PROBLEM 2: Implement t-SNE dim reduction, run on MNIST dataset.

In [2]:
```
# Load MNIST
from sklearn.datasets import fetch_openml
mnist = fetch_openml('mnist_784', version=1)
X = mnist.data.values.astype(np.float32)
labels = mnist.target.values.astype(np.float32)

# Sample 10000 images
indices = np.random.choice(X.shape[0], 10000, replace=False)
X = X[indices]
labels = labels[indices]
```

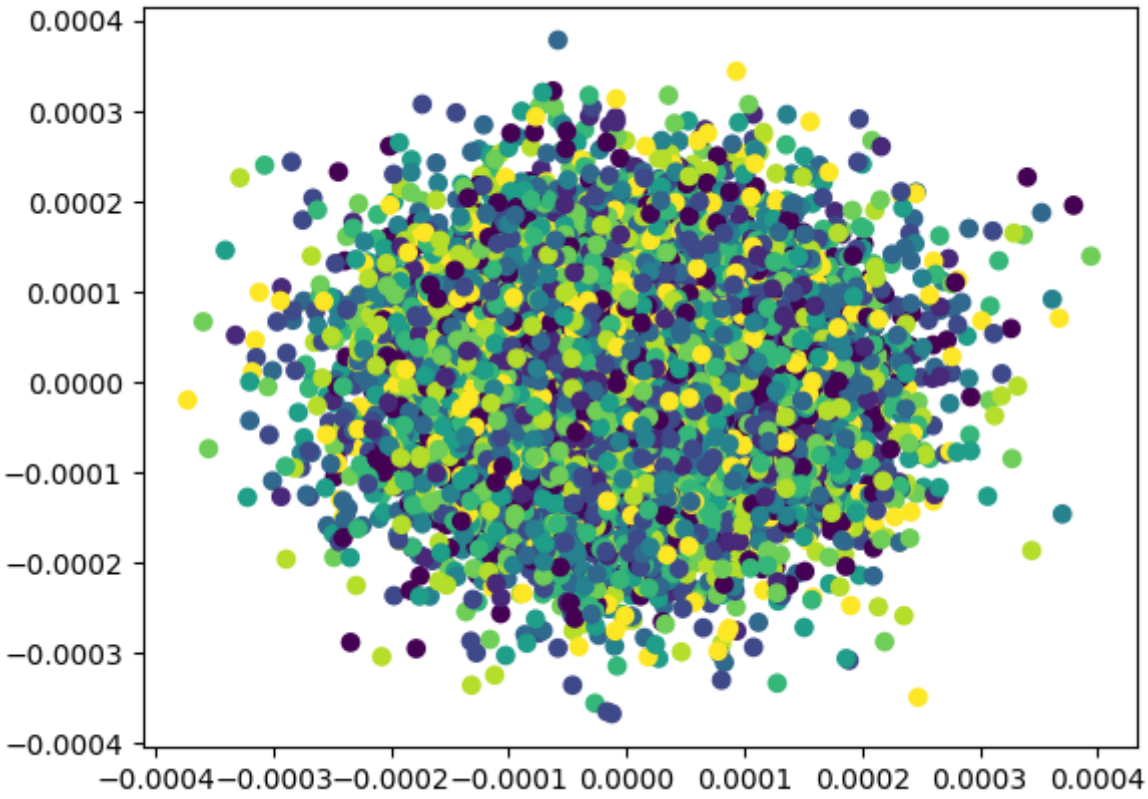
```
/usr/local/lib/python3.10/site-packages/sklearn/datasets/_openml.py:968:
FutureWarning: The default value of `parser` will change from `'liac-arf
f'` to `'auto'` in 1.4. You can set `parser='auto'` to silence this warni
ng. Therefore, an `ImportError` will be raised from 1.4 if the dataset is
dense and pandas is not installed. Note that the pandas parser may return
different data types. See the Notes Section in fetch_openml's API doc for
details.
