神经网络 作业4

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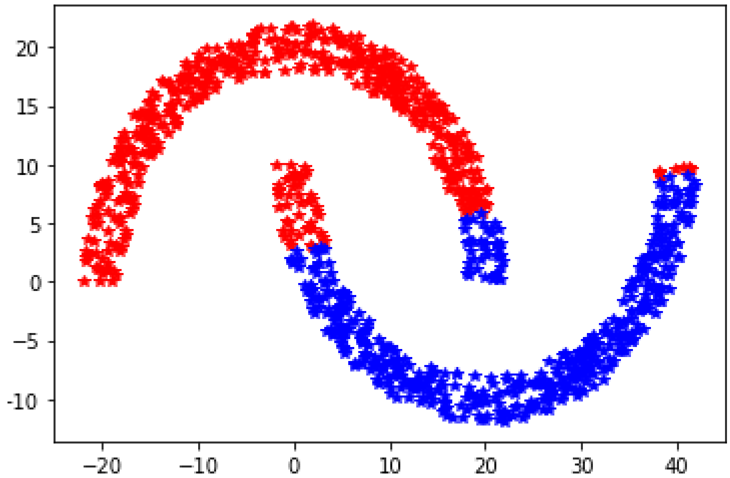
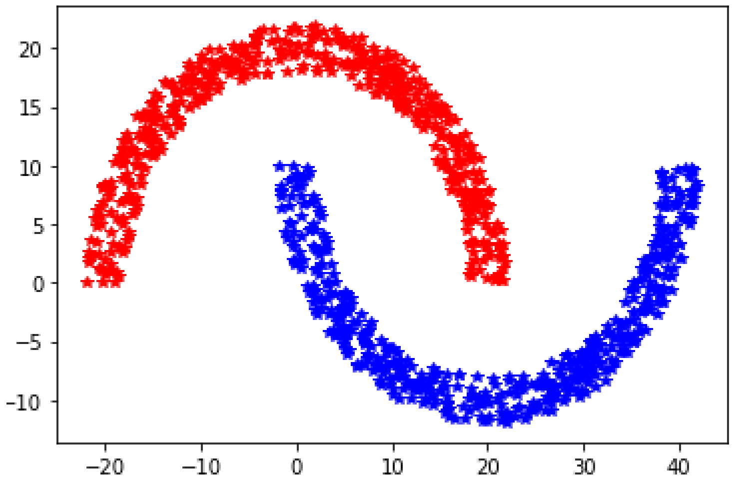
第一题

- 实验文件为 `第一题.ipynb` 。通过可视化的方式展示了单感知器、BP网络对双月数据集的分类情况。





- 分析：单层感知器的拟合能力相当于线性分类器，无法对线性不可分的双月数据集进行分类。而BP神经网络加入了隐藏层神经元，其中的激活函数采用了 `relu函数` 来去线性化，使网络的拟合能力超过了线性函数的限制，因此可以对非线性数据集进行拟合。

第二题

- 实验文件为 `第二题.ipynb` 。比较了不同隐层神经元数量的拟合正确率，之后又尝试了增加了隐藏层数量并采用交叉验证。
- 隐层神经元数量影响：隐藏层神经元数量越多，拟合能力越强，在充分训练的情况下精度越高。但是精度随神经元数量的提升速度呈下降趋势，这是因为已经能非常好的拟合训练集的时候额外提升拟合能力容易导致过拟合。

```
hidden: 1   acc: 0.304396
hidden: 5   acc: 0.805231
hidden: 10  acc: 0.930440
hidden: 20  acc: 0.954368
hidden: 50  acc: 0.954925
```

- 进一步提高方法：增加隐层神经元数量，增加层数，增加训练轮数，引入正则化减小过拟合。

```
0.9556135770234987
0.9869451697127938
0.9843342036553525
0.9842931937172775
0.9659685863874345
0.9869109947643979
0.9790575916230366
0.9764397905759162
0.9869109947643979
0.9764397905759162
hidden: 20,100,40 with 10_Fold_CrossValidation  acc: 0.959377
```

第三题

- 文件位于 `第三题.ipynb` 。采用pytorch实现，隐层激活函数用relu，训练器用adam，损失用mse，最终精度如下：

```
epoch 91, loss 0.0087
epoch 92, loss 0.0087
epoch 93, loss 0.0087
epoch 94, loss 0.0087
epoch 95, loss 0.0087
epoch 96, loss 0.0087
epoch 97, loss 0.0087
epoch 98, loss 0.0087
epoch 99, loss 0.0087
epoch 100, loss 0.0086
```

