# Advantages Analysis of Synchronous Modeling Technology Based on Solid Edge

LANG WANG, JING-YING ZHANG*, WEI YANG, QIONG FAN
School of Mechanical and Vehicle
Beijing Institute of Technology
NO.5 Zhongguancun South Street, Beijing
China
zjy2721@bit.edu.cn

*Abstract:* - Common three-dimensional (3D) modeling software mainly uses sequence modeling method based on feature tree structure. This kind of parametric modeling is achieved by using dimensional constraints. However, re-editing of any historical features will cause regeneration of the subsequent features, thus resulting in substantial waste of computer resources and time. Compared with sequence modeling technology, synchronous modeling technology is a new modeling technology whose advantages are studied through some examples analysis and nonparametric modeling can be truly and efficiently achieved. Synchronous modeling technology contributes to accelerate the pace of product innovation and it's of great significance to 3D CAD intelligent modeling.

*Key-Words:* - synchronous modeling; sequence modeling; features; dimensional constraints.

## 1 Introduction

In the information age today, computer has become an indispensable tool in our life especially in the early product design. It not only saves the design cycle, but also can express design ideas of designers clearly. With the development of three-dimensional (3D) modeling technology and the improvement of computer hardware and software, 3D modeling technology gets more and more attention. Compared to the traditional 2D model, the 3D model has the characteristic that it can easily produce plane projection and perspective projection view in any direction. In the 3D models, each parts of the object can be observed from any direction and angle. Some 3D solid models have physical properties such as mass, moment of inertia and center of gravity so that stress, motion and thermal effects can be analyzed with specialized software [1-2]. Based on the above characteristics, 3D modeling technology has been widely used in many fields.

For the traditional CAD technology, the support for design process is based on geometric modeling. Geometry modeling is one of the key technologies in computer aided design [3]. Boundary Representations method (B-Rep) and Constructive Solid Geometry method (CSG) are two common modeling methods. Both two methods only record the dots, lines, areas and volumes of the parts, and the topological relations between them. For the Boundary Representation method [4-6], boundary represents layers of volumes, surfaces, circles, lines and dots. Boundaries record the geometry information of all geometric elements and the interconnection topology relationship between them. The information can be obtained directly in operations. Since data structure is complex, a lot of storage space is needed. The program that is used to maintain the internal data structure is complicated. Boundary Representation does not necessarily correspond to a valid structure [7]. Usually the Euler operation is used to ensure the validity and regularity of the Boundary Representation. The Constructive Solid Geometry (CSG) technology obtains the new structure based on the volume pixel operations [8-9]. The volume pixels can be cubes, cylinders, cones, etc. The operations are transforms or Regularized set calculation such as union, intersection, subtraction, etc. Representations of the structure are restricted by the types of volume pixels and operations. In other words, the covering domain of the CSG method has great limitations. It is not easy to realize the local operation of structures.

In modern 3D graphics modeling, most software is based on sequence modeling technology. Sequence modeling is a method which is based on sequence history record architecture and uses parametric and feature-based modeling approach [10]. However, the disadvantage of sequence modeling is that, when model structure is very complicated, re-editing a historical feature will become a difficult task and cause all subsequent features to be temporarily removed by the system, and the system will regenerate the subsequent features after the historical feature is edited. In fact, due to the problems that large amounts of the CAD software versions exist [11], the artistic quality of mechanical parts are increasingly commanded and the structure of parts are getting more and more complex. Parametric model cannot meet the demand. The process based on the non-parametric model should be paid more attention to.

Interactive 3D solid synchronous modeling is a new modeling method applied in Solid Edge Product that is launched by Siemens PLM Software [12]. In this paper, synchronous modeling technology is studied on the basis of traditional sequence modeling. The advantages of synchronous technology are obtained through comparative analysis, and the results show that synchronous modeling technology accelerates the pace of product innovation and it is of great significance to 3D CAD intelligent modeling.

