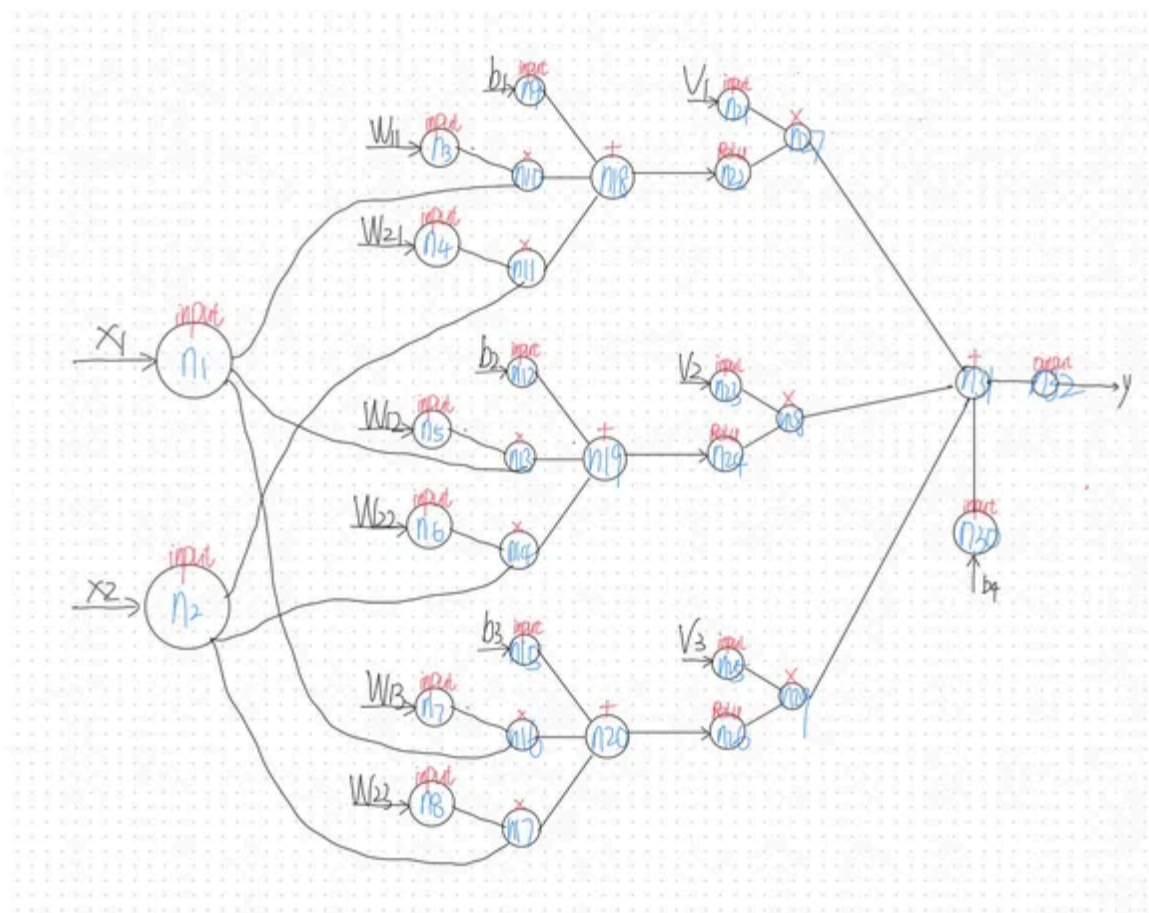


# 第六次上机作业

## 1. 写出上面网络的公式

$$y_1 = \sum_{j=1}^3 v_j \cdot \text{ReLU} \left( \sum_{i=1}^2 w_{ij} x_i + b_j \right) + b_4$$

## 2. 绘制计算图如下



## 3. 计算前向传播

按照上述计算图编写Python代码见 `src/Q3_forward_pass.py` :

运行计算, 得到结果为0.0

## 4. 反向传播计算梯度

按照上述计算图编写Python代码见 `src/Q4_backward_pass.py` :

