基于机器学习的冷轧板行功效系数矩阵辨识实验

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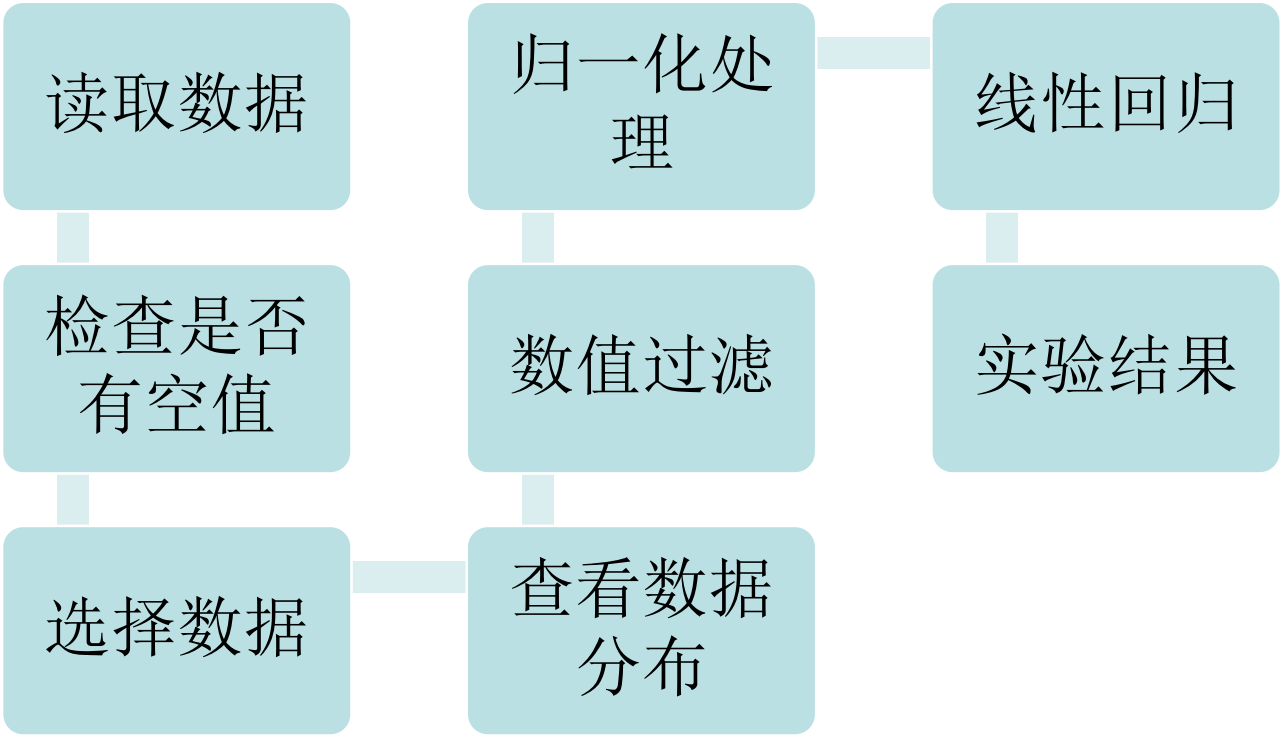
一、数据处理
二、机器学习方法
1、最小二乘法
2、脊回归
3、神经网络
三、实验结果

一、数据处理

流程图



一、数据处理

读取数据，并检查数据是否有空，然后每行数据减去上一行，数据维度（7113， 70）

	V6	V7	V8	V9	V10	V11	...	V90	V91	V92	V93	V94	V95
1	-18.1	-2.0	-2.2	8.3	-0.4	-0.94	...	1.0090	1.2890	1.123	0.650	1.077	1.4575
2	-16.9	2.0	9.3	6.8	9.5	-0.38	...	0.6490	1.1940	0.849	0.550	0.837	1.5765
3	-2.5	3.0	2.9	-1.3	1.1	-0.41	...	1.1236	1.5866	1.129	1.270	1.914	3.5270
4	-5.5	5.0	3.4	-0.3	22.0	-0.42	...	-0.5625	-0.5359	0.299	1.589	2.167	5.1750
5	-10.3	3.0	3.7	1.0	13.2	-0.46	...	-0.9451	-0.6617	-0.112	0.126	1.507	3.6870