# 2 Development of Three-dimensional Modeling Technology

## 2.1 Wireframe modeling

Wireframe modeling technology originated in the 1960s [13]. Wireframe modeling constructs three-dimensional solid objects with wireframes and polygons. It provides three-dimensional data, which breaks the constraints of 2D system. Wireframe model can show the internal structure and external shape of objects. It can generate views in any direction. The data of structure model is simple. These 3D data are described by a set of vertices and edges. However, the initial wireframe modeling technology can only express the basic geometry information, while it cannot effectively express topology relations between the geometric data. Due to the lack of the object surface information, it does not support hiding, shading, rendering and other operations. The CAM and CAE cannot be achieved and each object of the wireframe model has to be drawn and positioned separately. This modeling technology is the most time-consuming. In addition, because only vertices and edges represent objects, realism of the object will produce ambiguity due to the cross-coincidence between the sides. Many characteristics of the object are not expressed properly.

## 2.2 Surface modeling

In the 1970s, as the aircraft and automobile industry developed rapidly, a lot of free surface problems occurred in the manufacture of aircraft and automobile. Due to the imperfection of the three-view drawing expression, there is a big difference between the sample and the model that designers imagined. The French presented the Bezier algorithm, which allows people to use a computer to solve the curve and surface problems [14]. In 1977, the French firm Dassault developed a 3D surface modeling system, CATIA, which marked the CAD technology developed from 2D to 3D surface technology [15]. The computer aided design technology was freed from the simple three-view drawing mode and laid a foundation for the CAM technology. Surface modeling adds surface table to record the topological relations between the edge and the surface on the basis of data structure in wireframe modeling. It can achieve the correlation calculating and coloring on the surface of the model, which make the model more realistic [10]. However, the disadvantage of this modeling method is that it only represents the surfaces and boundaries. The object cannot be cut and the quality of the model, the center of mass and the moment of inertia cannot be calculated.

## 2.3 Solid modeling

Since the surface modeling technology can only express the surface information of structure, it is difficult to exactly express other features, such as quality, center of gravity, inertia, etc. In 1973, I. C. Brajd proposed to use cube, cylinder, circular cone and other basic volume pixels to construct complex objects based on the union, intersection, subtraction and other logical operations [16-18]. At the same time, solid modeling theory developed rapidly and a group of practical solid modeling system occurred. In 1979, SDRC released the I-DEAS, the first CAD/CAE software entirely based on the solid modeling technology [19-20]. For solid modeling, the physical characteristics of the objects can be defined in a computer. Information on modeled surface, as well as mass, center of gravity, moment of inertia and other characteristics of the object can be expressed accurately. In addition to the predefined 3D solid objects, new solid objects can be defined by stretching or rotating the 2D objects or by Boolean operations. This method constructs complex 3D model through Boolean operations between each solid elements based on the theory that solid model can be expressed with volume pixels construction method. It brings another breakthrough to three-dimensional modeling technology [12].

### 2.4 Parametric modeling

In the 1980s, with the rapid development of the computer technology and lower prices in hardware costs, many small and medium-sized enterprises also began to have the ability to use the CAD technology. In 1988, the Parametric Technology Corporation developed Pro/Engineer software based on the object oriented unified database and all parametric modeling technology [21]. The Pro/Engineer software provides a good platform for 3D solid modeling. Parametric modeling technology, also known as sequence modeling technology, is based on historical feature, full size constraints, full data dependency and dimension driving. It overcomes the unconstrained condition of free modeling and combines the shape and the size together in the whole process of design. Geometry is controlled by the dimension and achieves the control of the geometry through the restriction on the parameters constraints. Parametric modeling technology shows its simple and high speed in the design of many interchangeable parts and components, which greatly improve design efficiency of products. However, the disadvantage is that it has the characteristic that sub features will be deleted when parent features are deleted. The modification is driven by dimensions, while the range of dimension-driving is limited.

### 2.5 Synchronous modeling

Interactive 3D solid synchronous modeling, which is launched by Siemens PLM Software, is a new breakthrough in digital product development [12]. Its cores are to abandon historical record and change feature tree to feature set. It uses inference engine with new decisions to synchronize geometry and rules at the same time. Users can design and change fast, and realizes non-parametric modeling [22].

