

机电学院

051 系

序号	姓名	职 称 或学历	单位	论文题目	刊物、会议名称	年、卷、期
1	刘苏 陈旭玲	教授 讲师	051	Numeralization Modeling on Metro Car Gangway	12th International Conference Geometry and Graphics	2006. 8
2	王湖皎 刘苏	硕士 教授	051	基于遗传神经网络的AZ91镁合金力学性能预测	江苏大学学报	2006. 27. 5A
3	张珊珊 刘苏	硕士 教授	051	基于细分思想的自由造型技术在CADC中的应用	江苏大学学报	2006. 27. 5A
4	朱杰跃 尹明德	硕士 教授	051	Research on Parametric Design Approach of Body Skeleton of Passenger Car	技术与创新国际会议	2006
5	梁广省 尹明德	硕士 教授	051	基于ARM和CAN的汽车液晶仪表的设计	湖北汽车工业学院学 报	2006. 20. 4
6	王小雷	教授	051	Optimization of the Surface Texture for Silicon Carbide Sliding in Water	Applied Surface Science	2006. 253 1282-1286
7	王小雷	教授	051	The Effect of Surface Texture During the Wear Process of Brass	Proceeding of ASLTRIB 2006 KANAZAWA	2006
8	王小雷	教授	051	边界润滑条件下表面织构的研究	全国磨擦学学术会议 论文集	2006
9	王小雷	教授	051	碳化硅陶瓷的水润滑特性以及表面织构的影响	第六届全国表面工程 学术会议论文集	2006
10	岳林	教授	051	基于Morlet小波改善飞行颤振试验参数 识别精度的方法	中国机械工程	2006. 17. 17
11	周瑾 徐龙祥	副教授 教授	051	The Control of Sheet Motion in a Hot-Dip Galvanizing Line by Electromagnetic Actuator	The 10th International Symposium on Magnetic Bearings	2006
12	谢小刚 周小蔚 李靖谊	硕士 工程师 教授	051	服务于教学管理的师资状态管理系统的 实现	江苏大学学报	2006. 27. 5A
13	张关良 李靖谊	硕士 教授	051	基于有限元的客车车身的静动态特性分 析	计算机仿真	2006. 8
14	郭勤涛	讲师	051	结构动力学有限元模型修正的发展—— 模型确认	力学进展	2006. 36. 1
15	郭勤涛	讲师	051	用于确定性计算仿真的响应面法及其试 验设计研究	航空学报	2006. 27. 1
16	陈旭玲	讲师	051	基于JAVA的网络教学电子白板的设计与 实现	计算机技术与发展	2006. 16. 4
17	许兆棠 朱如鹏	博士 教授	051	直升机弹性多支点传动轴的主共振分岔 分析	航空动力学报	2006. 21. 2
18	许兆棠 朱如鹏	博士 教授	051	直升机复合材料传动轴的主共振分析	机械工程学报	2006. 42. 2
19	许兆棠 朱如鹏	博士 教授	051	阻尼分段阶梯传动轴主共振的分析	中国机械工程	2006. 17. 7
20	许兆棠 朱如鹏	博士 教授	051	刚性多支点传动轴的主共振分岔分析	振动与分析	2006. 25. 4
21	许兆棠 朱如鹏	博士 教授	051	刚性多支点传动轴的纵向振动分析	武汉大学学报	2006. 39. 5
22	许兆棠 朱如鹏	博士 教授	051	刚性多支点传动轴主共振分析	东南大学学报	2006. 36. 1

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NUMERALIZATION MODELING ON METRO CAR GANGWAY

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ABSTRACT: Today, the competition is so fierce in the market that the innovative ability for the product becomes the linchpin upon which success or failure depends, therefore, corporations have introduced many new techniques to enhance their innovative ability. With the computer and the relevant technologies are applied to the fields of design, analysis and manufacture of products, the demand for the information description of the product model is becoming ever more complicated. This paper mainly proposed a numeralization modeling process of metro car gangway. First, all the information should be taken into account, including design, process planning and manufacture course in the course of design. Using Pro/E, we establish metro car gangway parts and assembly parts, which comprise of both manufacture information and geometrical topological messages. Second, the key modeling technologies are introduced, such as the project from top to bottom, skeleton model, parts mapping, group control techniques. Third, by analyzing the characteristics on export of Pro/E and Rhino and combining Rhino's strongpoint on NURBS with 3Dmax's excellence on romance, this paper proposes a model conversion technique from Pro/E to 3Dmax which can make 3Dmax identify the surfaces changed from Pro/E, by which, we can use 3Dmax to romance the model with high quality and efficiency. Finally, this paper proposes the solutions in model change, which include surface lost, abnormal surface crack and so on. All these methods and technologies have been used in practice, and the expected results have been obtained.

Keywords: baffle modeling Pro/E render

基于遗传神经网络的 AZ91 镁合金力学性能预测

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摘要: 在合适的参数条件下径向基函数神经网络能够以任意的精度来逼近任意的函数, 遗传算法是一种高效的全局寻优的搜索方法. 将遗传算法和径向基函数神经网络相结合, 建立遗传神经网络, 运用到合金设计的性能预测方面. 使用简单易行的二进制编码方法, 在寻求径向基函数神经网络隐含层神经元最优中心矢量的同时确定其最优个数, 通过设定合理的目标函数解决网络函数逼近能力与泛化能力之间的矛盾. 试验证明, 该方法在合金性能预测方面有较好的效果, 能够成为合金设计有力的辅助手段.

关键词: 镁合金; 性能预测; 神经网络; 遗传算法; 径向基函数

中图分类号: TP183 **文献标识码:** A **文章编号:** 1671-7775(2006)05A-0067-04

Prediction of mechanical properties of AZ91 magnesium alloys based on genetic neural network

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Abstract: It has been shown that the radial basis function neural network with appropriate parameters is a universal approximator for continuous functions. The genetic algorithm is efficient in seeking for a global solution. A net was built with genetic algorithm and RBF neural network combined together, which was used to predict properties of alloys. The optimum number of the neuron was confirmed when these neurons had been found by using a simple bit string coding method. A reasonable fitness function was designed to settle the contradiction between approximative capability of the neural network and using capability. According to the result of the prediction of the mechanical properties of AZ91, this method can be considered as a potent assistant instrument to those non-linear systems.

