无锡太湖学院物联网工程学院面试汇报

汇报人：张辉耀
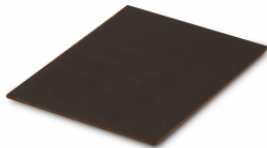
汇报时间：2022 年 4 月 24 号

教育背景

- **本科　大连工业大学**
- **硕士　上海东华大学**
    - **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**
    - **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
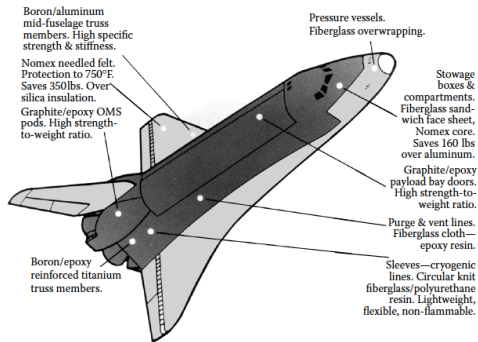
Figure 1: 复合材料的应用一 (Graphic courtesy of M.C. Gill Corporation, http://www.mcgillcorp.com.)

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

什么是层合板?
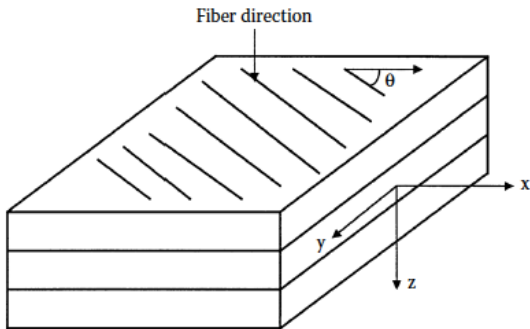
Figure 3: Schematic of a laminate. (Source: Autar k. kaw 2006)

How to Predict the Strength of a Laminate ?

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

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

$$(1)$$

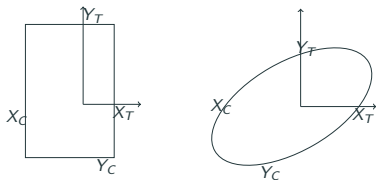$$A_{ij} = \sum_{k=1}^{n} (\overline{Q_{ij}})_k (h_k - h_{k-1}) \quad i = 1, 2, 6, j = 1, 2, 6,$$

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

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

$$(2)$$

How to Predict the Strength of a Laminate ?

Figure 4: Schematic failure surfaces for maximum stress and quadratic failure criteria

- Maximum stress failure

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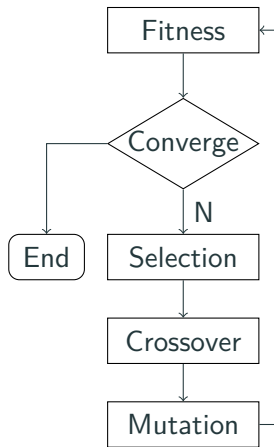
- Tsai-wu failure theory

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

But, How to Design a Laminate?

- Target: strength
- Constraints: weight cost etc.
- Variable: ply directiron, number of plies, material

- 1. formulate the objective function, assume it is $f(x)$.

- 2. to satisfy the constraints, adding punishment items $\phi_1(x), \phi_2(x), \cdots, \phi_n(x)$

- 3. reformulate the objective functions as $f(x) + c_1\phi_1(x) + c_2\phi_2(x) + \cdots + c_n\phi_n(x)$
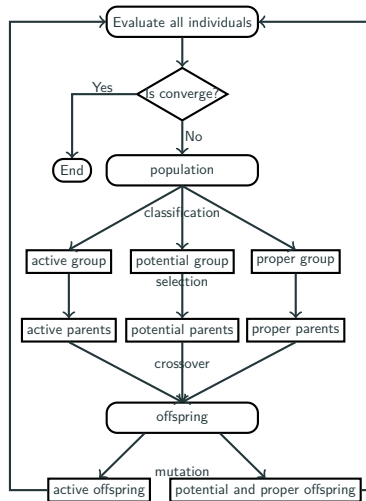

Figure 5: GA process

1. Methodology

- 1. formulate the objective function, assume it is $f(x)$.
- 2. to satisfy the constraints, maintaining different groups in the population
- 3. do not change the objective function $f(x)$.