## 3 Advantages of Synchronous Modeling Technology

### 3.1 Simplifying the assembly process

Assembly is an important part in mechanical manufacturing process. Statistics show that, in industrialized countries, approximately 1/3 of human labor is engaged in assembly related work, 20%~30% of the total manufacturing costs are used for product assembly, and work hours required for product assembly takes 40%~60% of total working hours of product manufacturing [23]. The flowchart of traditional sequential modeling assembly process is shown in Fig.1. If dimensions do not meet the requirements of product design during assembly, users must return to the partial feature and modify the 2D sketches in order to regenerate 3D data, and then go back to assembly interface. Such a separation of modification interface and assembly interface makes the operation process more complicated. In synchronous modeling, the assembly process (Fig.2), allows users to modify features directly in the integrated 2D and 3D system, and views of other parts are still visible at the same time. When features are modified, the tree structure of the entire assembly can be navigated. So it can eliminate interference that may exist in the normal sequential modeling, isolate other components quickly, and drive 3D data directly.

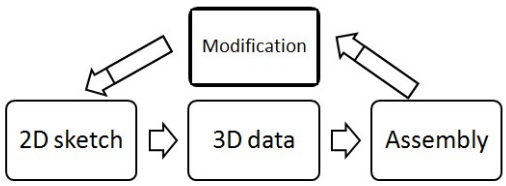


**Fig.1** Flowchart of sequential modeling assembly process

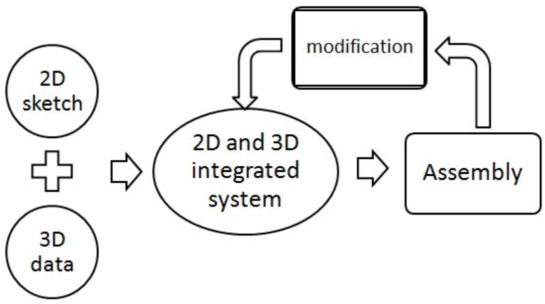


**Fig.2** Flowchart of synchronous modeling assembly process

As shown in Fig.3, the assembly drawing of a one-way valve is drawn with Solid Edge ST5. The diameter of the seal seat (part 3) turns out to be too small during the process of assembly. With synchronous modeling technology, the modification of the diameter of seal seat can be done in assembly drawing directly. Likely, the assembly tree can also be operated in the assembly drawing. It's easy to modify features when other parts are selected to be shown or hided appropriately. This operation method simplifies the process of product assembly, especially for the assembly of complicated product. It can shorten the assembly time significantly, improve the speed of product development, and enhance enterprise productivity.

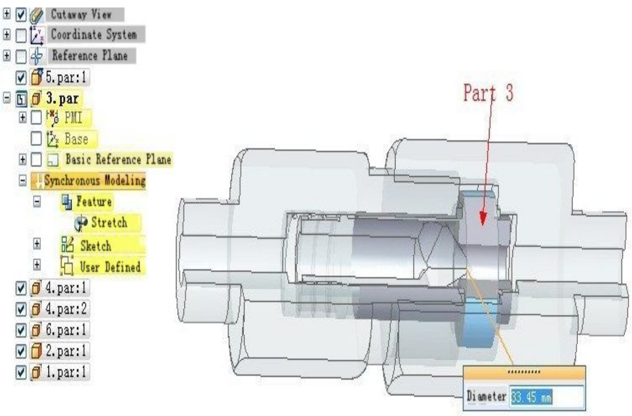


**Fig.3** Assembly drawing of a one-way valve

## 3.2 Synchronous solve

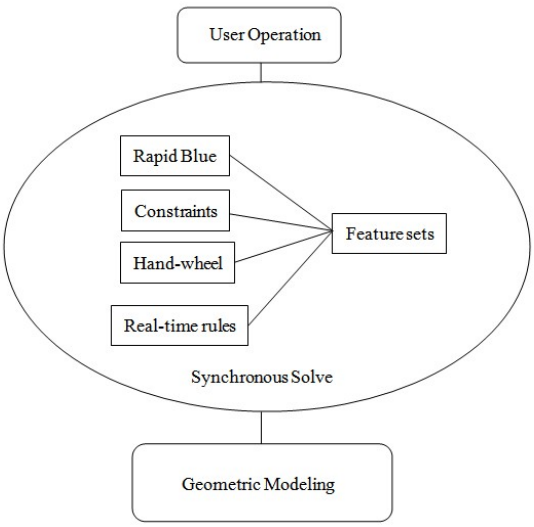


**Fig.4** The process of synchronous solve

The process of synchronous solve is shown in Fig.4. Synchronous solve is the core of synchronous modeling technology. Rapid Blue technology is used in synchronous modeling. Curve is made up of three different types of points: edit point, control point, contour point. Any shape of flexible curves can be designed through these points. When curves need be modified, the original intent of design is integrated into curves rather than adjust each curve by the cumbersome manual adjustment. Dynamic editing of Rapid Blue technology allows designers modify any feature at any location of model. Drag mouse on the screen and you can see the results immediately.