运行计算，得到各参数梯度如下：

梯度结果：

$$\frac{\partial y}{\partial x_1}(2, -2) = 0.0$$

$$\frac{\partial y}{\partial x_2}(2, -2) = 0.0$$

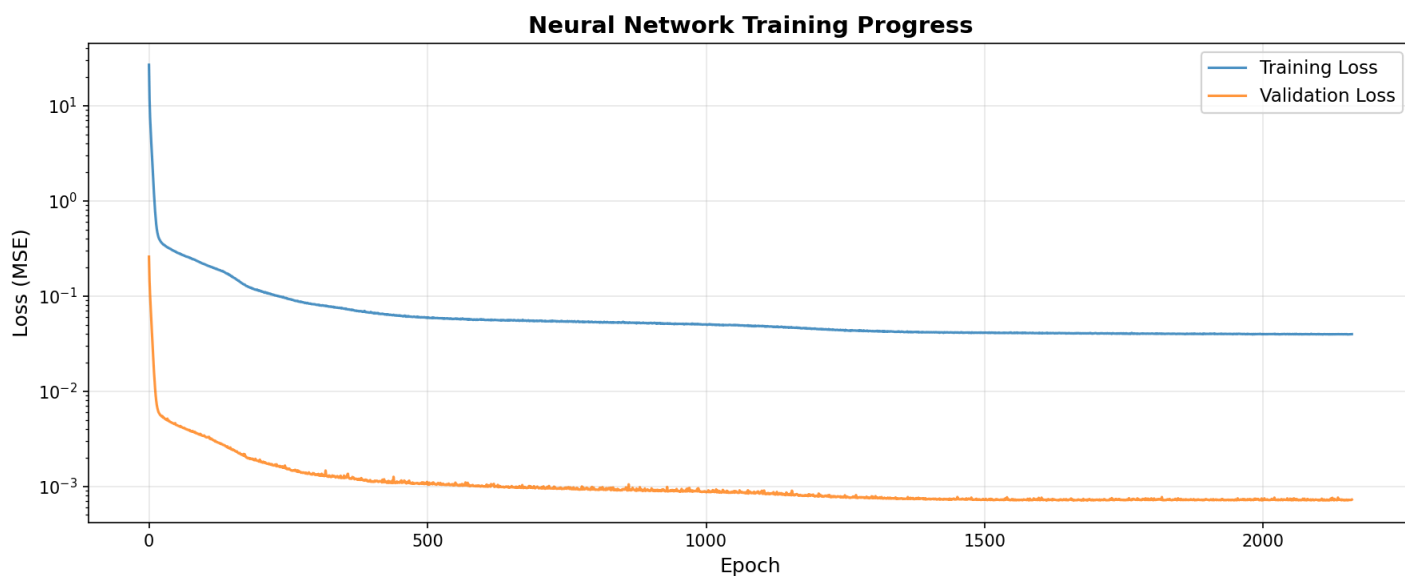
## 5. 训练网络预测函数 $f(x_1, x_2) = 2x_1 + x_1x_2$

