第二届崇真青年学者学术沙龙报告

计算机与人工智能学院

武汉纺织大学

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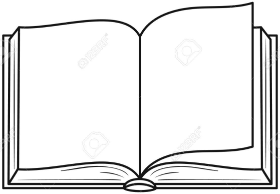
汇报时间：2022 年 4 月 23 号

汇报内容

- 教育背景
- 博士课题
- 近五年发表论文



教育背景

- 本科　大连工业大学　2011.09-2015.07
- 硕士　上海东华大学　2015.09-2018.03
  - 专业：数字化纺织工程
  - 研究内容：椭圆傅立叶和凸包算法在人体建模的应用
- 博士　日本京都工艺纤维大学　2018.09-2022.03
  - 专业：先端纤维学
  - 研究内容：遗传算法和神经网络在材料科学的应用

研究契机

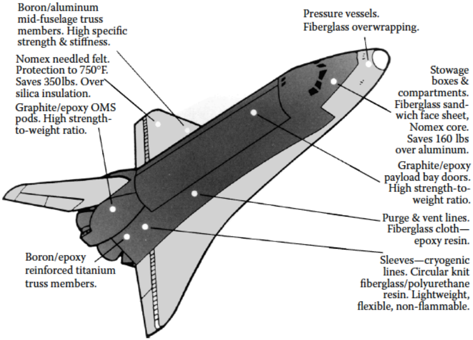


Figure 1: **层合材料的应用一** (Graphic courtesy of M.C. Gill Corporation, http://www.mcgillcorp.com.)

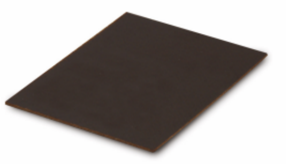


Figure 2: **层合材料的应用二** (https://www.thegillcorp.com)

什么是层合材料?

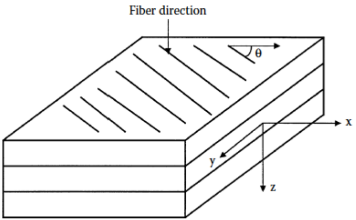


Figure 3: 层合材料结构图 (来源: Autar k. kaw 2006)

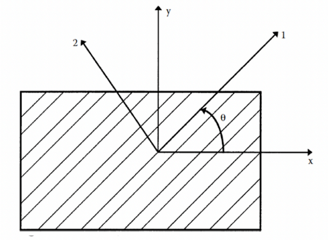


Figure 4: 层合材料的断面图 (来源: Autar k. kaw 2006)

- 层合材料设计:
    - 目标：强度
    - 约束条件：重量，成本等
    - 变量：铺层角度，铺层数，材料等
- 本质上是受约束离散变量的优化设计问题

- 1. **构造目标函数** $f(x)$.
- 2. **为满足约束条件，添加惩罚项** $\phi_1(x), \phi_2(x), \cdots, \phi_n(x)$
- 3. **重新构造目标函数** $f(x)+c_1\phi_1(x)+c_2\phi_2(x)+\cdots+c_n\phi_n(x)$

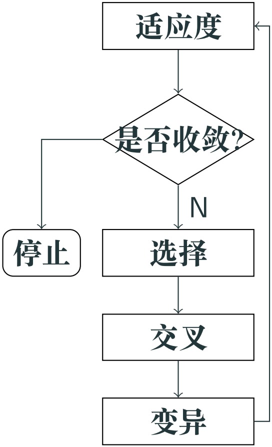


Figure 5: 遗传算法流程图

- 1. **构造目标函数** $f(x)$.
- 2. **为满足约束条件，在群体中维护不同的子群**
- 3. **不改变目标函数** $f(x)$.