- 输入-隐藏，隐藏-输出层权值为

```
linear1.weight Parameter containing:
tensor([[-0.0263],
        [-0.6343],
        [ 0.4072],
        [-1.1352],
        [ 0.1665]], requires_grad=True)
linear1.bias Parameter containing:
tensor([-0.4353, -0.0133,  0.4695,  0.0069,  0.1663], requires_grad=True)
linear2.weight Parameter containing:
tensor([[ 0.0360,  0.0840,  0.4442, -0.2487,  0.4166]], requires_grad=True)
linear2.bias Parameter containing:
tensor([-0.1576], requires_grad=True)
```

- 因为采用relu函数，因此可以发现每一个神经元都存在一个由0转非0的分界点，具体数值如下（十分庞大）。最终的输出即这些神经元（分段函数）的组合，针对不同的输入，只有部分神经元有有效输出参与最终计算。

```
tensor([[0.0000e+00, 1.9793e+00, 0.0000e+00, 3.5733e+00, 0.0000e+00],
        [0.0000e+00, 1.9391e+00, 0.0000e+00, 3.5013e+00, 0.0000e+00],
        [0.0000e+00, 1.8988e+00, 0.0000e+00, 3.4292e+00, 0.0000e+00],
        [0.0000e+00, 1.8585e+00, 0.0000e+00, 3.3572e+00, 0.0000e+00],
        [0.0000e+00, 1.8183e+00, 0.0000e+00, 3.2851e+00, 0.0000e+00],
        [0.0000e+00, 1.7780e+00, 0.0000e+00, 3.2131e+00, 0.0000e+00],
        [0.0000e+00, 1.7378e+00, 0.0000e+00, 3.1410e+00, 0.0000e+00],
        [0.0000e+00, 1.6975e+00, 0.0000e+00, 3.0690e+00, 0.0000e+00],
        [0.0000e+00, 1.6573e+00, 0.0000e+00, 2.9969e+00, 0.0000e+00],
        [0.0000e+00, 1.6170e+00, 0.0000e+00, 2.9249e+00, 0.0000e+00],
        [0.0000e+00, 1.5768e+00, 0.0000e+00, 2.8528e+00, 0.0000e+00],
        [0.0000e+00, 1.5365e+00, 0.0000e+00, 2.7808e+00, 0.0000e+00],
        [0.0000e+00, 1.4963e+00, 0.0000e+00, 2.7087e+00, 0.0000e+00],
        [0.0000e+00, 1.4560e+00, 0.0000e+00, 2.6367e+00, 0.0000e+00],
        [0.0000e+00, 1.4158e+00, 0.0000e+00, 2.5646e+00, 0.0000e+00],
        [0.0000e+00, 1.3755e+00, 0.0000e+00, 2.4926e+00, 0.0000e+00],
        [0.0000e+00, 1.3352e+00, 0.0000e+00, 2.4205e+00, 0.0000e+00],
        [0.0000e+00, 1.2950e+00, 0.0000e+00, 2.3485e+00, 0.0000e+00],
        [0.0000e+00, 1.2547e+00, 0.0000e+00, 2.2764e+00, 0.0000e+00],
        [0.0000e+00, 1.2145e+00, 0.0000e+00, 2.2044e+00, 0.0000e+00],
        [0.0000e+00, 1.1742e+00, 0.0000e+00, 2.1323e+00, 0.0000e+00],
        [0.0000e+00, 1.1340e+00, 0.0000e+00, 2.0603e+00, 0.0000e+00],
        [0.0000e+00, 1.0937e+00, 0.0000e+00, 1.9882e+00, 0.0000e+00],
        [0.0000e+00, 1.0535e+00, 0.0000e+00, 1.9162e+00, 0.0000e+00],
        [0.0000e+00, 1.0132e+00, 0.0000e+00, 1.8441e+00, 0.0000e+00],
        [0.0000e+00, 9.7296e-01, 0.0000e+00, 1.7721e+00, 0.0000e+00],
        [0.0000e+00, 9.3271e-01, 0.0000e+00, 1.7000e+00, 0.0000e+00],
        [0.0000e+00, 8.9245e-01, 0.0000e+00, 1.6280e+00, 0.0000e+00],