Figure 6: General flowchart of proposed GA model.

Definition

- An individual is active if its constraint value is far smaller than the threshold. A group is consist of active individuals are called as active group.
- An individual is potential if its constraint value is close but smaller than the thresold. The corresponding group is refered as potential group.
- An individual is proper if it satisfy all the constraints. Its counterpart group is written as proper group.

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

- md means mutation direction.
- CT_i denotes the i-th constraint, such as weight, strength ratio.
- ICV_i denotes individual's i-th constraint value, such as, weight, strength ratio of current individual.

- length mutation $=$

$$\begin{cases} LMC * [0, \sum_{i=1}^{N} md_i] & \text{if } \sum_{i=1}^{N} md_i > 0 \\ LMC * [\sum_{i=1}^{N} md_i, 0] & \text{if } \sum_{i=1}^{N} md_i < 0 \end{cases}$$

LMC stands for length mutation coefficient, it's a positive integer.

- $P(AM) =$

$$\begin{cases} 0.5, & AM = [0, AMC \sum_{i=1}^{N} (|CT_i - CV_i|)] \\ 0.5, & AM = [AMC \sum_{i=1}^{N} (-|CT_i - CV_i|), 0] \end{cases}$$

AMC stands for angle mutation coefficient.

1. Result

Table 1: Comparison of experiment results of Choudhury and Mondal's and current study under in-plane loading $N_x = 1e6$ N. The results of present study is from previous experiment.

Cross Ply $[0_M/90_N]$	Choudhury and Mondal's study		Present study	
Material	Glass-Epoxy	Graphite-Epoxy	Glass-Epoxy	Graphite-Epoxy
M	68	17	76	19
N	72	18	49	2
no. of lamina(n)	140	35	125	21
SR	2.01	2.10	2.08	2.15
weight	9.10	1.84	8.12	1.10
cost	140	87.50	125	53

发表论文

- 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?

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

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

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

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

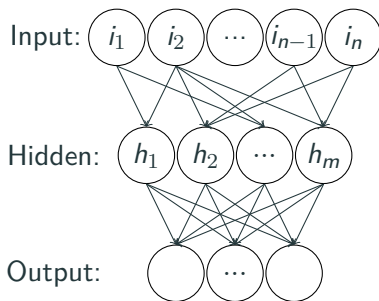$D_{ij} = \frac{1}{3} \sum_{k=1}^n (\overline{Q_{ij}})_k (h_k^3 - h_{k-1}^3) i = 1, 2, 6, j = 1, 2, 6,$

- Maximum stress failure

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

- Tsai-wu failure theory

$$H_1 \sigma_1 + H_2 \sigma_2 + H_6 \tau_{12} + H_{11} \sigma_1^2 + H_{22} \sigma_2^2$$
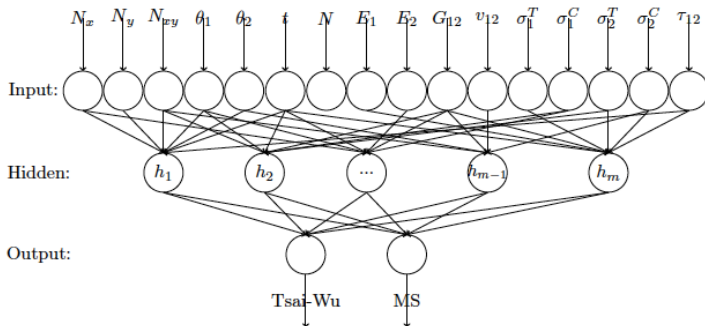$$+ H_{66} \tau_{12}^2 + 2 H_{12} \sigma_1 \sigma_2 < 1$$
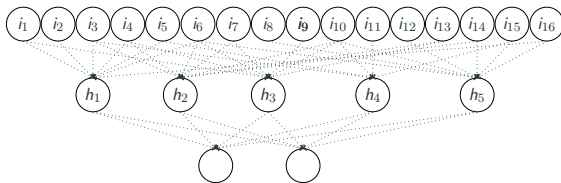
如何设计网络的拓扑结构?