Key words: magnesium alloys; prediction of properties; neural network; genetic algorithm; radial basis function

合金材料设计的核心思想就是确定合金成分、工艺及其性能之间的关系, 合金性能预测在其设计过程中占有举足轻重的地位. 但是由于材料成分、工艺、组织、性能之间的关系和规律极其复杂, 迄今为止没有传统的数学模型能够对它们之间的定量关系进行准确描述. 将遗传算法和神经网络技术结合运

用到该领域, 能够较好地解决这类非线性的问题.

径向基函数(radial basis function, RBF)网络具有最优逼近和全局逼近的特性, 无论在逼近能力、分类能力和学习速度等方面均优于传统的 BP 网络^[1], 因此被广泛的应用于函数逼近、模式识别、预测和控制等领域.

收稿日期: 2006-06-18

基金项目: 江苏省重点基金资助项目(P0251-061)

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遗传算法(genetic algorithm, GA)是以自然选择和遗传理论为基础,将生物进化过程中适者生存规则与群体内部染色体的随机信息交换机制相结合的高效全局寻优搜索方法.遗传算法不依赖于问题具体的领域,对问题的种类有很强的鲁棒性,所以被广泛的应用于模式识别、人工智能等方面^[2].

作者将遗传算法引入 RBF 网络,使用简单易行的编码方式,在寻求隐含层神经元最优中心矢量的同时确定其最优个数,通过设定合理的目标函数使得网络既具有较好的函数逼近能力,又避免了过度逼近引起网络的泛化能力的下降.该方法在对 AZ91 镁合金力学性能的预测试验中达到了预期的效果,证明了其有效性.

1 遗传神经网络构建

1.1 网络模型设计

影响压铸镁合金性能的主要因素是合金元素的组成和制备工艺.由于镁合金 AZ91 中的 Al 和 Zn 的质量分数已经基本确定,因此在影响因子中去掉 Al 和 Zn 的质量分数,选择 Cu, Mn, Ni, Si, Fe, Sb, Ag, Be, Re, Ce, Sc, Ca, Y, Sr 的质量分数作为输入变量.在实际生产中,制备工艺的影响不可忽视,因此再选择热处理工艺和加工方法作为输入变量.

所建立的网络结构如图 1 所示.

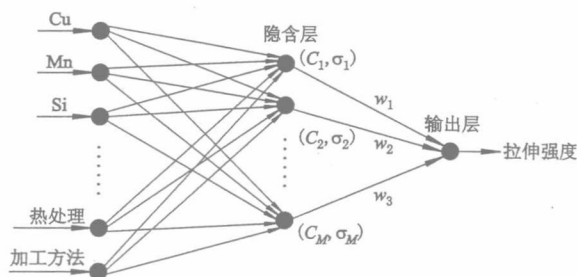


图1 神经网络结构模型

1.2 RBF 网络的构建

RBF 网络是一种三层前向网络.第一层由信号源节点构成.第二层为隐含层,变换函数是 RBF,它是一种局部分布的对中心点径向对称衰减的非负非线性函数,通过该函数实现输入空间到隐含层空间的非线性变换.第三层为输出层,它对输入模式的作用做出响应,从隐含层空间到输出层空间变换是线性的.

RBF 网络的隐含层中每个神经元的权值和阈值指定了相应的径向基函数的位置和宽度,每一个

线性层神经元由径向基函数的加权和组成.只要每一层都有正确的权值和阈值,并且有足够的隐含层神经元,那么 RBF 网络就能够以任意的精度来逼近任意的函数.

RBF 选用高斯函数,构建的 RBF 网络的函数映射为

$$f(X_j) = \sum_{i=1}^M w_{ji} g_i + b = \mathbf{W} \mathbf{G}, j = 1, 2, \dots, n \quad (1)$$

式中, $\mathbf{W} = [w_{n1}, w_{n2}, \dots, w_{nM}, b]$, $\mathbf{G} = [g_1, g_2, \dots, g_M, 1]^T$, $g_i = \exp\left(-\frac{\|X_n - C_i\|^2}{2\sigma^2}\right)$, X_j 为网络的样本空间中某输入矢量, $\mathbf{W}$ 为网络输出层权值, g_i 为网络隐含层输出, $\|\cdot\|$ 为范数,通常取欧氏范数.

网络的函数逼近性能评定函数为.

$$E = \sum_{j=1}^n (y_j - f(X_j))^2 \quad (2)$$

式中, y_j 为与输入矢量相对应的期望输出, $f(X_j)$ 为网络的实际输出.

由式(1),整个网络中有四个未知参数: C 为径向基中心, σ 为径向基宽度, $\mathbf{W}$ 为输出层权值, M 为隐含层神经元数目.

神经网络的算法一般都是分别调整参数的值以达到网络的最优化解,例如, K-means 聚类算法求中心值,这种方法选用聚类中心作为网络隐含层神经元的中心,但是由于没有考虑输出节点的权值,所以相对于实际输出而言,可能选择的节点并不是最优的.传统的方法割裂了所有参数的综合作用,往往不能使整个网络性能达到最优化的状态.下面引入遗传算法,将所有参数对函数的作用结合起来,使得网络的整体性能达到最优化的状态.

1.3 遗传算法的引入

遗传算法是一种基于生物进化原理构想出来的搜索最优解的仿生算法,它模拟基因重组与进化的自然过程,把待解决问题的参数编成二进制码或十进制码——基因,若干基因组成一个染色体(个体),许多染色体进行类似于自然选择、配对交叉和变异的运算,经过多次重复迭代直至得到最后的优化结果.遗传算法以群体为基础,不是以单点搜索为基础,能同时从不同点获得多个极值,因此不易陷入局部最优^[2].

同时寻求 RBF 网络的四个未知参数的最优解显然不合理.可知宽度参数 σ 的影响并不是很大,可以采用式(3)使得其和中心参数联系起来求解;

输出层权值的计算可以采用最小二乘法直接求解得到,只要设置合理的适应度函数,将输出层权值的影响考虑进去,就不需要直接使用遗传算法寻求其最优解.因此,需要用遗传算法寻求最优解的只有径向基中心和隐含层神经元个数,采用文中的编码方法就可以同时解决这两个问题.

$$\sigma = \frac{distance_max}{\sqrt{M}} \tag{3}$$

式中, distance_max 表示隐含层中心之间的最大距离, M 为隐含层神经元个数.