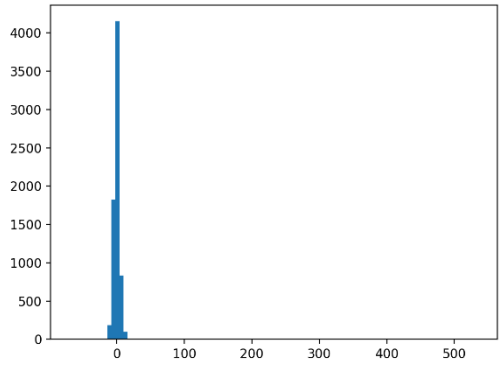
数据前5行

```
V6     0
V7     0
V8     0
V9     0
V10    0
      ..
V91    0
V92    0
V93    0
V94    0
V95    0
```

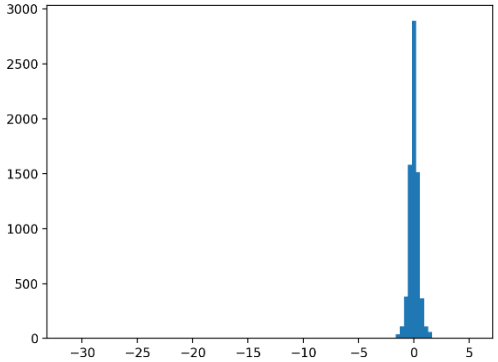
检查是否有空

一、数据处理

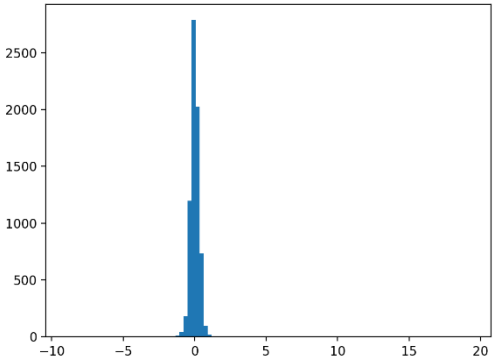
划分数据：选择五号机架的轧制力 V10、五号轧机的工作辊 V15、五号轧机的中间辊弯辊力 V16 作为自变量，V62-V95为因变量
X维度(7113, 3) Y维度(7113, 34)
数据数值分布如下图（未处理）