Figure 7: Neural Network Model

Figure 8: General neural network for prediction the strength of an angle ply laminate.
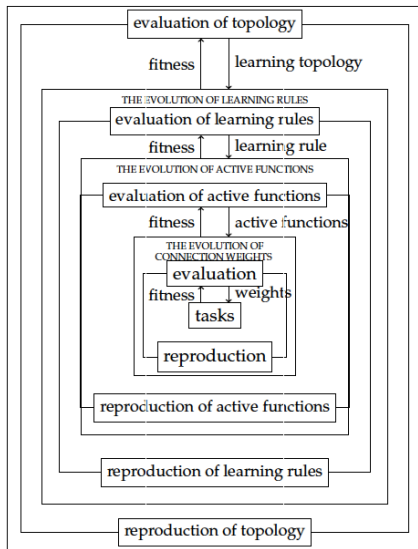
Figure 9: Example of proposed architecture.

Table 2: The binary representation of Figure 9.

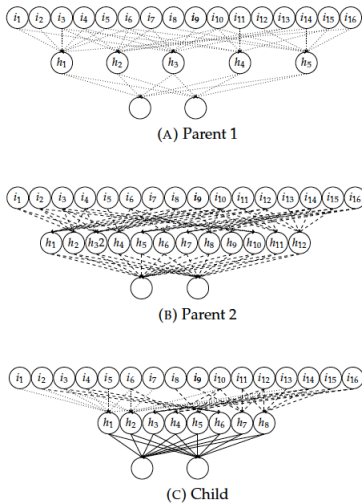| Nodes	i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}	i_{11}	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}	f	f
h_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
h_2	0	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	1	1
h_3	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0
h_4	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1
h_5	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1	1	0	1

2. Methodology

Figure 10: The evolution of this neural network

2. Methodology

(A) Parent 1

(B) Parent 2

(C) Child

Figure 11: Examples of three ANNs, with (a) and (b) as parent ANNs, and (c) as the child of (a) and (b).

Table 3: Part of train dataset

	Input			Output	
Load	Laminate Structure	Material Property	Failure Property	MS	Tsai-Wu
-70,-10,-40,	90,-90,4,1.27,	38.6,8.27,0.26,4.14,	1062.0,610.0,31,118,72,	0.0102,	0.0086
-10,10,0,	-86,86,80,1.27,	181.0,10.3,0.28,7.17,	1500.0,1500.0,40,246,68,	0.4026,	2.5120
-70,-50,80,	-38,38,4,1.27,	116.6,7.67,0.27,4.173,	2062.0,1701.0,70,240,105,	0.0080,	0.0325
-70,80,-40,	90,-90,48,1.27,	38.6,8.27,0.26,4.14,	1062.0,610.0,31,118,72,	0.0218,	0.1028
-20,-30,0,	-86,86,60,1.27,	181.0,10.3,0.28,7.17,	1500.0,1500.0,40,246,68,	0.6481,	0.9512
0,-40,0,	74,-74,168,1.27,	181.0,10.3,0.28,7.17,	1500.0,1500.0,40,246,68,	1.3110,	3.9619

2. Result

Table 4: Comparsion of Fully-connected Neural Network and GA-based Neural Network

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

- 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.

Thank You