1.3.1 中心参数的编码

遗传算法的编码是应用遗传算法求解问题的第一步.在类似的问题上,许多研究者采用多参数级联编码,即将中心矢量、宽度、输出层权值编成一个染色体,也有研究者为了确定隐含层神经元个数使用分阶遗传算法,但是因为神经元个数的影响,以及输出层权值的搜索空间难以确定,所以这样的编码方法具有一定的难度.考虑到在样本空间搜索中心值,将输入样本排列,采用二进制编码方法,如图 2 所示.其中,“1”表示对应位置的样本作为一个中心点,“0”表示该样本不是中心点^[3].

1	0	...	1	0
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图 2 染色体结构

这样就将整个输入样本空间中每个样本是否作为中心点的状态作为设计变量,将样本输入矢量相应的位置编成染色体的基因.每一个编码表示一种中心的选取方案,经过多次重复迭代直至最后的优化结果,最后的编码即为最优的中心选择方案.

解码时,编码中“1”的个数即为隐含层的节点数,“1”的分布位置所对应的样本输入矢量即为中心矢量.这种编码方法简单、实用,特别适合样本输入矢量个数不庞大的情况.

1.3.2 适应度函数的设计

在遗传算法中使用适应度(Fitness)这个概念来度量群体中各个个体在优化计算中能达到或接近于或有助于找到最优解的优良程度.一般情况下,RBF网络采用式(2)作为网络的目标函数,但是,这样只能使得网络的函数逼近性能较好.采用式(4)作为目标函数,这样既能保证网络的函数逼近的精度,又能够保证网络的中心不至于过分密集,这样保证了网络的预测性能.

$$f(t) = k \times E \tag{4}$$

式中, k 是有关于阈值 δ 的一个参数. δ 代表 RBF 中心距离的阈值, k 代表中心之间的距离小于该阈值的个数.该方法由 Growing and Pruning (GAP)方法思想得出^[4].由于该阈值的选取没有公式参照,所以采用试凑法.

适应度比例参数选用排列方法,排列方法是根据个体的适应度值的排列顺序而不是根据个体适应度值的大小来衡量个体的优劣.

1.3.3 遗传操作

选择又称为复制,是在群体中选择生命力最强的个体产生新的群体过程,遗传算法使用无回放式余数随机方法和最优保存策略来对群体中的个体进行优胜劣汰操作.前者的选择误差最小;后者能确保适应度最好的个体保留到下一代群体中.

交配重组是生物遗传和进化过程中的一个主要环节,模仿这个环节,遗传算法中使用交叉算子来产生新的个体.鉴于二进制编码,采用分散交叉算子.

遗传算法模仿生物遗传和进化过程中的变异环节,变异是以较小的概率对个体编码串上的某个或者某些位置进行改变.文中采用均匀变异,增加群体的多样性,使算法处理更多的模式.

1.3.4 算法控制参数

交叉运算决定了遗传算法的全局搜索能力,突变运算决定了遗传算法的局部搜索能力,文中采用了自适应算法控制交叉概率和变异概率,将进化过程划分为渐进和突变两个不同的阶段,渐进阶段强交叉,弱变异,突变阶段弱交叉,强变异.

2 系统仿真

2.1 数据预处理

将热处理工艺和加工方法^[5]进行编码,编码见表 1,表 2.

表 1 热处理工艺编码表

代码			编号	
一般分类	F	1	T1	40
	O	2	T2	41
	H	3	T3	42
	T	4	T4	43
	W	5	T5	44
H 细分			T6	45
			T7	46
			T8	47
			T9	48
			T10	49

表2 加工方法编码表

加工方法	铸造	压力铸造	喷射沉积法
编码	1	2	3

原始数据来源于 Matweb 网站和文献[6~9]等. 由于试验条件的不同, 数据中必然存在某些样本会对神经网络训练结果产生影响, 所以要先对数据进行预处理, 剔除无用数据. 以下两种情况的数据为无用数据: ①影响因子的值完全相同, 但是网络的输出值不同; ②只有同一个影响因子的值不同, 但是网络的输出值相同.

为了使得网络的训练效果更佳, 需要对数据进行归一化处理. 使用式(5)对数据进行归一化处理. 将数据归一化到区间(0,1)之间.

$$X_j = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \quad (5)$$

式中, X_i 表示归一化前的输入变量值, X_j 表示归一化后的数据, $X_{\min}$ 和 $X_{\max}$ 分别表示每一个影响因子的变量值的最小值和最大值. 检验数据同样需要经过归一化的处理.

2.2 仿真结果

使用 MATLAB 神经网络工具箱和遗传算法工具箱作为开发工具, 将数据中的 60 组数据用来训练神经网络, 余下的 5 组数据用来检验网络的预测性能. 系统的收敛曲线如图 3 所示.

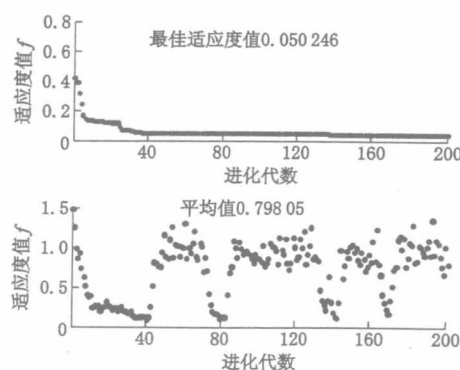


图3 遗传算法寻求最优解的收敛曲线

结果显示数据的输出平方和误差为 0.004 7, 同时, 绝对值百分比误差为 3.47%, 0.058 6%, 0.023 1%, 0.027 6%, 0.031 9%, 绝对误差平均值为 6.780 9 MPa.

数据表明, 该方法构造的神经网络达到了预期的效果. 使用该种方法构造的遗传神经网络具有收敛速度快, 预测效果好的特点.

3 结论

(1) 以 AZ91 合金元素的组成和加工工艺为输入量, 以其力学拉伸性能为输出建立了遗传神经网络, 并且对一部分数据进行了预测. 试验结果表明, 该种网络具有收敛速度快, 预测性能良好的特点, 是辅助合金设计的有力工具.

(2) 采用二进制编码的方式有性能不稳定的缺点, 且阈值 δ 的选取主观性太强, 需要经过多次尝试才能完成, 下一步研究的重点将是改进这两点不足.