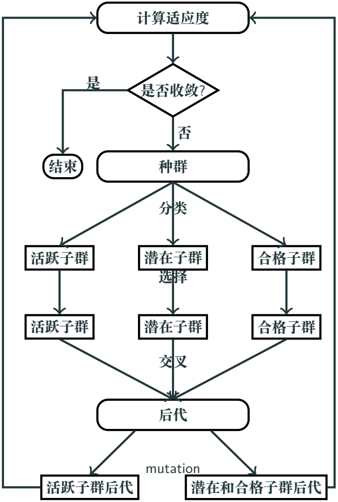


Figure 6: 改进后遗传算法流程图

- 活跃个体和活跃子群：如果一个个体的约束值远小于约束条件，那么我们称该个体为活跃个体，该个体所在的子群为活跃子群。
- 潜在个体和潜在子群：如果一个个体的约束值小于或者接近约束条件，那么我们称该个体为潜在个体，该个体所在的子群为潜在子群。
- 合格个体和合格子群：如果一个个体的约束值满足约束条件，那么我们称该个体为合格个体，该个体所在的子群为合格子群。

$$md = [CT_1, \cdots, CT_{n-1}, CT_n] - [ICV_1, \cdots, ICV_{n-1}, ICV_n] \quad (1)$$

- md 表示变异向量
- CT_i 表示第 i 个约束条件，比如质量，强度等。
- ICV_i 表示当前个体的相应的约束值。

$$\text{长度变异算子} = \begin{cases} LMC * [0, \sum_{i=1}^{N} md_i] \text{ if } \sum_{i=1}^{N} md_i > 0 \\ LMC * [\sum_{i=1}^{N} md_i, 0] \text{ if } \sum_{i=1}^{N} md_i < 0 \end{cases} \quad (2)$$

$$\text{角度变异算子} = \begin{cases} 0.5, \ \text{AM} = [0, AMC \sum_{i=1}^{N} (|CT_i - CV_i|)] \\ 0.5, \ \text{AM} = [AMC \sum_{i=1}^{N} (-|CT_i - CV_i|), 0] \end{cases} \quad (3)$$

- Huiyao Zhang, Atsushi Yokoyama. 2021. A Technique for Constrained Optimization of Cross-ply Laminates Using a New Variant of Genetic Algorithm. International Journal of Advanced Computer Science and Applications, 12(6): 760-767.
- Huiyao Zhang, Atsushi Yokoyama. 2022. Optimum Design of Laminated Composites for Minimum Thickness by a Variant of Genetic Algorithm. Journal of Textile Engineering(accepted)

问题二：如何预测层合材料的强度?

$$
\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{11} & B_{12} & B_{16} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} k_x \\ k_y \\ k_{xy} \end{bmatrix}
$$

$$
\begin{bmatrix} M_x \\ M_y \\ M_{xy} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{12} & B_{22} & B_{26} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} D_{11} & D_{12} & D_{16} \\ D_{11} & D_{12} & D_{16} \\ D_{16} & D_{26} & D_{66} \end{bmatrix} \begin{bmatrix} k_x \\ k_y \\ k_{xy} \end{bmatrix}
$$

$$A_{ij} = \sum_{k=1}^{n} (\overline{Q_{ij}})_k (h_k - h_{k-1}) i = 1,2,6, j = 1,2,6,$$

$$B_{ij} = \frac{1}{2} \sum_{k=1}^{n} (\overline{Q_{ij}})_k (h_k^2 - h_{k-1}^2) i = 1,2,6, j = 1,2,6,$$

$$D_{ij} = \frac{1}{3} \sum_{k=1}^{n} (\overline{Q_{ij}})_k (h_k^3 - h_{k-1}^3) i = 1,2,6, j = 1,2,6.$$

- Maximum stress failure

$$
SF_{MS}^k = \text{min of} \begin{cases} SF_X^k = \begin{cases} \frac{X_t}{\sigma_{11}}, & \text{if } \sigma_{11} > 0 \\ \frac{X_c}{\sigma_{11}}, & \text{if } \sigma_{11} < 0 \end{cases} \\ SF_Y^k = \begin{cases} \frac{Y_t}{\sigma_{22}}, & \text{if } \sigma_{22} > 0 \\ \frac{Y_c}{\sigma_{22}}, & \text{if } \sigma_{22} < 0 \end{cases} \\ SF_S^k = \left\{ \frac{S}{|\tau_{12}|} \right. \end{cases}
$$

- Tsai-wu failure theory

$$
\begin{aligned} & H_1\sigma_1 + H_2\sigma_2 + H_6\tau_{12} + H_{11}\sigma_1^2 + H_{22}\sigma_2^2 \\ & \quad + H_{66}\tau_{12}^2 + 2H_{12}\sigma_1\sigma_2 < 1 \end{aligned}
$$

如何设计网络的拓扑结构?

