametric modeling is used to control the geometrical accuracy of design model; the specification of engineering elements is used to control the accuracy of information about mechanism, mechanics and material etc. The specification of engineering elements is the key point of transforming from design model to analysis model which supports physics modeling and behavior modeling.

In the phases of design validation and performance simulation, the entire design model has been assembled and the engineering elements definition has been completed.

So, developers can employ CAD/CAE/VR software to accomplish multi-dimensions and macro-scene product data visualization, perform human-computer interactive virtual assembly to complete engineering prognostication and synthesis evaluation.

The result of analysis can be related to design parameters to facilitate design updating and optimization.

The model produced by CAD/CAE software is a sort of parametric solid model vis-à-vis the model used by VR software is a sort of non-parametric lightweight model.

We can execute the data integration through manifold ways like model translation or program interface in order to complete transfer all sorts of virtual objects between different virtual environments in DMU system.

V.FROM PHYSICS MODELING TO BEHAVIOR MODELING

Physics modeling is physical abstract for actual product, which describes the physical attributes of VO like mass, centre of mass, moment of inertia, surface finish, elasticity and plasticity etc. This information can be inosculated with geometrical features and mechanical principle to provide with a more realistic VE. Mechanical products are always multi-body system, which is abstract and description of general mechanical system. It means that the multi-body system comprises rigid or flexible bodies which have been connected by joints and be able to take some relative movement [14].

The term of behavior in DMU is the movement, transformation of VO and dynamic relation between VE and VO. The purpose of behavior modeling is to build a kind of model which can furthest imitate the actions of real object in real world, which guides the developers of DMU to construct the VE and VO with believable behaviors. The research of behavior modeling based on kinetics theory should be focused on how the VO changes its movement driven by outside force giving initial boundary conditions, and how the virtual objects response when they collide each other.

When we apply the behavior modeling and relevant kinetics problem solver to product design, it is very helpful for designer to examine design plan and improve product quality in early time without any actual product mockup. The instance of design model is shown in Fig.3 and the corresponding DMU model for virtual assembly is shown in Fig. 4.

VI. CONCLUSION

The virtual environment, virtual object and interaction between VE and VO are basic framework of DMU system. The developers of DMU system require appropriate method of modeling to construct VE, VO and correlative data, thereby establish virtual product model with human-computer interactive capacity for design and analysis.

Based upon research on DMU system architecture, modeling process and software programming approaches, this paper shows a general and practical method for development of mechanic product DMU based on multi-body system.

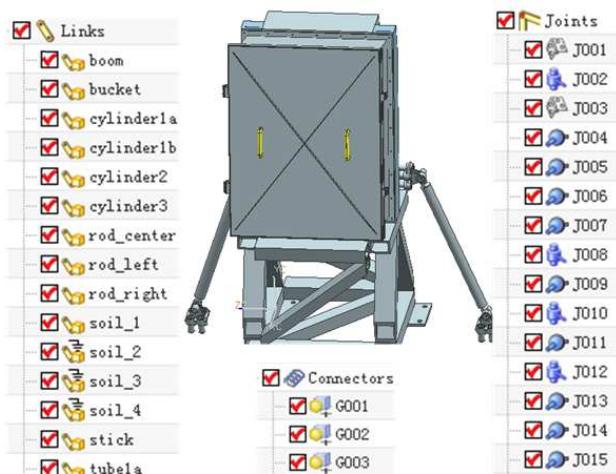


Fig. 3 The design model of product

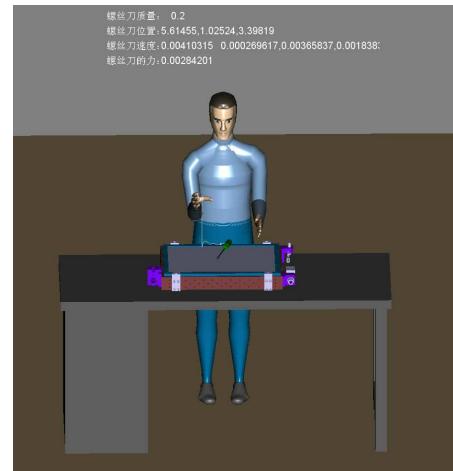


Fig. 4 The product DMU for virtual assembly

ACKNOWLEDGMENT

This work was financially supported by Technology Development Fund of China Academy of Engineering Physics (2009A0203011).

REFERENCES

- [1] Liping Chen , *The kinetics analysis of mechanics system and tutorial of ADAMS*, Beijing: TsingHua University Press, 2005.
- [2] Dingfang Chen, *The virtual design*, Beijing: China Machine Press, 2002.
- [3] Jianrong Tan, *Digital mockup: key technologies and product applications*, Beijing: China Machine Press, 2007.
- [4] Wen Zhao, "Research on the architecture of collaborative DMU environment", *Journal of National University of Defense Technology*, 22(6), pp. 60-64, 2000.
- [5] Fan Dai, Wolfgang Felger, Martin Gobel. *Applying Virtual Reality to Electronic Prototyping-Concept and First Results: Virtual Prototyping: Virtual environments and the product design process*. Chapman and Hall Press, 1995.
- [6] Kertula M, Salmela M, Heikkinen M. "Virtual reality prototyping-a framework for the development of electronics and telecommunications products", *Proceeding of 8th IEEE International Workshop on Rapid System Prototyping*, 1997.
- [7] Andert E. P. Jr., Morgan D. Collaborative "Virtual Prototyping and Test", *Naval Engineer journal*, 11(6), pp. 17-23, 1998.

- [8] Tseng M M, Jianxin Jiao, et al. "A Framework of Virtual Design for Product Customization", Proceeding of IEEE Intal Conference on Emerging Technologies and Factory Automation, 1997.
- [9] Bohu Li, "Virtual prototype engineering of complex product", CIMS System, 8(9), pp. 678-683, 2002.
- [10] Bohu Li, "Research on the virtual prototype of complex product", Journal of System Simulation, 14(3), pp. 336-341, 2002.
- [11] Wen Zhao, "Research on the method of integrative modeling for virtual prototype", Journal of System Simulation, 14(1), pp. 100-103, 2002.
- [12] Wen Zhao, "Research on the DMU of weapon system, Journal of National University of Defense Technology", 21(1), pp. 58-61, 1999.
- [13] Min Chen, *Research on the key technologies in integrated missile overall design system*. Ph.D. Thesis, National University of Defense Technology, Changsha, 2008.
- [14] Jiazen Hong, *Calculating mechanics of multi-body system*. Beijing: Higher Education Press, 1999.