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基于细分思想的自由造型技术在 CACD 中的应用

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摘要: 设计一个快速的交互式工具支持概念设计, 将细分曲面及自由变形技术应用到计算机辅助概念设计(CACD)中; 在 t -FFD 算法基础上, 提出了基于细分曲面的自由变形算法思想, 将两者相融合, 克服了 t -FFD 算法为获得光滑变形采用的距离加权融合方法的不足, 使变形空间更光滑, 变形更快速. 应用该算法开发的 CACD 系统可提供用户一个方便快捷的设计工具, 提高设计效率, 优化变形效果.

关键词: 计算机辅助概念设计; Loop 细分曲面; Catmull - Clark 细分曲面; 自由变形

中图分类号: TP391 **文献标识码:** A **文章编号:** 1671 - 7775(2006)05A - 0001 - 04

Application of FFD based on subdivision surfaces in CACD system

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Abstract: In the process of product design, the conceptual design phase is decisive. A real-time interactive tool is developed. Catmull - Clark subdivision surfaces and free-form deformation are used in Computer Aided Conceptual Design (CACD). On the basis of t -FFD, an approach for free-form deformation based on subdivision surfaces is proposed, which may overcome the t -FFD's shortage that uses the blending method for smooth deformation. Finally, the real-time interactive and smoothly deformed shapes are achieved.

Key words: computer aided conceptual design; Loop subdivision surfaces; Catmull - Clark subdivision surfaces; free-form deformation(FFD)

概念设计在整个产品设计过程中起着决定性作用, 概念设计中所作的决策直接决定着产品最终价值的 75% 以上, 而且在其后的详细设计阶段很难纠正由于概念设计的失误而造成的缺陷. 但现有 CAD 软件主要面向详细设计, 缺乏对概念设计的支持, 近年来已有不少学者对计算机辅助概念设计(CACD)进行研究, 但都没有涉及到概念设计中模型的造型方法问题^[1]. 基于 Loop 细分和 Catmull - Clark 细分曲面造型方法, 作者将细分技术应用于空间变形领域, 设计了一个产品外形概念设计原型系统, 系统的整个设计思想如图 1 所示, 目的在于提供

给设计人员一个交互工具来支持概念设计, 允许用户如雕刻家对油泥进行雕塑一般, 直观地修改模型的几何形状.

1 细分方法

目前的 CAD 系统主要采用 NURBS 曲面表示方法. NURBS 曲面适用于详细设计阶段的精确造型, 而对概念设计阶段的形状定义很不方便. 细分曲面是有望代替 NURBS 曲面的新一代曲面造型方法, 它具有任意拓扑适应性的优点, 能够对不同细化精

收稿日期: 2006 - 06 - 10

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度的网格方便地进行整体与局部编辑^[2].

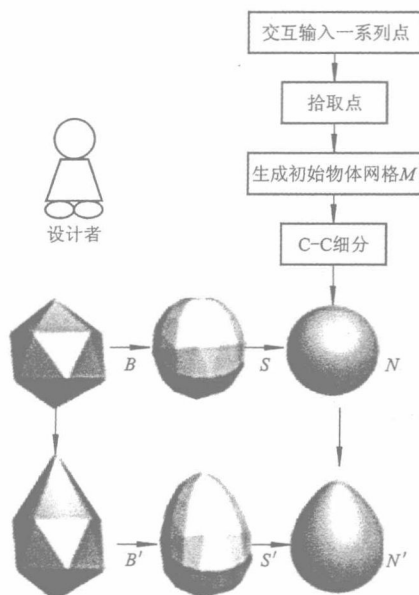


图1 产品外形概念设计原形系统设计思想

Catmull - Clark 细分曲面(见图2)是原始细分格式的典型代表,不仅克服了 NURBS 曲面的缺点,而且能转换为 NURBS 曲面进行精确造型,与现有的 CAD 软件相兼容^[3].

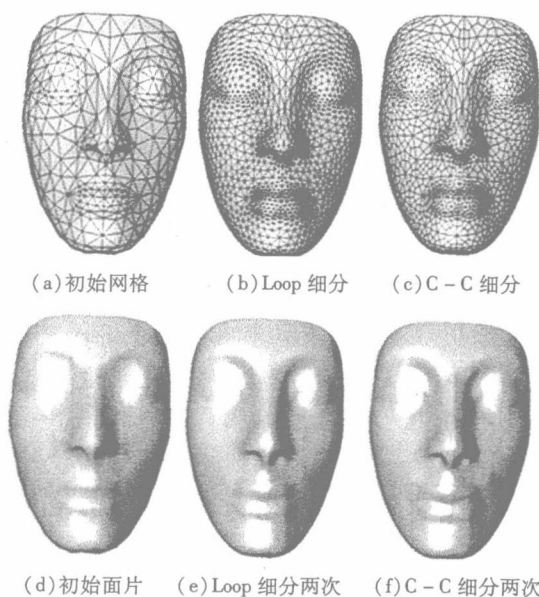


图2 细分曲面

作为研究的关键技术之一, Catmull - Clark 细分方法用来对系统产生的初始物体网格进行细分,表达任意拓扑的复杂形体,同时还能引入诸如尖角和折痕之类的几何特征.

Loop 细分方法基于三向箱样条(three-directional box spline),在规则网格上能够生成 C^2 连续的

曲面^[4](如图2).

采用 Loop 细分的目的在于,对将研究的自由变形算法的控制框架进行细分,以细分曲面作为变形空间,以任意拓扑网格来控制变形,这既包括了物体的整体特征,也包括了局部细节特征,为用户提供了一个快速、直观的工具来编辑物体模型.

2 基于细分曲面的自由变形思想

2.1 自由变形技术的发展

为更方便直观地构造及编辑三维形体,继自由变形(free-form deformation, FFD)造型方法^[5]提出之后,越来越多的学者开始了对这种造型方法的研究. EFFD(extend FFD)方法^[6]使得初始的控制框架除了平行六面体(regular parallelepiped)外,还可以是棱柱体、圆柱体等其他形状,从而增加了 FFD 技术的使用范围. 基于任意拓扑的参数体来控制模型变形的的方法^[7],使得变形控制更加直观和灵活.

t-FFD 造型方法是一种基于三角形网格的变形技术^[8]. 此方法的控制网格由非退化(non-degenerated)的离散三角形组成. 用户通过编辑控制网格来达到变形目的.