按照上述计算图编写训练代码,见 `src/Q5_train_predict.py` 。

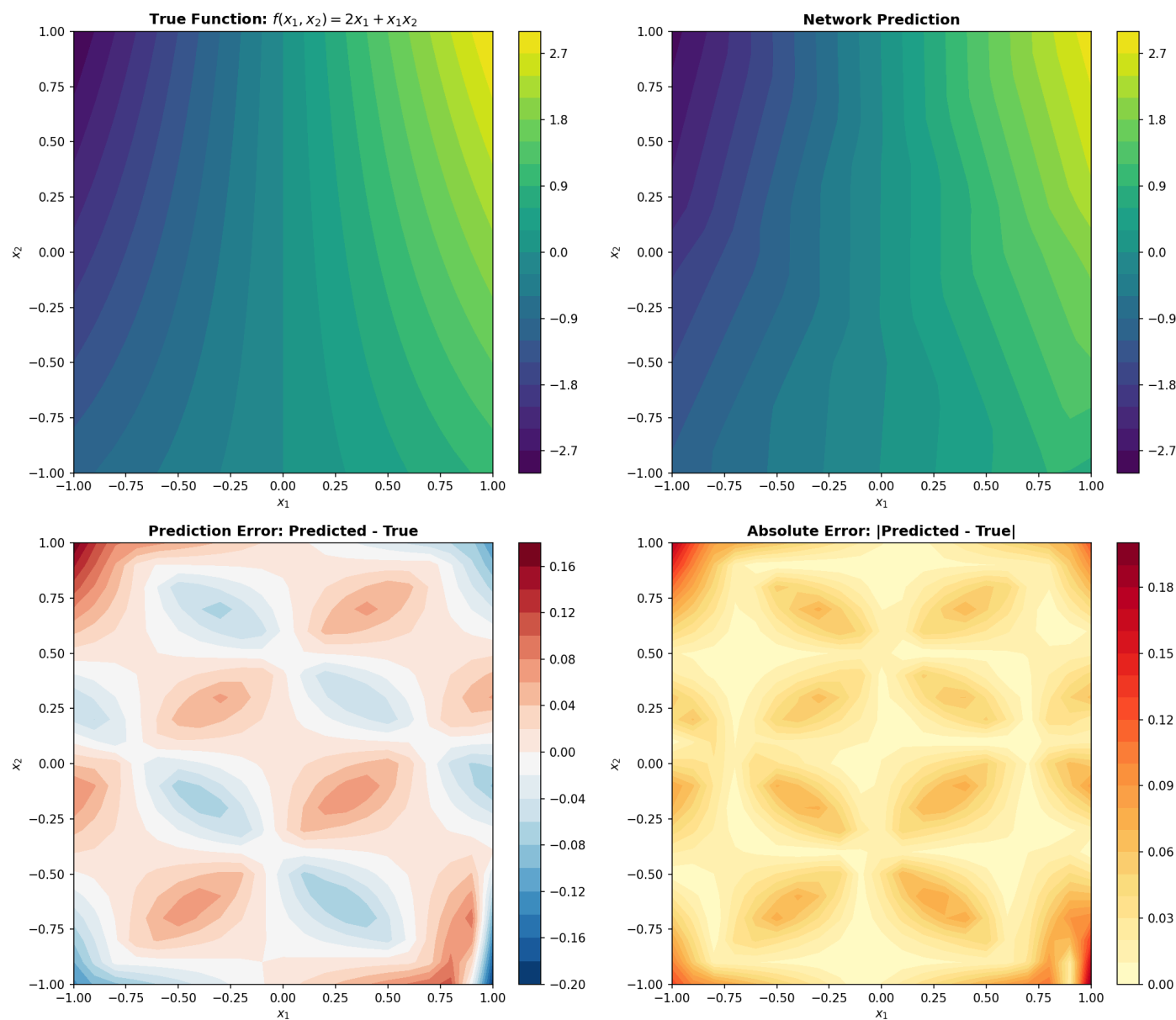
矩阵保存在`data/3220102895.mat`中。

经过2160次迭代训练后触发早停，最终损失值约为0.000710。

### 训练损失曲线



# 预测结果对比图



# 训练日志

Q5: 神经网络拟合函数  $f(x_1, x_2) = 2 \cdot x_1 + x_1 \cdot x_2$

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【1】生成训练数据...

数据范围:  $x_1, x_2 \in [-1, 1]$

样本数: 2000

标签范围:  $[-2.8083, 2.8436]$

【2】划分训练集和验证集...

【3】开始训练神经网络...

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开始优化的神经网络训练

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训练集大小: 1600, 验证集大小: 400

初始学习率: 0.1, 批大小: 64

早停止耐心值: 500

=====

Epoch	0		Train Loss: 26.996739		Val Loss: 0.259363		LR: 0.100000		Patience: 0/500
Epoch	100		Train Loss: 0.215769		Val Loss: 0.003358		LR: 0.100000		Patience: 0/500
Epoch	200		Train Loss: 0.113023		Val Loss: 0.001815		LR: 0.095000		Patience: 0/500
Epoch	300		Train Loss: 0.081288		Val Loss: 0.001334		LR: 0.095000		Patience: 1/500
Epoch	400		Train Loss: 0.066605		Val Loss: 0.001118		LR: 0.090250		Patience: 0/500
Epoch	500		Train Loss: 0.058881		Val Loss: 0.001049		LR: 0.090250		Patience: 0/500
Epoch	600		Train Loss: 0.056766		Val Loss: 0.000995		LR: 0.085737		Patience: 5/500
Epoch	700		Train Loss: 0.055025		Val Loss: 0.000950		LR: 0.085737		Patience: 0/500
Epoch	800		Train Loss: 0.053390		Val Loss: 0.000931		LR: 0.081451		Patience: 8/500
Epoch	900		Train Loss: 0.052168		Val Loss: 0.000903		LR: 0.081451		Patience: 14/500
Epoch	1000		Train Loss: 0.050349		Val Loss: 0.000869		LR: 0.077378		Patience: 0/500
Epoch	1100		Train Loss: 0.048141		Val Loss: 0.000898		LR: 0.077378		Patience: 4/500
Epoch	1200		Train Loss: 0.045110		Val Loss: 0.000782		LR: 0.073509		Patience: 5/500
Epoch	1300		Train Loss: 0.042686		Val Loss: 0.000754		LR: 0.073509		Patience: 7/500
Epoch	1400		Train Loss: 0.041821		Val Loss: 0.000741		LR: 0.069834		Patience: 7/500
Epoch	1500		Train Loss: 0.041178		Val Loss: 0.000722		LR: 0.069834		Patience: 7/500
Epoch	1600		Train Loss: 0.040706		Val Loss: 0.000718		LR: 0.066342		Patience: 21/500
Epoch	1700		Train Loss: 0.040647		Val Loss: 0.000723		LR: 0.066342		Patience: 41/500
Epoch	1800		Train Loss: 0.040379		Val Loss: 0.000723		LR: 0.063025		Patience: 141/500
Epoch	1900		Train Loss: 0.040009		Val Loss: 0.000724		LR: 0.063025		Patience: 241/500
Epoch	2000		Train Loss: 0.039864		Val Loss: 0.000721		LR: 0.059874		Patience: 341/500
Epoch	2100		Train Loss: 0.039932		Val Loss: 0.000721		LR: 0.059874		Patience: 441/500

早停止触发! 验证损失在最后 500 个epoch内未改进

最佳验证损失: 0.000710

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训练完成! 总epoch数: 2160

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**【4】绘制训练曲线...**

损失曲线已保存为 `loss_curve.png`

**【5】生成测试网格并评估...**

均方误差 (MSE): `0.001826`

平均绝对误差 (MAE): `0.031705`

均方根误差 (RMSE): `0.042727`

最大误差: `0.195061`

预测结果已保存到 `prediction.mat`

**【6】绘制结果对比图...**

对比图已保存为 `comparison.png`

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训练和评估完成!

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