Geometric modeling uses ACIS technology. ACIS is a three-dimensional geometric modeling engine developed by American Spatial Technology Company. It uses object-oriented technology that integrates wireframe, surface and solid modeling in the same data structure and provides a geometric modeling platform for a variety of 3D modeling applications.

## 3.3 Breaking down barriers of design based on inherent structure of historical record

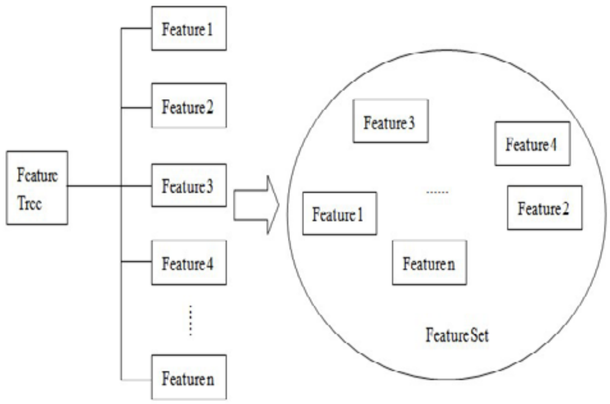


**Fig.5** Feature tree and Feature set

The core of synchronous modeling is that it changes feature trees to feature sets (Fig.5), and abandons the concept of historical record completely. Therefore, all features are placed in the same layer in synchronous modeling, and feature editing is no longer constrained by the order of creation. There are no parent-child dependencies between features either within a single component or between a few components. However, for sequence modeling, which is based on historical records, unexpected changes of a feature will lead to regeneration of subsequent features. Not only is this time-consuming, the result of changes is also unpredictable due to the complexity and correlation between parts. It requires designers to prepare complicated models in advance. For synchronous modeling, design intent can be captured quickly, features can be changed quickly, and the generation of other unrelated features will not be affected. So the model reconstruction in change process can be eliminated. In general, synchronous modeling technology can make the design speed increase by 100 times, since there is no need for pre-planning and pre-designing [12].

### 3.4 Creating experience of user interoperation

For traditional CAD modeling methods, sketches are first constructed in 2D planes, and surface is subsequently formed by sketch curves. However, for synchronous modeling surface is a directly driven object. User interoperation in synchronous modeling integrates 2D sketches and 3D data together. It simplifies the process of CAD operations, and makes 3D as simple to use as 2D. For example, in Fig.6, the top cover of speed reducer is created with Solid Edge ST5 synchronous modeling technology. In this case, the right side of the top cover lacks a rib. To modify this side, users do not have to draw a sketch in a 2D plane, yet can lock a drawing surface on 3D solid, and draw a sketch on the 3D solid directly. The sketches form a closed plane (Fig.7). With synchronous modeling technology, the plane can be driven, and the desired dimensions of features can be generated in real time. Synchronous modeling technology improves the speed and flexibility of modeling. It gives users the fastest and most flexible experience, and makes it easy to learn for beginners.