为获得光滑的变形空间 t-FFD 方法采用截断距离加权融合的方式,但其光滑性并不能从数学上得到有力的证明. 而且用 t-FFD 方法对物体进行整体变形时,都要计算并存储物体上的每一个点在每一个控制三角形局部坐标系中的参数及影响权,时间空间开销非常大.

2.2 细分曲面与自由变形技术的融合

各种 FFD 方法的关键在于如何获得一个光滑的变形空间. 作者在 t-FFD 算法的基础上,提出了基于细分曲面的自由变形思想. 在详细介绍本算法以前,先作如下定义:

B : 初始控制网格. 它可以是任意拓扑,但必须是二维流形网格.

S : 对 B 作 Loop 细分后的三角网格.

S_i : S 上的一个三角形.

M : 初始物体网格.

B', S', S'_i, M' : 分别是变形后的 B, S, S_i, M .

p_i, p'_i : 分别是修改控制网格前后,初始物体网格 M 上的一个顶点.

q_i, q'_i : 分别是修改控制网格前后, p_i 对应的局部坐标系的原点.

$\Xi = \{q_i; U_i, V_i, W_i\}$: M 上的每一个顶点 p_i

对应的局部坐标系,由 S 上距离顶点 p_i 最近的三角形决定。

为了在控制网格上定义变形空间,首先将模型的每一个顶点直接参数化到控制网格 B 上距离最近的点所在的三角形的局部坐标上。然而,由于 B 是由许多离散面片组成,其变形空间并不光滑,因此得到变形后的物体网格 M' 也是非常不光滑的。虽然控制网格 B 的密度增大,变形效果也更光滑,但是网格 B 的控制顶点相应增多,物体和网格混杂在一起,反而更增加了操作的难度。因此为了操作方便,控制网格 B 的密度不宜过大,保证 B 的分辨率要小于 M 的分辨率。

出于上述考虑,将控制网格 B 的细分网格 S 作为 B 到 M 的中间过渡,定义 S 及其法向张成的空间作为变形空间,将物体 M 上的点通过最近点规则,对应嵌入到变形空间中。对控制网格 B 的改变,经由细分网格 S ,最终传递到物体 M 上,实现对物体网格 M 的变形。而且控制网格 S 对于用户不可见,这便大大改进了变形手段,优化了变形结果。对控制网格应用细分规则的次数可以由用户来定,细分次数越多,虽变形也越光滑,但是系统计算量会很大,不利于实时交互。一般一到两次细分得到的加密网格,即可满足需要。经过各种细分算法的比较,采用 Loop 细分规则获得控制网格的加密网格。

由 Loop 细分规则得到的 Loop 细分网格具有局部性质,如果移动初始网格上的一个顶点,在最终的细分网格或细分曲面上,只会在邻近该顶点的有限区域内发生改变,这便为本变形方法的局部雕塑能力提供了有力的保证,因为当局部改变控制网格时,其细分网格以及在细分网格上张成的变形空间也只会发生局部的改变。

2.2.1 参数化过程

M 上每一个顶点的参数化,是通过找到距离控制网格 B 细分后的细分网格 S 上最近的一个点来实现的。 p_i 是物体网格 M 上的一个顶点,首先要找到细分网格 S 上距离 p_i 最近的点 q_i ,在 q_i 所在的三角形上建立局部坐标系, q_i 为坐标系的原点,将 p_i 参数化到该局部坐标系上,获得点 p_i 的局部坐标参数。

细分网格 S 上每个三角形 $S_i = \triangle q_i q_1 q_2$ 构成一个仿射坐标系 Ξ_i (图3)。 Ξ_i 的三个坐标轴的方向向量由以下公式给出:

$$\begin{cases} U_i = q_1 - q_i \\ V_i = q_2 - q_i \\ W_i = n_q \end{cases} \quad (1)$$

其中 $n_q = \frac{\sum A_i n_i}{\sum A_i}$, 为 q_i 点的平均法向,它由该顶点周围一圈领域内三角片的法向和面积加权平均得到。

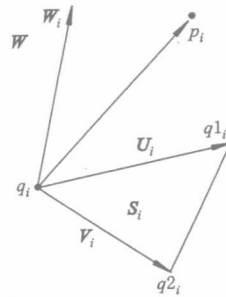


图3 点 q_i 以及对应的在 S_i 上的局部坐标

这样物体网格 M 上的一点 p_i ,便找到在细分网格 S 上距离它最近的那个点 q_i ,并被建立在 q_i 所在三角形上的局部坐标系 $\Xi = \{q_i, U_i, V_i, W_i\}$ 参数化,得到参数 (u_i, v_i, w_i) ,这个参数在变形过程中是保持不变的,可以通过下方方程计算得到。

$$p_i = q_i + u_i U_i + v_i V_i + w_i W_i \quad (2)$$

在建立局部坐标系时,如果直接采用 t -FFD 中的方法,将三角形 S_i 的法向量 $U_i \times V_i / \sqrt{|U_i \times V_i|}$ 作为 W_i ,由于三角面片之间并不连续,这样建立的变形空间是不连续的,因此采用 q_i 点处的周围一圈领域内三角片的法向和面积加权平均得到的光滑法向作为 W_i ,定义细分网格 S 及该插值法向张成的空间作为变形空间,这样的变形空间是连续的,保证了变形空间的光滑性。

2.2.2 控制网格的修改及变形

通过逐个移动控制网格 B 的顶点,对控制网格进行变形,在变形过程中控制网格的拓扑保持不变。最终控制网格 B 的修改,经由细分网格 S 传递到物体网格 M 上,实现变形。

变形后细分网格 S 上的每个三角形 S_i 的几何形状发生改变,局部坐标的原点 q_i' 和 Ξ_i 的三个坐标轴 U_i', V_i', W_i' ,都需要进行重新计算,最后得到 p_i 的新位置 p_i' 。

$$p_i' = q_i' + u_i U_i' + v_i V_i' + w_i W_i' \quad (3)$$

此算法同样应用于物体网格 M 上的其他点,这样物体网格 M 上的每一个顶点,都计算得到了新位置,生成变形后的物体网格 M' 。对控制网格 B 的每一次修改,都将传递到物体网格 M 上,使网格 M 产生光滑的变形。用户可以对控制网格 B 不断地进行修改,最终获得满意的变形效果。