V10 数据分布
最大值：533.7
最小值：-68.2



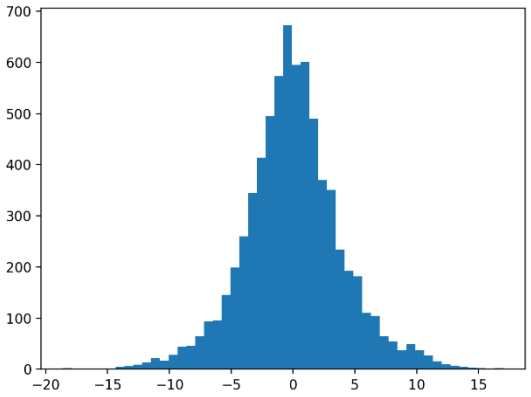
V15 数据分布
最大值：5.31
最小值：-31.33



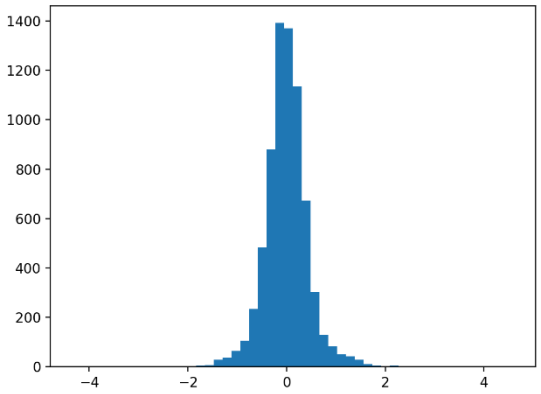
V16 数据分布
最大值：19.307
最小值：-9

一、数据处理

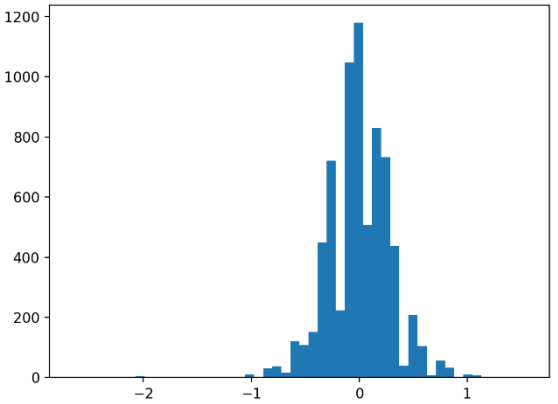
数据过滤：最大最小值限制后的数据，下方区间处理后的数据取值区间
X-(7098, 3) Y-(7098, 34)



V10
[-20, 20]



V15
[-5, 5]



V16
[-2, 2]

一、数据处理-归一化

由于不同的特征数据量级差异过大，需要对数据进行归一化处理，对所有特征进行 MinMax 缩放，使其数值在[-1, 1]范围内，计算公式如下：

$$x_{std} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

$$x_{scaled} = x_{std} * (MAX - MIN) + MIN$$

其中 MAX 为 1，MIN 为-1，max()表示求特征的最大值，min()表示求特征的最小值。

注：将X按列进行MINMAX归一化，Y不做处理

二、机器学习方法-模型分析

板形调控功效系数是在一种调控手段的单位调节量作用下，冷轧机架的轧辊辊缝凸度沿带钢宽度方向上各处的变化量，可表示为：

$$\Delta f_j(x_i) = \Delta u_i \cdot eff_{i,j}^{(1)} + \Delta u_{i,j}^2 \cdot eff_{i,j}^{(2)} + \cdots + \Delta u_i^n \cdot eff_{i,j}^{(n)}$$

$$eff_{i,j} = \frac{\Delta f_j(x_i)}{\Delta u_j}$$

$$E = \frac{\Delta f(x)}{\Delta u} = \begin{bmatrix} \Delta f(x_1) \\ \Delta f(x_2) \\ \vdots \\ \Delta f(x_{34}) \end{bmatrix} \begin{bmatrix} \frac{1}{\Delta u_1} & \frac{1}{\Delta u_2} & \cdots & \frac{1}{\Delta u_5} \end{bmatrix}$$

$$= \begin{bmatrix} eff_{1,1} & eff_{1,2} & \cdots & eff_{1,5} \\ eff_{2,1} & eff_{2,2} & \cdots & eff_{2,5} \\ \vdots & \vdots & \ddots & \vdots \\ eff_{34,1} & eff_{34,2} & \cdots & eff_{34,5} \end{bmatrix}$$