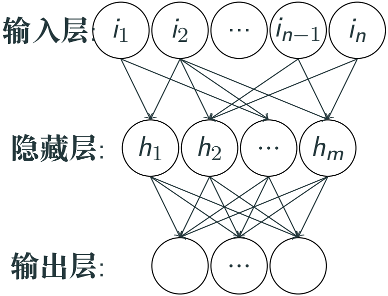


Figure 7: 神经网络模型

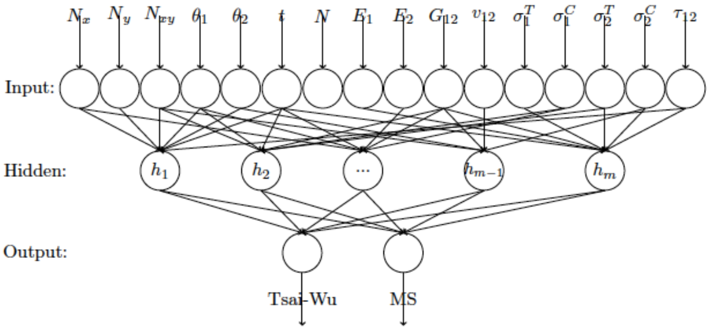


Figure 8: 用于层合材料强度预测的神经网络

研究方法

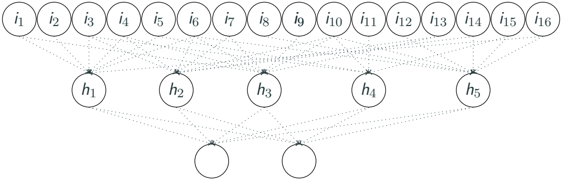
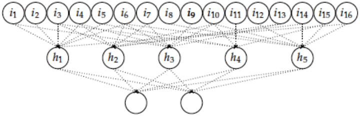


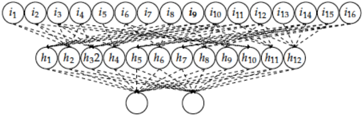
Figure 9: 材料预测模型

Table 1: 网络结构的二进制表示

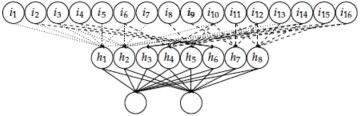
Nodes	i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}	i_{11}	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}	f	f
h_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
h_2	0	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	1	1
h_3	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0
h_4	0	0	1	0	1	0	0	0	0	1	0	1	0	0	1	0	0	1
h_5	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1	1	0	1



(A) Parent 1



(B) Parent 2



(C) Child

Figure 10: 基于遗传算法产生子神经网络

Table 2: 全连接神经网络和演化神经网络实验结果对比

Model	Training Error	Validation Error
Fully-connected ANN	0.054	0.055
GA-based ANN	0.051	0.050

- Huiyao Zhang, Atsushi Yokoyama. 2021. Predicting Strength Ratio of Laminated Composite Material with Evolutionary Artificial Neural Network. International Journal of Advanced Computer Science and Applications, 12(6): 11-18.

近五年发表论文

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- Huiyao Zhang, Atsushi Yokoyama. 2021. Predicting Strength Ratio of Laminated Composite Material with Evolutionary Artificial Neural Network. International Journal of Advanced Computer Science and Applications, 12(6): 11-18.
- Huiyao Zhang, Atsushi Yokoyama. 2022. Optimum Design of Laminated Composites for Minimum Thickness by a Variant of Genetic Algorithm. Journal of Textile Engineering(accepted).
- Hui-Yao Zhang, Duan Li, Hao-Yang Xie, Yue-Qi Zhong. 2017. A Study on the Female Chest Contour with Elliptic Fourier Analysis. Journal of Fiber Bioengineering and Informatics, 10(3): 131-139.
- Hui-Yao Zhang, Duan Li, Hao-Yang Xie, Yue-Qi Zhong. 2017. Elliptic Fourier Analysis on Female Chest Contour. Textile Bioengineering and Informatics Symposium.

请各位老师批评指正

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