        [0.0000e+00, 8.5220e-01, 0.0000e+00, 1.5559e+00, 0.0000e+00],
        [0.0000e+00, 8.1194e-01, 0.0000e+00, 1.4839e+00, 0.0000e+00],
        [0.0000e+00, 7.7169e-01, 0.0000e+00, 1.4118e+00, 0.0000e+00],
        [0.0000e+00, 7.3144e-01, 0.0000e+00, 1.3398e+00, 0.0000e+00],
        [0.0000e+00, 6.9118e-01, 1.7208e-02, 1.2677e+00, 0.0000e+00],
        [0.0000e+00, 6.5093e-01, 4.3053e-02, 1.1957e+00, 0.0000e+00],
        [0.0000e+00, 6.1067e-01, 6.8898e-02, 1.1237e+00, 2.5408e-03],
```

```
        [0.0000e+00, 5.7042e-01, 9.4743e-02, 1.0516e+00, 1.3106e-02],
        [0.0000e+00, 5.3017e-01, 1.2059e-01, 9.7955e-01, 2.3671e-02],
        [0.0000e+00, 4.8991e-01, 1.4643e-01, 9.0751e-01, 3.4236e-02],
        [0.0000e+00, 4.4966e-01, 1.7228e-01, 8.3546e-01, 4.4802e-02],
        [0.0000e+00, 4.0940e-01, 1.9812e-01, 7.6341e-01, 5.5367e-02],
        [0.0000e+00, 3.6915e-01, 2.2397e-01, 6.9136e-01, 6.5932e-02],
        [0.0000e+00, 3.2890e-01, 2.4981e-01, 6.1931e-01, 7.6497e-02],
        [0.0000e+00, 2.8864e-01, 2.7566e-01, 5.4726e-01, 8.7063e-02],
        [0.0000e+00, 2.4839e-01, 3.0150e-01, 4.7521e-01, 9.7628e-02],
        [0.0000e+00, 2.0813e-01, 3.2735e-01, 4.0317e-01, 1.0819e-01],
        [0.0000e+00, 1.6788e-01, 3.5319e-01, 3.3112e-01, 1.1876e-01],
        [0.0000e+00, 1.2763e-01, 3.7904e-01, 2.5907e-01, 1.2932e-01],
        [0.0000e+00, 8.7372e-02, 4.0488e-01, 1.8702e-01, 1.3989e-01],
        [0.0000e+00, 4.7118e-02, 4.3073e-01, 1.1497e-01, 1.5045e-01],
        [0.0000e+00, 6.8638e-03, 4.5657e-01, 4.2923e-02, 1.6102e-01],
        [0.0000e+00, 0.0000e+00, 4.8242e-01, 0.0000e+00, 1.7158e-01],
        [0.0000e+00, 0.0000e+00, 5.0826e-01, 0.0000e+00, 1.8215e-01],
        [0.0000e+00, 0.0000e+00, 5.3411e-01, 0.0000e+00, 1.9271e-01],
        [0.0000e+00, 0.0000e+00, 5.5995e-01, 0.0000e+00, 2.0328e-01],
        [0.0000e+00, 0.0000e+00, 5.8580e-01, 0.0000e+00, 2.1385e-01],
        [0.0000e+00, 0.0000e+00, 6.1165e-01, 0.0000e+00, 2.2441e-01],
        [0.0000e+00, 0.0000e+00, 6.3749e-01, 0.0000e+00, 2.3498e-01],
        [0.0000e+00, 0.0000e+00, 6.6334e-01, 0.0000e+00, 2.4554e-01],
        [0.0000e+00, 0.0000e+00, 6.8918e-01, 0.0000e+00, 2.5611e-01],
        [0.0000e+00, 0.0000e+00, 7.1503e-01, 0.0000e+00, 2.6667e-01],
        [0.0000e+00, 0.0000e+00, 7.4087e-01, 0.0000e+00, 2.7724e-01],
        [0.0000e+00, 0.0000e+00, 7.6672e-01, 0.0000e+00, 2.8780e-01],
        [0.0000e+00, 0.0000e+00, 7.9256e-01, 0.0000e+00, 2.9837e-01],
        [0.0000e+00, 0.0000e+00, 8.1841e-01, 0.0000e+00, 3.0893e-01],