二、机器学习方法-最小二乘法

最小二乘法：

由于功效系数只考虑线性部分，故可用最小二乘法求解功效矩阵，最小二乘法的目标是最小化误差函数：

目标函数：$\min_{W} ||XW - Y||_2^2$

正规方程解：$W=(X^T X)^{-1} X^T y$

二、机器学习方法-脊回归

脊回归：

脊回归就是在线性回归的基础上，加上正则化

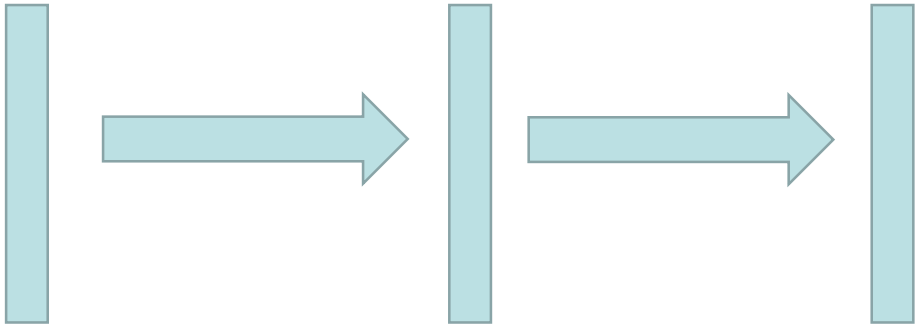
目标函数：

$$\min_{W} ||XW - Y||_2^2 + \alpha||W||_2^2$$

正规方程解：

$$W=(X^TX + \alpha E)^{-1}X^Ty$$

二、机器学习方法- 神经网络



输入层：3　　隐藏层：64　　输出层：34
无激活函数　　无激活函数

输入-隐藏参数W1维度：(3, 64)
隐藏-输出参数W2维度：(64, 34)
则功效矩阵为：（W1 @ W2）.T　　（@表示矩阵乘法）

数据集划分：数据中20%作为测试集，验证模型效果（使用决定系数）
优化器：Adam

二、机器学习方法- 神经网络

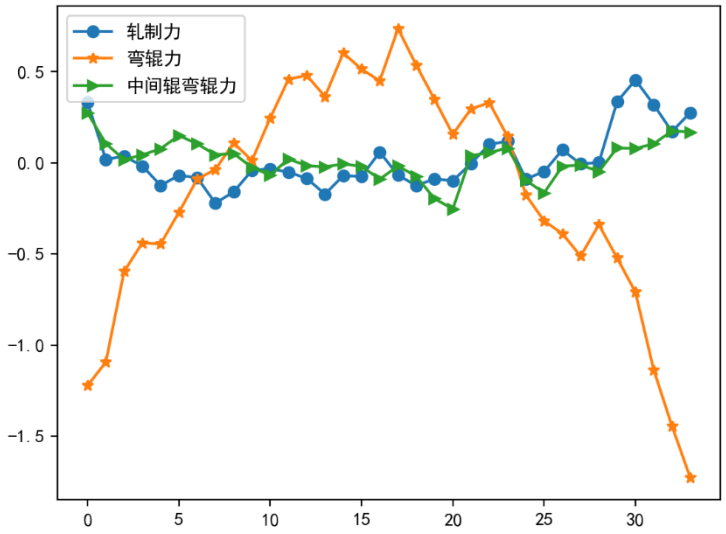
决定系数：

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{N} (y_i - \bar{y})^2}$$

模型预测越准确，上式中等式右侧趋于0

三、实验结果

最小二乘法：

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 [ 3.71776017e-02 -5.95523409e-01  1.82425399e-02]
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 [-1.58712521e-01  1.09683207e-01  5.10757376e-02]
 [-4.15616219e-02  1.27686208e-02 -2.47734373e-02]
 [-3.16678605e-02  2.45850454e-01 -6.74549825e-02]
 [-5.08941901e-02  4.59187086e-01  2.18747500e-02]
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 [ 7.13986544e-02 -3.88294734e-01 -1.86885572e-02]
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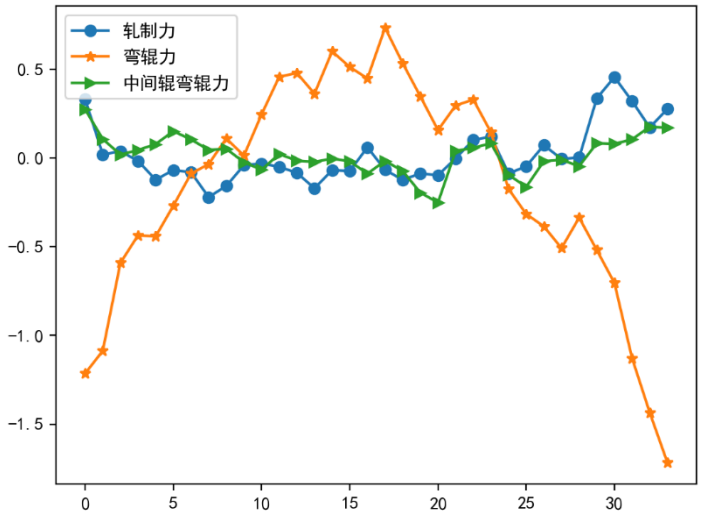
 [ 3.20023623e-01 -1.13488354e+00  1.04359300e-01]
 [ 1.71698687e-01 -1.44302375e+00  1.75580987e-01]
 [ 2.75609625e-01 -1.72596670e+00  1.69486419e-01]]