图4为基于文中算法思想的概念设计实例,展示了鹿的耳朵和嘴巴分别被拉长的变形过程。通过移动控制网格上的一个顶点,实现了鹿的耳朵被拉长的变形,编辑和移动控制网格的一条边,实现鹿的嘴巴的拉长变形。这两次变形基本没有对其他部位的几何形状造成影响,而且变形结果非常光滑。

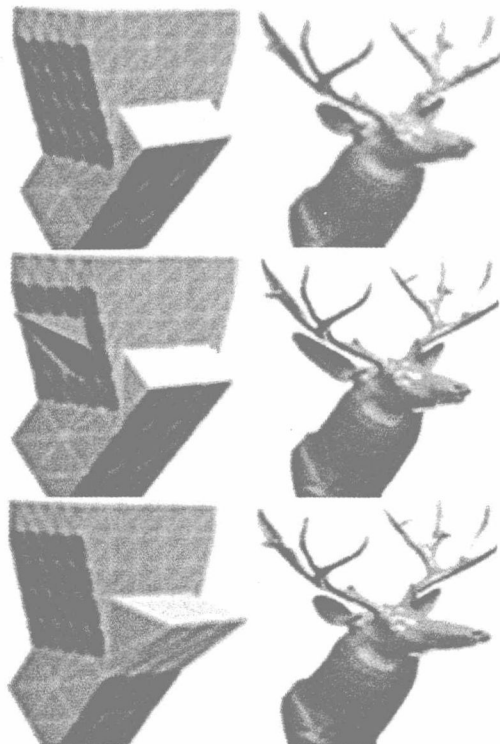


图4 鹿的耳朵和嘴巴的变形过程

3 结 论

作者将细分曲面和自由变形这两大关键技术应用到计算机辅助概念设计中,提出了基于细分方法的自由变形算法思想,该算法将细分网格作为控制网格到物体网格的中间过渡,定义细分网格及其法

向张成的空间作为变形空间.为使变形空间更加光滑,采用的是面积加权平均的插值法向,而不是细分网格的真实法向.应用该算法开发的CACD系统可提供给用户一个方便快捷的设计工具,大大提高设计效率,优化变形效果。

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RESEARCH ON PARAMETRIC DESIGN APPROACH OF BODY SKELETON OF PASSENGER CAR

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Keywords: parametric design; feature-based; constraints; bus body; CAD technology

Abstract

This paper deals with advanced parametric design approach which realized in the process of modelling and assembly of body skeleton of passenger cars. A parameterized model for the body skeleton is created through a programming language in terms of the common structural features of passenger cars, which can be automatically regenerated into another desired model as the crucial parameters have been modified. There are some significant distinctions between conventional 3D solid modelling — a concrete graphical editing activity, and parameterized programmed modelling — an abstract algorithm-construction activity. Constrains, limits and relations of the dimensions have been applied to the model so as to make it a digital and intelligent one in which the CAD technology has been exerted sufficiently as well. Some principles of the features and constraints based on parametric design are also presented. The realization of this parameterized model lays a foundation for the sequential processes of FEM analysis, sensitivity analysis, structural optimization and the product information management, and consequently, it will improve efficiency and reliability for the body structural design and will promote serial production of passenger cars.

1 Introduction

Parametric design is a modern approach widely used in the CAD industry and has become the mainstream of mechanical design [1,2], for it conform well to the modern conception design and the combinative design. While sketching, the designer does not need to care about exact dimensions and may freely apply the constraints afterwards. The renovation of the same series products can be easily realized through modifying the prototype [3].

The realization of rapid modeling and dimension modifying of different design schemes, however, is still a problem [4]. An example is parametric design of the body skeleton. Body is an important assembly of a passenger car, which bears various complex loads during driving. The design of the body is always the key point and needs a long

development cycle in the traditional designing process of a new car [5].

In this paper, a constructive approach of parametric design based on features and constraints of the body skeleton of the medium-size passenger car are presented, and a parametric model is accomplished.

In particular, the paper makes the following technical contributions:

- a) The rationale of the parametric design of the body skeleton of the medium-sized passenger car is presented;
- b) The approach of parameters testing is proposed;
- c) The experience and attention proceeding in the process of the parameterized modeling is presented.

Rest of this paper is structured as follows. Section 2 introduces the theory of the feature-based parametric design. In Section 3, the process and the approach of parametric design of the body skeleton are presented. Section 4 describes the parameters testing and validation of the parametric model. Section 5 presents some matters needing attention summarized in the process of the parametric modelling. Section 6 provides conclusions.

2 Theory of feature-based parametric design

The description of the features is the crux of the feature-based modelling. Feature description includes the representation of the geometric shape, interrelated process mechanism, and high-level semantic information of the feature. The feature of shape is mainly discussed at present.

The process of features shaping can be viewed as constraint solving process, and designing is the detection of valid constraints to structure model and constraint solving essentially.

Constraints can be subdivided into basic constraints, dimension constraints, geometric constraints and topological constraints, which relatively constrain the structure of the parts and components, the interrelations of the geometric elements, the structure dimensions and one entity's position to the other [6,7].

In the process of parametric design of the body skeleton, those parameters which describe the structure features of the whole bus body should be chosen as the main parameters such as vehicle length, vehicle width, and vehicle height and so on to drive other parameters. The rationale of parametric design is shown in Fig. 1. Once given new values, the main

parameters will drive the feature parameters of shape and position of all parts and components assembling body skeleton through basic constraints. Then the feature parameters of shape and position will drive all the dimension parameters through dimension constraints. Afterwards, the geometric benchmark elements and the surface profile elements of the parts are driven by dimension parameters through the geometric and topological constraints, and regenerate the original part into the new desired one. These new parts will regenerate the original components into new ones through the relations and constraints bottom-to-top and restructure the product eventually.

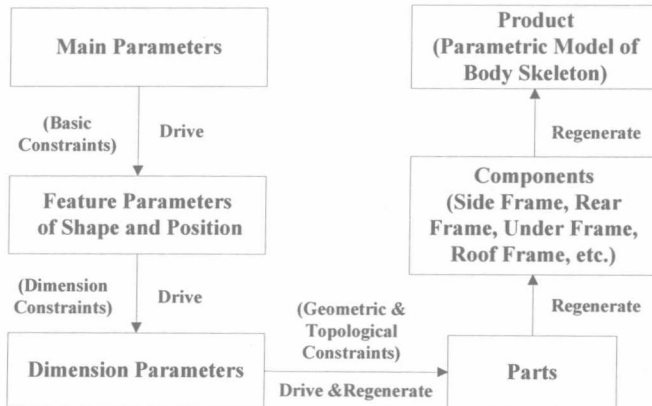


Fig. 1 Rationale

3 Parametric design of the body skeleton

3.1 Research basis

This parametric model is restructured on the basis of existing bus patterns, which are the Pattern NJ6746SKF and Pattern NJ6826TMF of the "Travel in Venice" series of Nanjing Automobile Group Corporation. After modelling the prototype of the body skeleton, the relations and constraints are applied to the model to restructure it into the parametric one. Furthermore, the model data of the two vehicle patterns have stored in the database of the parametric model, which can be utilized anytime.