        [0.0000e+00, 0.0000e+00, 8.4425e-01, 0.0000e+00, 3.1950e-01],
        [0.0000e+00, 0.0000e+00, 8.7010e-01, 0.0000e+00, 3.3006e-01],
        [0.0000e+00, 0.0000e+00, 8.9594e-01, 0.0000e+00, 3.4063e-01],
        [0.0000e+00, 0.0000e+00, 9.2179e-01, 0.0000e+00, 3.5119e-01],
        [0.0000e+00, 0.0000e+00, 9.4763e-01, 0.0000e+00, 3.6176e-01],
        [0.0000e+00, 0.0000e+00, 9.7348e-01, 0.0000e+00, 3.7232e-01],
        [0.0000e+00, 0.0000e+00, 9.9932e-01, 0.0000e+00, 3.8289e-01],
        [0.0000e+00, 0.0000e+00, 1.0252e+00, 0.0000e+00, 3.9345e-01],
        [0.0000e+00, 0.0000e+00, 1.0510e+00, 0.0000e+00, 4.0402e-01],
        [0.0000e+00, 0.0000e+00, 1.0769e+00, 0.0000e+00, 4.1458e-01],
        [0.0000e+00, 0.0000e+00, 1.1027e+00, 0.0000e+00, 4.2515e-01],
        [0.0000e+00, 0.0000e+00, 1.1285e+00, 0.0000e+00, 4.3572e-01],
        [0.0000e+00, 0.0000e+00, 1.1544e+00, 0.0000e+00, 4.4628e-01],
        [0.0000e+00, 0.0000e+00, 1.1802e+00, 0.0000e+00, 4.5685e-01],
        [0.0000e+00, 0.0000e+00, 1.2061e+00, 0.0000e+00, 4.6741e-01],
        [0.0000e+00, 0.0000e+00, 1.2319e+00, 0.0000e+00, 4.7798e-01],
        [0.0000e+00, 0.0000e+00, 1.2578e+00, 0.0000e+00, 4.8854e-01],
        [0.0000e+00, 0.0000e+00, 1.2836e+00, 0.0000e+00, 4.9911e-01],
        [0.0000e+00, 0.0000e+00, 1.3095e+00, 0.0000e+00, 5.0967e-01],
        [0.0000e+00, 0.0000e+00, 1.3353e+00, 0.0000e+00, 5.2024e-01],
        [0.0000e+00, 0.0000e+00, 1.3612e+00, 0.0000e+00, 5.3080e-01],
        [0.0000e+00, 0.0000e+00, 1.3870e+00, 0.0000e+00, 5.4137e-01],
        [0.0000e+00, 0.0000e+00, 1.4128e+00, 0.0000e+00, 5.5193e-01],
```

```
        [0.0000e+00, 0.0000e+00, 1.4387e+00, 0.0000e+00, 5.6250e-01],
        [0.0000e+00, 0.0000e+00, 1.4645e+00, 0.0000e+00, 5.7306e-01],
        [0.0000e+00, 0.0000e+00, 1.4904e+00, 0.0000e+00, 5.8363e-01],
        [0.0000e+00, 0.0000e+00, 1.5162e+00, 0.0000e+00, 5.9419e-01],
        [0.0000e+00, 0.0000e+00, 1.5421e+00, 0.0000e+00, 6.0476e-01],
        [0.0000e+00, 0.0000e+00, 1.5679e+00, 0.0000e+00, 6.1532e-01],
        [0.0000e+00, 0.0000e+00, 1.5938e+00, 0.0000e+00, 6.2589e-01],
        [0.0000e+00, 0.0000e+00, 1.6196e+00, 0.0000e+00, 6.3645e-01],
        [0.0000e+00, 0.0000e+00, 1.6454e+00, 0.0000e+00, 6.4702e-01],
        [0.0000e+00, 0.0000e+00, 1.6713e+00, 0.0000e+00, 6.5758e-01],
        [0.0000e+00, 0.0000e+00, 1.6971e+00, 0.0000e+00, 6.6815e-01],
        [0.0000e+00, 0.0000e+00, 1.7230e+00, 0.0000e+00, 6.7872e-01],
        [0.0000e+00, 0.0000e+00, 1.7488e+00, 0.0000e+00, 6.8928e-01]],
```