m3-l2-p1

February 9, 2024

1 M3-L2 Problem 1 (5 points)

[9]:
```
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.colors import ListedColormap
from scipy.stats import mode
from sklearn.linear_model import LogisticRegression
```

2 One-vs-One Multinomial Classification

2.1 Load Dataset

(Don't edit this)

- (x,y) values are stored in rows of `xy`
- class values are in `c`

[10]:
```
x = np.array([7.4881350392732475,16.351893663724194,22.427633760716436,29.
↪04883182996897,35.03654799338904,44.45894113066656,6.375872112626925,18.
↪117730007820796,26.036627605010292,27.434415188257777,38.71725038082664,43.
↪28894919752904,7.680445610939323,18.45596638292661,17.110360581978867,24.
↪47129299701541,31.002183974403255,46.32619845547938,9.781567509498505,17.
↪90012148246819,26.186183422327638,31.59158564216724,35.41479362252932,45.
↪805291762864556,3.182744258689332,15.599210213275237,17.833532874090462,33.
↪04668917049584,36.018483217500716,42.146619399905234,4.64555612104627,16.
↪942336894342166,20.961503322165484,29.284339488686488,30.98789800436355,44.
↪17635497075877,])
y = np.array([0.11120957227224215,0.1116933996874757,0.14437480785146242,0.
↪11818202991034835,0.0859507900573786,0.09370319537993416,0.
↪2797631195927265,0.216022547162927,0.27667667154456677,0.27706378696181594,0.
↪2310382561073841,0.22289262976548535,0.40154283509241845,0.
↪4063710770942623,0.427019677041788,0.41386015134623205,0.46883738380592266,0.
↪38020448107480287,0.5508876756094834,0.5461309517884996,0.5953108325465398,0.
↪5553291602539782,0.5766310772856306,0.5544425592001603,0.705896958364552,0.
↪7010375141164304,0.7556329589465274,0.7038182951348614,0.7096582361680054,0.
↪7268725170660963,0.9320993229847936,0.8597101275793062,0.9337944907498804,0.
↪8596098407893963,0.9476459465013396,0.8968651201647702,])
xy = np.vstack([x,y]).T
```

```
c = np.
 ↪array([0,2,2,2,2,2,0,2,2,2,2,2,0,0,2,0,1,2,0,0,1,1,1,2,0,1,0,1,1,1,0,0,1,1,1,1,])
```

2.2 Binomial classification function

You are given a function that performs binomial classification by using sklearn's `LogisticRegression` tool: `classify = get_binomial_classifier(xy, c, A, B)`

To use it, input: - `xy`, an array in which each row contains (x,y) coordinates of data points - `c`, an array that specifies the class each point in `xy` belongs to - `A`, the class of the first group (0, 1, or 2 in this problem) - `B`, the class of the second group (0, 1, or 2 in this problem), but different from `A`

The function outputs a classifier function (`classify()` in this case), used to classify any new `xy` into group A or B, such as by using `classify(xy)`.

[11]:
```
def get_binomial_classifier(xy, c, A, B):
    assert A != B
    xyA, xyB = xy[c==A], xy[c==B]
    cA, cB = c[c==A], c[c==B]
    model = LogisticRegression()
    xy_new = np.concatenate([xyA, xyB], 0)
    c_new = np.concatenate([cA, cB], 0)
    model.fit(xy_new,c_new)

    def classify(xy):
        pred = model.predict(xy)
        return pred

    return classify
```

2.3 Coding a 1v1 classifier

Now you will create a one-vs-one classifier to do multinomial classification. This will generate binomial classifiers for each pair of classes in the dataset. Then to predict the class of a new point, classify it using each of the binomial classifiers, and select the majority winner as the class prediction.

Complete the two functions we have started: - `generate_all_classifiers(xy, c)` which returns a list of binary classifier functions for all possible pairs of classes (among 0, 1, and 2 in this problem) - `classify_majority(classifiers, xy)` which loops through a list of classifiers and gets their predictions for each point in `xy`. Then using a majority voting scheme at each point, return the overall class predictions for each point.

[12]:
```
def generate_all_classifiers(xy, c):
    # YOUR CODE GOES HERE
    # Use get_binomial_classifier() to get binomial classifiers for each pair␣
 ↪of classes,
    # and return a list of these classifiers
    classifiers = []
```

```
    for i in range(3):
        for j in range(i+1,3):
            classifiers.append(get_binomial_classifier(xy,c,i,j))
    return classifiers

def classify_majority(classifiers, xy):
    # YOUR CODE GOES HERE
    # Use the list of classifiers to classify the data points in xy, and return␣
 ↪the majority vote
    # of the classifiers for each data point
    votes = np.zeros((len(xy),3))
    for i in range(len(classifiers)):
        votes[:,i] = classifiers[i](xy)
    majority_vote = mode(votes, axis=1)[0].flatten()
    return majority_vote
```

2.3.1 Trying out our multinomial classifier:

[13]:
```
classifiers = generate_all_classifiers(xy, c)
preds = classify_majority(classifiers, xy)
accuracy = np.sum(preds == c) / len(c) * 100
print("True Classes:", c)
print(" Predictions:", preds)
print("    Accuracy:", accuracy, r"%")
```

```
True Classes: [0 2 2 2 2 2 0 2 2 2 2 2 0 0 2 0 1 2 0 0 1 1 1 2 0 1 0 1 1 1 0 0 1
1 1 1]
 Predictions: [0. 0. 2. 2. 2. 2. 0. 0. 2. 2. 2. 2. 0. 0. 0. 2. 2. 2. 0. 0. 1. 1.
1. 1.
 0. 0. 0. 1. 1. 1. 0. 0. 1. 1. 1. 1.]
    Accuracy: 80.55555555555556 %
```