The vehicles of this series are all with front engine and single door. There are 4 seats per traverse row in spite of the last traverse row with 5 seats. In addition, the front wheel is before the door in the direction of vehicle length for a nice appearance.

3.2 Parametric modelling of the body

Parametric modeling is the basic and vital technology of realization of parametric design [8].

In terms of the parametric design rationale above, a parametric model of body skeleton will be created by the secondary development tool—Pro/Program of Pro/Engineer system.

In Pro/Engineer system, a program will be created automatically which records the modelling process. The designer can modify the program according to the

requirement. Once the program is running, the system can control the system parameter values, whether a feature appear or not and the features' dimension in the manner of human-computer interaction. Consequently, the efficiency will be improved drastically [9].

Considering the complicated structure of the body skeleton and the existing patterns treated as prototypes, the bottom-to-top assembly and design are adopted. The whole body skeleton is divided into several components such as the side frames, rear frame, roof frame, under frame, etc., which are built first. If these components consist of several sub-components, the sub-components should be built first of all.

In addition, given that there are many curve elements in the front frame geometric entity which embodies less main parameters than other components, the parts and the relative parametric relations of it will be applied when the whole body skeleton is assembled.

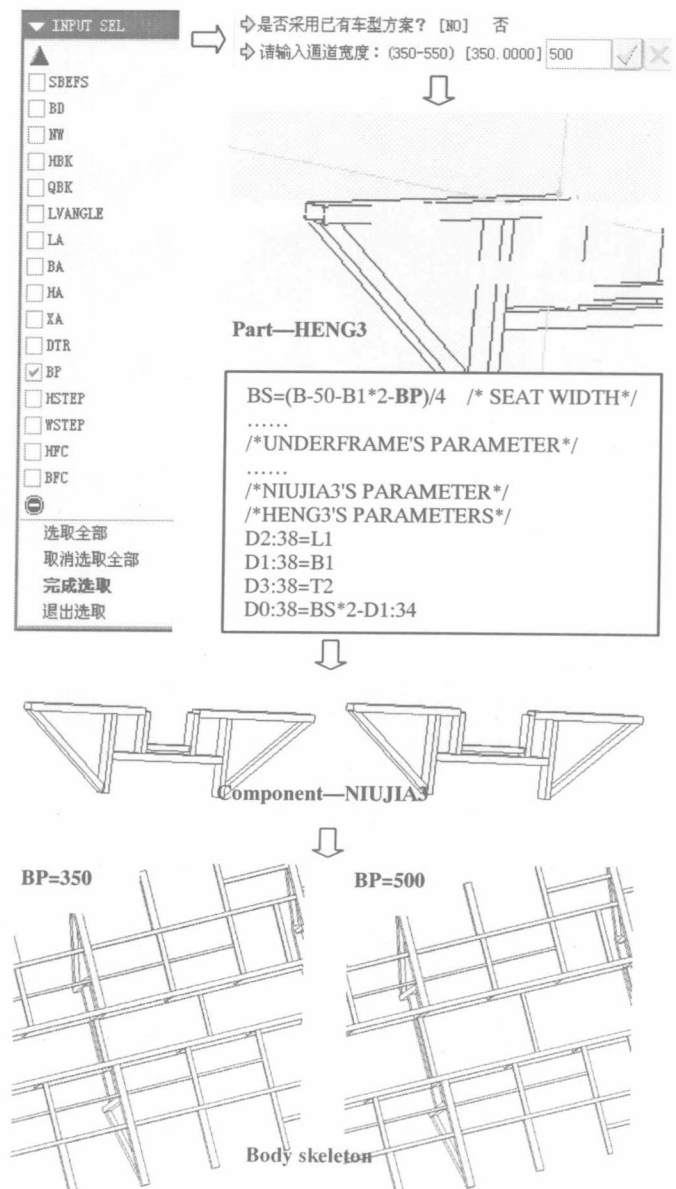


Fig. 2 An example of model modifying

The adoption of the bottom-to-top approach here is beneficial for the detecting and correcting negligence and mistakes in time.

An example is shown in Fig. 2. If the value of the parameter *BP* needs to be changed from 350mm to 500mm, Fig. 2 has shown the process of parameter selection and value input. And a part named *HENG3* which is indirectly driven by *BP* and its relations are presented. As a part of the component *Niujia3* which is sub-component of under frame, *HENG3*'s change will influence and drive the components it belongs to. The ultimate result is also shown that the aisle is widened as desired with all the parts' position relatively unchanged.

3.3 Program scheme

A set of parameters input scheme for driving model to regenerate is proposed. The flow chart of the scheme is shown in Fig. 3. Once clicking the button "regenerate", the program will be launched. The designer can choose whether to input new values of the main parameters or not. If yes, every main parameter with a blank pane will appear. The designer can make a "√" in the blank pane before the parameter to modify. While if the "current values" is chosen, the system will output the original model. In the former case, the system will inquire the designer whether to adopt the existing pattern scheme or not. If adopt, the passenger number should be inputted. Then the model will regenerate into the Pattern NJ6746SKF or Pattern NJ6826TMF according to the number inputted. By contrast, if the designer desires to create a brand-new pattern, he can choose "NO" and input the new values in the blank after the parameters need to modify and with a "√".