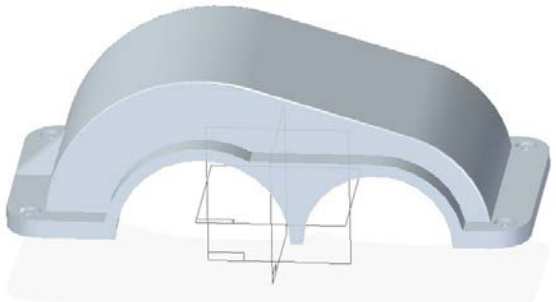

**Fig.6** Top cover of speed reducer without a rib on the right

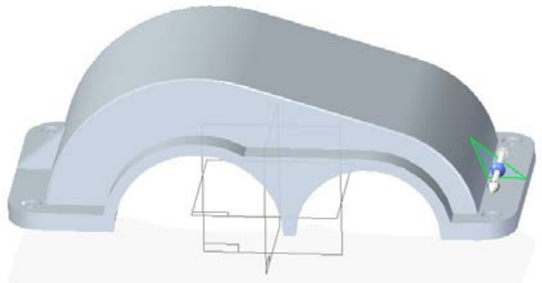

**Fig.7** Top cover of speed reducer with a rib stretch on the right

### 3.5 Hand-wheel integrated of points, axes, plane and ring

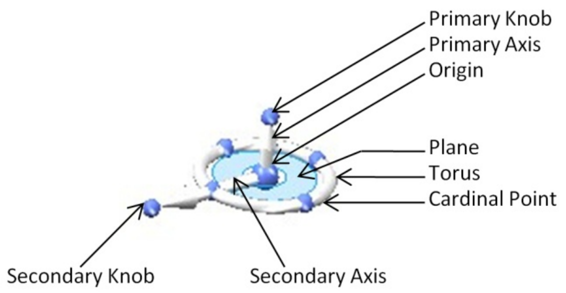


**Fig.8** Structure of operation hand-wheel

In the Solid Edge ST5 version, hand-wheel is used for synchronous modeling technology. Using the hand-wheel skillfully is the key to master synchronous modeling technology. It can shorten the product development cycle greatly. The structure of operation hand-wheel is shown in Fig.8. The hand-wheel is formed by points, axes, ring, plane and other structures based on part features. With the operation hand-wheel being dragged, rotated and orientated, the model size can be driven quickly. A bottom case is shown in Fig.9. When the length needs modification on the right side, click on the right side surface, then the hand-wheel appears. By clicking on the Secondary Axis of hand-wheel, users can control the distance of extension freely (Fig.10), and realize the command of moving features synchronously.

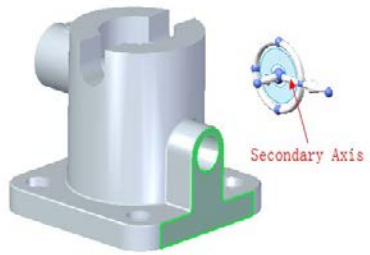


**Fig.9** Edit of a bottom case

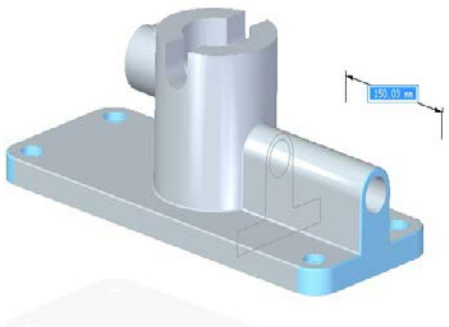

**Fig.10** Stretch freely

Actually, when the hand-wheel is dragged, Solid Edge ST5 system will detect mouse actions all the time. System implies some design rules, which are called real-time rules in Solid Edge ST5. Real-time rules always guarantee the changes of models, and only features that comply with real-time rules can be changed. There are no such real-time rules in sequence modeling, and this is the charm of synchronous modeling technology!

## 4 Conclusion

Synchronous modeling technology integrates all the advantages of modeling technologies. It abandons historical record of features, and creates a 2D and 3D integration system. For beginners, the interoperation experience makes it easier to operate. Models can be controlled efficiently, and designing process becomes faster. For designers, they can capture design intention quickly, and modify features quickly. It reduces redundant workload, and improves design efficiency greatly. For enterprises, it shortens product design time, accelerates product innovation, and improves product design efficiency. For initial modeling or modification in later stage, the speed and efficiency of synchronous modeling is much higher than that of sequential modeling. This modeling technology, which is independent of historical record of features, will be the direction of future development of three-dimensional (3D) modeling, and it is of great significance to 3D CAD intelligent modeling and product innovation.

*References:*

[1] Y. X. Wei, Kinetic Analysis of Collision of Micro-robot Based on ADAMS, *Mechanical Engineering & Automation*, No.2, April, 2011, pp. 82-85.

[2] L. Yan, W. Y. Xu and Q. Zhang, Modeling of Complex Geological Body in FLAC3D Based on HYPERMESH, *Journal of China Three Gorges University(Natural Sciences)*, Vol.35, No.3, June, 2013, pp. 40-43.

[3] B. Shu, X. J. Qiu and Z. Q. Wang, Survey of Shape from Image, *Journal of Computer Research and Development*, Vol.47, No.3, 2010, pp. 549-556.