  warn(
```

In [ ]:

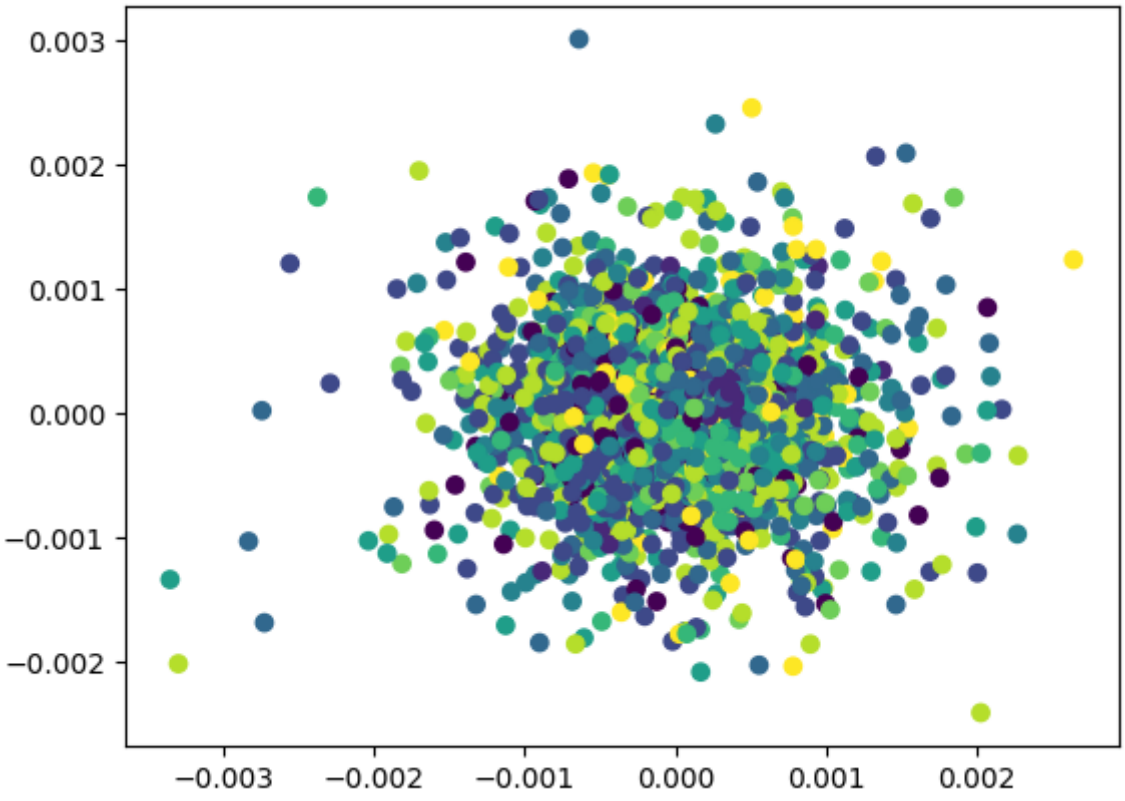
```
# Prep X
X -= np.min(X)
X /= np.max(X)
X -= np.mean(X, axis=0)

N, F = X.shape
no_dims = 2
PCA_dims = 50
use_momentum = 1

# Run PCA
pca = PCA(n_components=PCA_dims)
X = pca.fit_transform(X)

# Compute pairwise distance
sum_X = np.sum(X**2, axis=1)
D = np.add.outer(sum_X, sum_X) - 2 * np.dot(X, X.T)

# Compute the similarities p_ij for each row i
P = np.zeros((N, N))
beta = np.ones((N,))
for i in range(N):
    trials = 0
    Hdiff = 1
    betamin = -np.inf
    betamax = np.inf
    while abs(Hdiff) > 1e-5 and trials < 50:
        P_i = np.exp(-D[i] * beta[i])
        sumP = np.sum(P_i)
        H = np.log(sumP) + beta[i] * np.sum(D[i] * P_i) / sumP
        Hdiff = H - np.log2(30)
        if Hdiff > 0:
            betamin = beta[i]