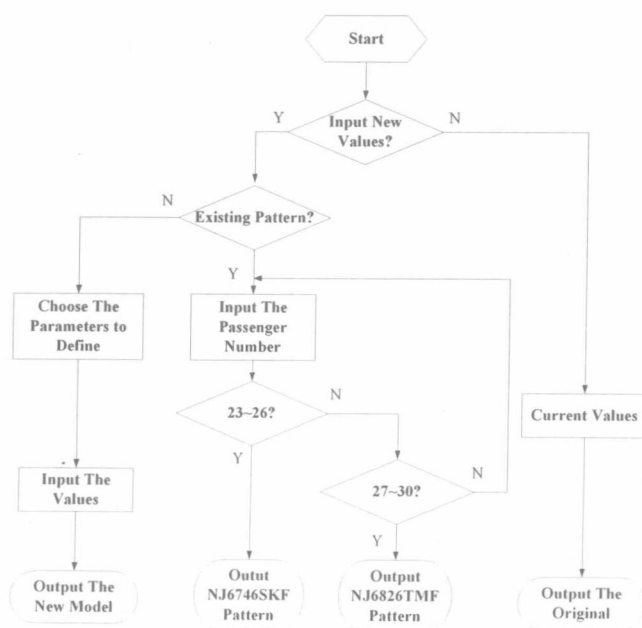


Fig. 3 Parameters input flow chart

If the new model is unsatisfactory, the designer can remodify the relative parameter with the faulty features to restructure the model. For example, if the side windows look too dense, the designer can only choose the parameter *NW* and change its value as desired. Moreover, to complete a perfect design, some detailed parts can also be removed or added.

Apparently, design and modification through this parametric model are much more efficient than the traditional method.

3.4 Main parameters and the range

The main parameters are extracted in the process of the bottom-to-top parametric modeling, which are provided the designer to input their values to drive the model regeneration. Twenty-four main parameters are fixed in terms of the structural features of the bus body, internal arrangement features and other relative features [10]. The prompt conversations are as shown in Fig. 4(a).

Some combinations of parameter values may not be possible to fit the constraints of the system or to regenerate the geometric model. In general, the user does not know exactly which values are allowed and which are not [11,12]. So the parameter ranges are provided in the input statement, which are made reference to the practical design conditions and requirements of the "Travel in Venice" series, vehicle design handbooks and criterions, and some results range of constraints solving as well.

In addition, there are some parameters representing the head structural features of the whole body, which are formulated by the main parameters on the basis of the dimension chains or other constraints. They are called subordinate parameters. Take the rear overhang (ID: *DHX*) for example. As the "Travel in Venice" series vehicle has a front engine and fixed chassis, the parameters ranges of front overhang (ID: *DQX*), wheelbase (ID: *DZ*) and the vehicle length (ID: *L*) are determinate. Therefore, the rear overhang is formulated by front overhang, wheelbase and the vehicle length as " $DHX = L - DQX - DZ$ ". However, in the low level parameter relations, the rear overhang will drive the change of other parameter values.

3.5 Data management of relations

Considering the complex structure and large amount of parts and components, the data management of the numerous parameter relations is significant to avoid redefining or neglecting the relations. Here the single database function of the Pro/Engineer system is mainly utilized.

First, the information of all the parameters defined by the designer including the main parameters and the subordinate parameters can be browsed by the tool "Parameters". ID, value, explanation and other properties are list in its table. Then, the material list and all the parameters and relations can be browsed by the tool "Information". Furthermore, all the modifiable relations are recorded in the tool "Relations". The numerous relations are classified in term of the part and component which they belong to. The commentary of "/*part

(or component) name's parameters*/' is labeled above each corresponding relation group for quick search.

4 Parameters testing and inspection of the parametric model

The method of parametric design and development of the parametric system are discussed frequently, while the research on the parameters testing is barely concerned. The testing for the feasibility and rationality of the selected parameters, however, is necessary whether for a sound parametric system or a reasonable parametric model.

4.1 Parameters testing

After modeling the body skeleton parametrically, the twenty-four parameters should have a testing. Here the designer may inspect the parameters one by one through just changing one parameter's value from minimum to maximum. But given the combinations of parameter values, it may not be possible to satisfy the system of constraints or to regenerate the geometric model. For instance, if the wheelbase keeps a large value while the vehicle length is given a small value, it is probably to regenerate into an unreasonable model or fail to regenerate.

Therefore, parameter testing should follow certain principles and process. The process for parameters testing in this paper is as follows:

- Step 1** Inspect the model with the data of the existing patterns. In this way, the parameter NR will be checked first and every other parameter will have a relatively logical value as well.
- Step 2** Test the parameters one by one in a small value range based on the values gained in step 1 to check if there are constraints or parameters undefined in the model.
- Step 3** Divide the rest twenty-three parameters into three groups in terms of the three directions of vehicle length, width and height. Then inspect the parameters in groups within their value ranges.
- Step 4** Simultaneously change all the parameter values (according to the interaction) to inspect the model's regeneration.

4.2 Inspection of the parametric model

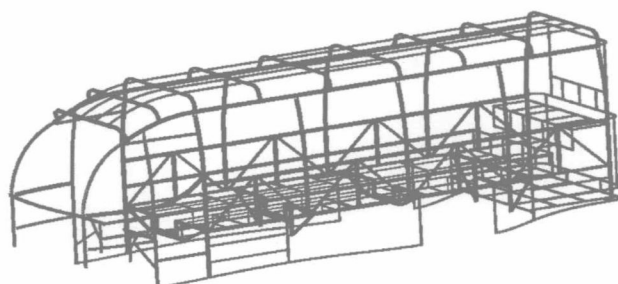
If the four steps above are successfully finished, the parametric model is accomplished.

A body skeleton model of customized parameter values is shown in Fig. 4(b). After changing its main parameters' values, a new model is regenerated successfully. Part of its parameter table is shown in Fig. 4(c).

If the designer dissatisfied with some features, they can change relative parameters to modify the model. The process is shown as Fig. 2. Modifying model through this parametric model is much more efficient than the traditional method.

◇是否采用已有车型方案? [NO] 否
 ◇请输入车长: (7200-9800) [9250.0000] 9350
 ◇请输入车高: (2900-3200) [3100.0000] 3200
 ◇请输入车宽: (2300-2500) [2500.0000] <CR>
 ◇请输入轴距 (55%~60%车长): (4000-5700) [5400.0000] 5500
 ◇请输入前悬: (1050-1100) [1100.0000] 1080
 ◇请输入同向座位间距: (750-850) [830.0000] 835
 ◇请输入座椅长度: (400-550) [500.0000] 500
 ◇请输入最前排座垫前缘至障碍物距离: (280-350) [350.0000] 320

(a)



(b)



(c)

Fig. 4 A body skeleton of customized parameter values
 (a) Prompt conversation
 (b) A new model (c) Part of the parameter table