```

三、实验结果

脊回归：

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 [-1.71867384e-02 -4.36185950e-01  4.38047811e-02]
 [-1.23553660e-01 -4.41977591e-01  7.76651999e-02]
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 [ 5.90553766e-02  4.47399890e-01 -8.89181070e-02]
 [-6.72077187e-02  7.32339558e-01 -1.69910804e-02]
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 [-8.75068322e-02  3.45957173e-01 -1.95902666e-01]
 [-9.83949543e-02  1.56131919e-01 -2.51595802e-01]
 [-2.38018156e-03  2.94763975e-01  3.89428332e-02]
 [ 1.00406498e-01  3.28095721e-01  5.66272523e-02]
 [ 1.19579891e-01  1.43928586e-01  8.14848573e-02]
 [-8.81893060e-02 -1.75202410e-01 -9.51340378e-02]
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 [ 1.42677024e-03 -3.36749036e-01 -4.64884592e-02]
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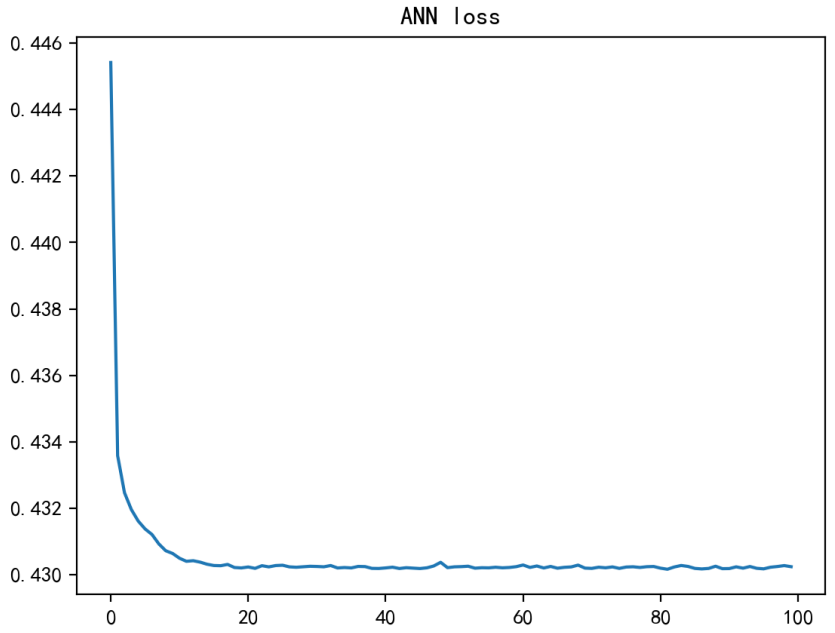
 [ 1.71188073e-01 -1.43416234e+00  1.75240598e-01]
 [ 2.74892079e-01 -1.71534691e+00  1.69229651e-01]]
```

三、实验结果

神经网络训练集损失和测试集决定系数：

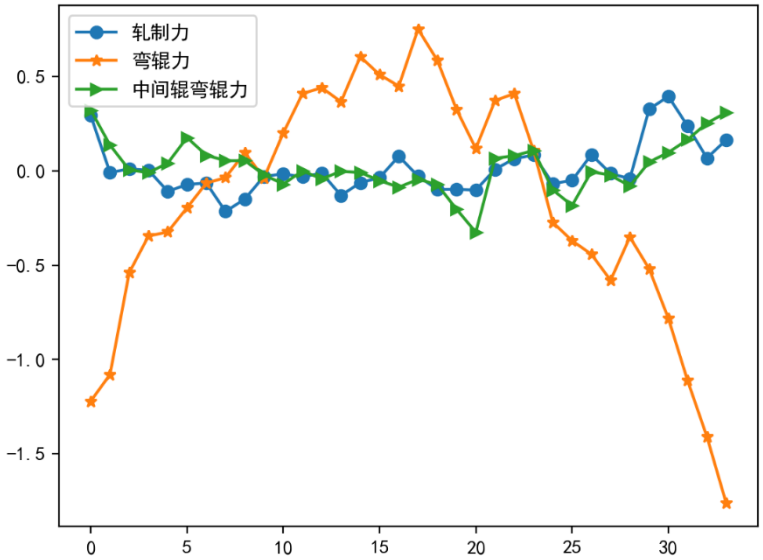
测试集决定系数
R=0.005442743562043028



训练过程中的损失

三、实验结果

神经网络：

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 [ 8.59649863e-02 -4.41547866e-01 -3.83544762e-03]
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```

Github:
https://github.com/langdu/Al_course/tree/main/function_matrix_latest

Thank You