            if betamax == np.inf:
                beta[i] *= 2
            else:
                beta[i] = (beta[i] + betamax) / 2
        else:
            betamax = beta[i]
            if betamin == -np.inf:
                beta[i] /= 2
            else:
                beta[i] = (beta[i] + betamin) / 2
        trials += 1
    P[i] = P_i / sumP

# Make sure P is correct
np.fill_diagonal(P, 0)
P = (P + P.T) / 2
P /= np.sum(P)

ConstKL = np.sum(P * np.log(P))

# Initialize tSNE
max_iter = 400
epsilon = 500
min_gain = .01
```

```
y = .0001 * np.random.randn(N, no_dims)
y_incs = np.zeros_like(y)
gains = np.ones_like(y)

# Run tSNE iterations
for iter in range(max_iter):
    sum_y2 = np.sum(y**2, axis=1)
    Qnum = 1 / (1 + np.add.outer(sum_y2, sum_y2) - 2 * np.dot(y, y.T))
    np.fill_diagonal(Qnum, 0)
    Q = Qnum / np.sum(Qnum)
    L = (P - Q) * Qnum
    y_grads = 4 * (np.diag(np.sum(L, axis=1)) - L).dot(y)
    if use_momentum:
        gains = (gains + .2) * (np.sign(y_grads) != np.sign(y_incs)) + (gai
        gains[gains < min_gain] = min_gain
        y_incs = - epsilon * (gains * y_grads)
    else:
        y_incs = -epsilon * y_grads
    y += y_incs
    y -= np.mean(y, axis=0)
    if iter % 10 == 0:
        cost = ConstKL - np.sum(P * np.log(Q))
        print(f'Iteration {iter}: error is {cost}')
        plt.scatter(y[:, 0], y[:, 1], c=labels)
        plt.show()
```

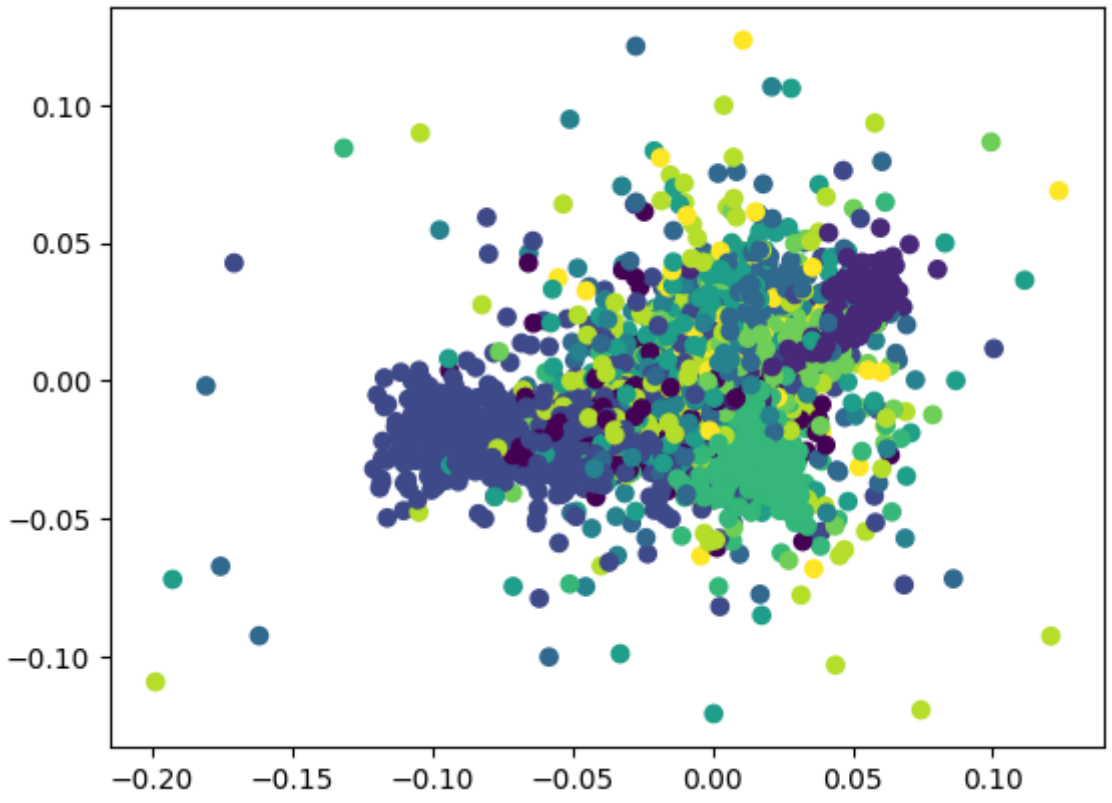
```
/var/folders/2d/kjz0bk3s5nj4p4v10t35f8f40000gn/T/ipykernel_6921/229719775
6.py:52: RuntimeWarning: divide by zero encountered in log
  ConstKL = np.sum(P * np.log(P))