[4] S. K. Ma, C. A. Liu and W. T. Fang, Geometric Updating Method for B-rep Model Based on Machining Features, *Modular Machine Tool & Automatic Manufacturing Technique*, No.4, April, 2010, pp. 20-24.

[5] X. Zhang, Y. Yang, Building Workpiece Surface Dynamic Geometry Model Basing on B-rep Model, *Computing Technology and Automation*, Vol.31, No.3, September, 2012, pp. 96-99.

[6] F. Li, R. Mo, Partial matching algorithm of sub-region based on model segmentation, *China Metalforming Equipment & Manufacturing Technology*, Vol.48, No.5, 2013, pp. 93-96.

[7] Z. Ding, Z. Q. Guan and C. J. Zhang, Mid-Surface Extraction Based on Wireframe Mapping, *Journal of Computer-Aided Design & Computer Graphics*, Vol.26, No.9, September, 2014, pp. 1522-1527.

[8] J. X. Lu, S. P. Tang and X. F. Yan, Projected Bounding Box Accelerating Algorithm Based on CSG, *Journal of Wuhan University of Technology(Information & Management Engineering)*, Vol.34, No.4, August, 2012, pp. 430-444.

[9] Z. D. Huang, S. P. Tian, Determination of equivalent parameter domains of two parametric CSG part models, *Journal of Huazhong University of Science and Technology(Nature Science Edition)*, Vol.32, No.3, March, 2004, pp. 1-4.

[10] T. Chi, X. B. Shen and R. Li, Application of Synchronous Modeling Technology in Products Design, *Manufacturing Informatization*, No.7, 2011, pp. 51-52.

[11] L. R. Zhang, Application of 3D CAD Technology in Mechanical Design, *Coal Technology*, Vol.30, No.2, February, 2011, pp. 16-17.

[12] C. Y. Ding, Design of Accelerator, *China Computer Users*, June, No.23, 2008, pp. 51.

[13] X. S. Ran and L. Lin, Comparative Analysis between Synchronous Modeling Techniques and Traditional Modeling Techniques in Product Design, *Design and Research*, No.6, 2010,pp.69-72.

[14] K. Wan, Z. Huang, Z. H. Zhong, Algorithm for Urban Road Detection Based on Uncertain Bezier Deformable Template, *Journal of Mechanical Engineering*, Vol.49, No.8, March, 2013, pp. 143-150.

[15] H. L. Zhuang, DS CATIA V6 Making Flat World Stereoscopic, *Aeronautical Manufacturing Technology*, No.11, 2009, pp. 28-31.

[16] C. L. Mo, B. Li and X. M. Tan, A Study of the Teaching Method of Shade-analyzing in 3D Solid Modeling, *Journal of Guangdong University of Technology(Social Sciences*

*Edition)*, Vol.3, No.4, December, 2003, pp. 41-43.

[17] B. Xin, 3D Solid Models Based on AutoCAD R14, *Journal of China Agricultural University*, Vol.5, No.2, 2000, pp. 75-77.

[18] H. Wu, Y. Cao and Y. Bai, Application of Synchronous Modeling Technology to Part Feature Recognition, *Development & Innovation of Machinery & Electrical Products*, Vol.24, No.1,2011, pp. 88, 99-100.

[19] W. T. Yang, G. M. Zhu and R. Y. Fei, A Kind of CAD/CAM Network System Based on I-DEAS, *Journal of Beijing Polytechnic University*, Vol.27, No.4, December, 2001, pp. 489-492.

[20] Z. Y. Wei, Structural optimized design for moving cross header of extrusion press based on I-DEAS, *China Metalforming Equipment & Manufacturing Technology*, Vol.49, No.1, 2014, pp. 54-56.

[21] C. B. Hu, J. F. Huang and P. Huang, Drawing's rapid design based on Pro/TOOLKIT of Pro/ENGINEER, *Manufacturing Automation*, Vol.36, No.6, 2014, pp. 37-39.

[22] H.C. Li, Study on three-dimension CAD synchronous modeling based on UG, *Mechanical Research & Application*, No.4, 2010,pp. 102-104.

[23] W.L. Chen, X.G. Yan, Z.N. Chen and H.Z. Bin, Research on 3D-CAD Oriented Assembly Sequence Modeling System, *China Mechanical Engineering*, Vol.16, No.20, October, 2005,pp. 1839-1842.