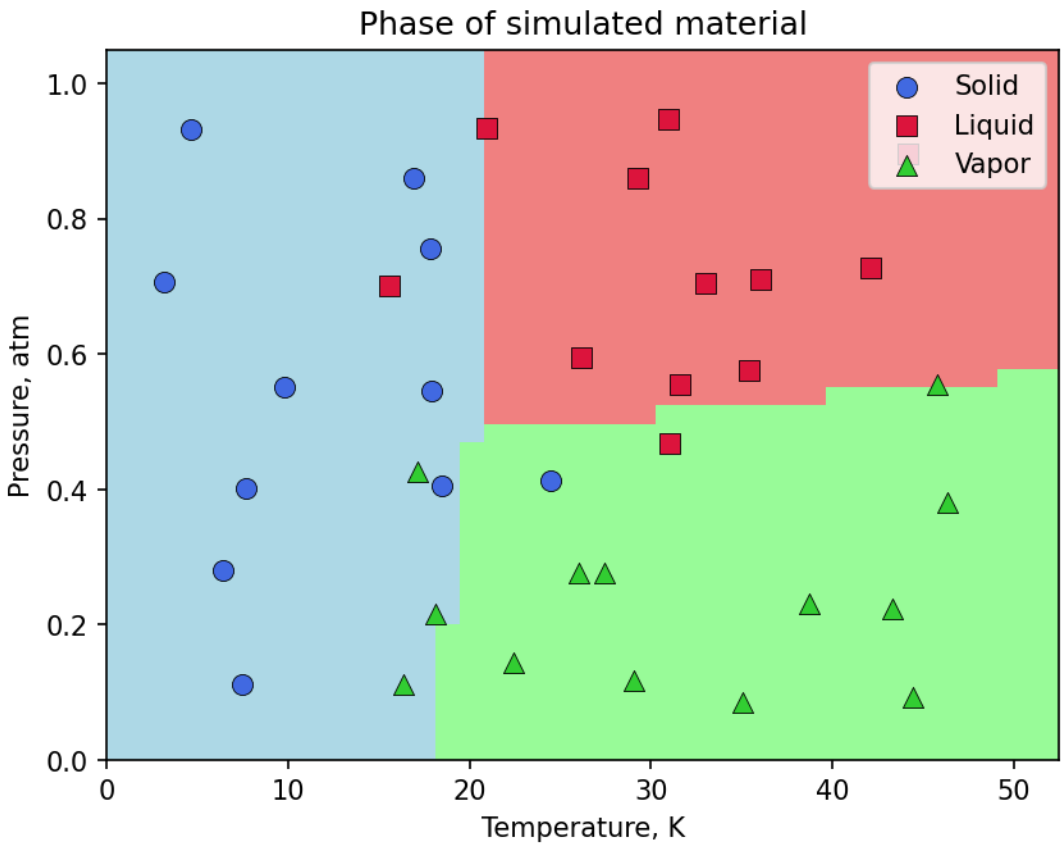
2.3.2 Plotting a Decision Boundary

Here, we have made some plotting functions – run these cells to visualize the decision boundaries.

[14]:
```
def plot_data(x, y, c, title="Phase of simulated material", newfig=True):
    xlim = [0,52.5]
    ylim = [0,1.05]
    markers = [dict(marker="o", color="royalblue"), dict(marker="s",␣
 ↪color="crimson"), dict(marker="^", color="limegreen")]
    labels = ["Solid", "Liquid", "Vapor"]

    if newfig:
        plt.figure(dpi=150)

    for i in range(1+max(c)):
```

```
        plt.scatter(x[c==i], y[c==i], s=60, **(markers[i]), edgecolor="black",␣
 ↪linewidths=0.4,label=labels[i])

    plt.title(title)
    plt.legend(loc="upper right")
    plt.xlim(xlim)
    plt.ylim(ylim)
    plt.xlabel("Temperature, K")
    plt.ylabel("Pressure, atm")
    plt.box(True)

def plot_colors(classifiers, res=40):
    xlim = [0,52.5]
    ylim = [0,1.05]
    xvals = np.linspace(*xlim,res)
    yvals = np.linspace(*ylim,res)
    x,y = np.meshgrid(xvals,yvals)
    XY = np.concatenate((x.reshape(-1,1),y.reshape(-1,1)),axis=1)
    if type(classifiers) == list:
        color = classify_majority(classifiers,XY).reshape(res,res)
    else:
        color = classifiers(XY).reshape(res,res)
    cmap = ListedColormap(["lightblue","lightcoral","palegreen"])
    plt.pcolor(x, y, color, shading="nearest", zorder=-1,␣
 ↪cmap=cmap,vmin=0,vmax=2)
    return
```

[15]:
```
plot_data(x,y,c)
plot_colors(classifiers)
plt.show()
```



We can also look at the results of each binary classifier:

[16]:
```
plt.figure(figsize=(16,3),dpi=150)
for i in range(3):
    plt.subplot(1,3,i+1)
    plot_data(x, y, c, title=f"Binary Classifier {i+1}", newfig=False)
    plot_colors(classifiers[i])
plt.show()
```