/var/folders/2d/kjz0bk3s5nj4p4v10t35f8f40000gn/T/ipykernel_6921/229719775
6.py:52: RuntimeWarning: invalid value encountered in multiply
  ConstKL = np.sum(P * np.log(P))
/var/folders/2d/kjz0bk3s5nj4p4v10t35f8f40000gn/T/ipykernel_6921/229719775
6.py:79: RuntimeWarning: divide by zero encountered in log
  cost = ConstKL - np.sum(P * np.log(Q))
/var/folders/2d/kjz0bk3s5nj4p4v10t35f8f40000gn/T/ipykernel_6921/229719775
6.py:79: RuntimeWarning: invalid value encountered in multiply
  cost = ConstKL - np.sum(P * np.log(Q))

Iteration 0: error is nan
```



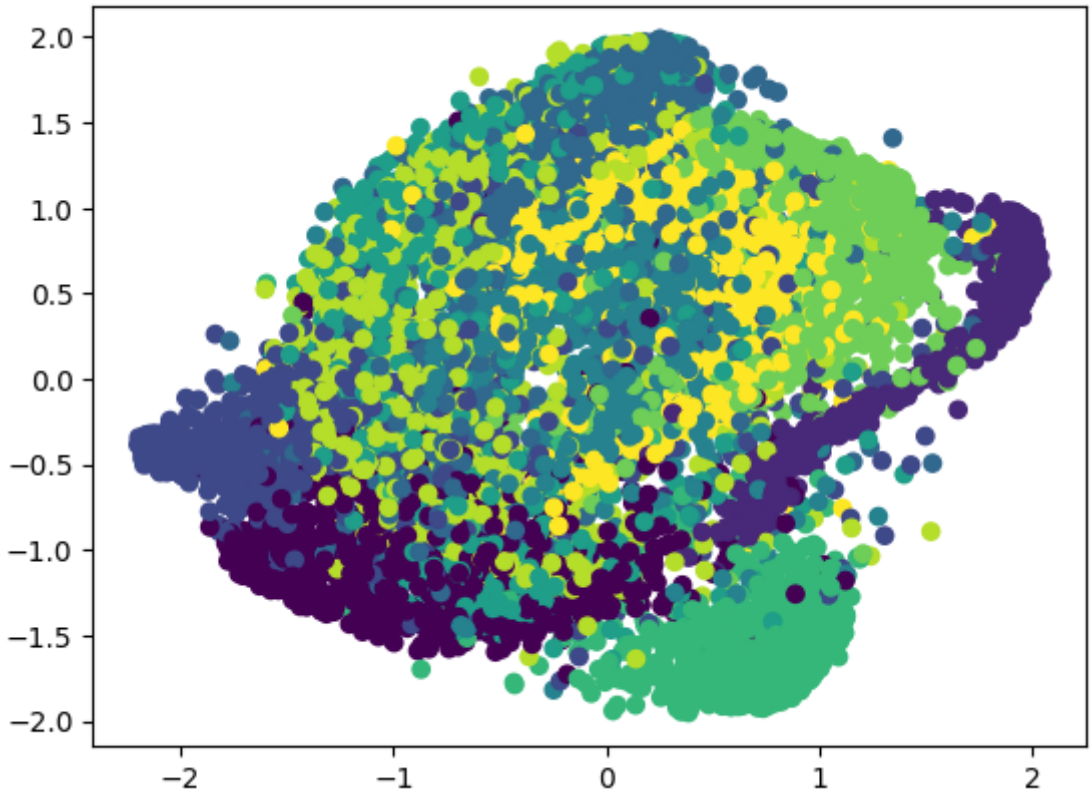

```
Iteration 10: error is nan
```



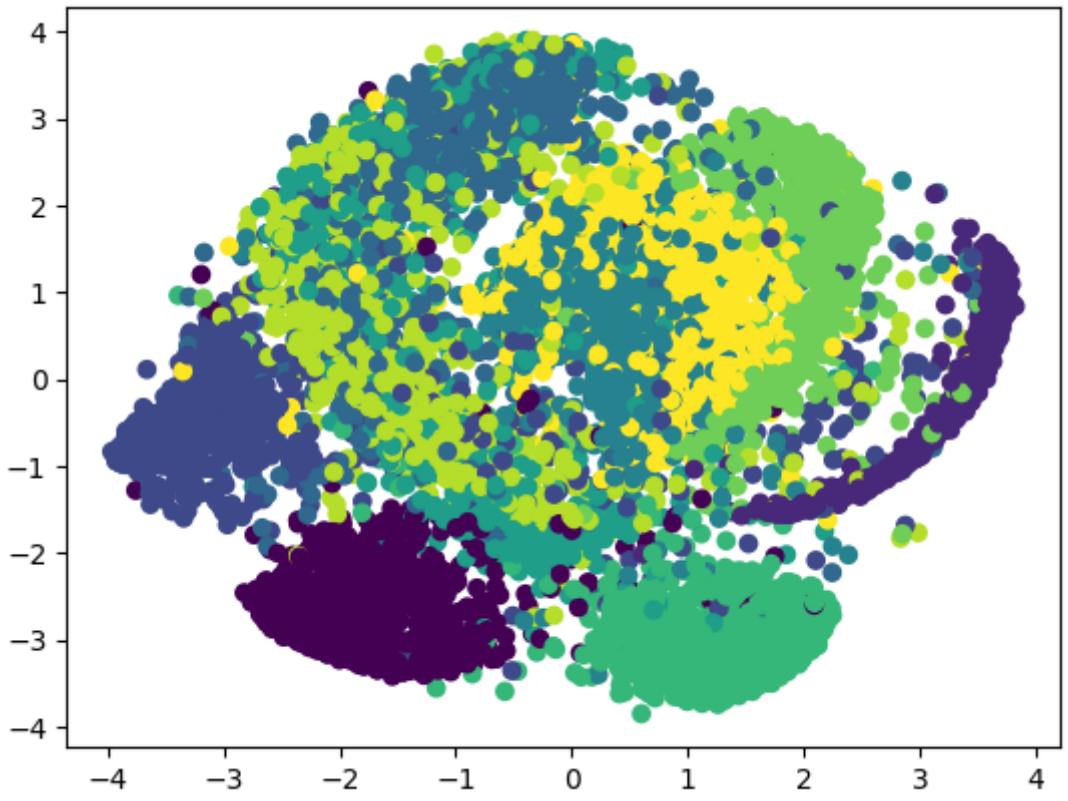

```
Iteration 20: error is nan
```



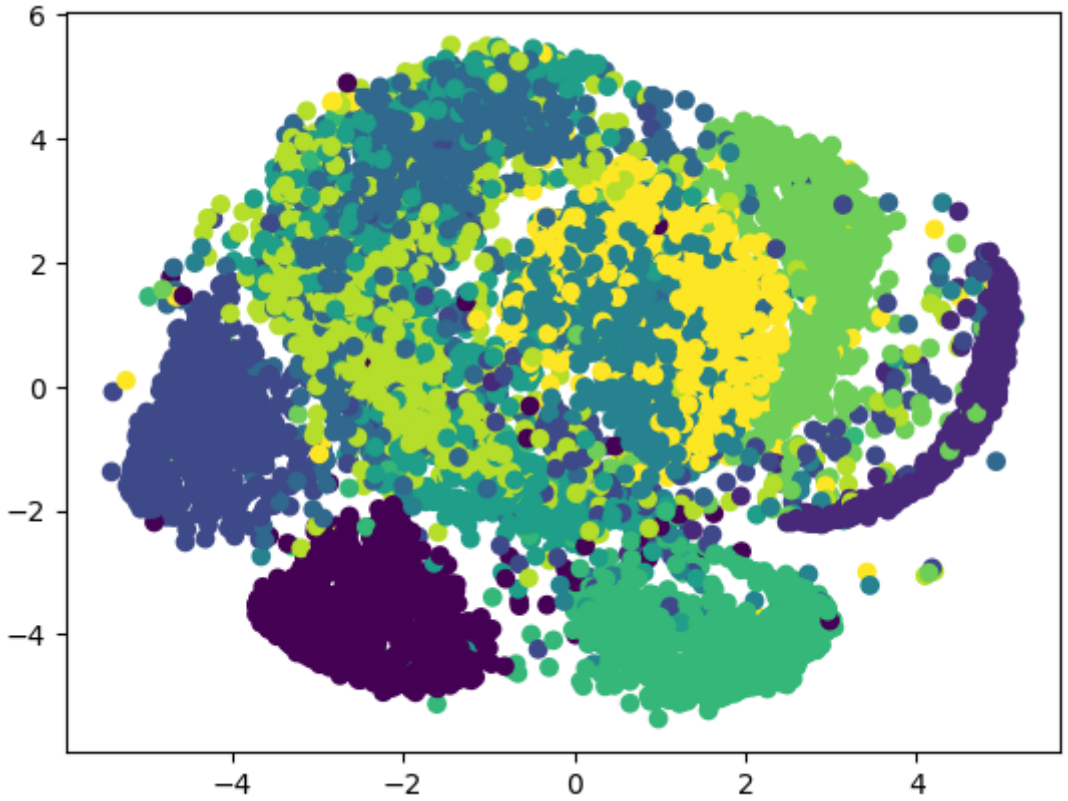

```
Iteration 30: error is nan
```



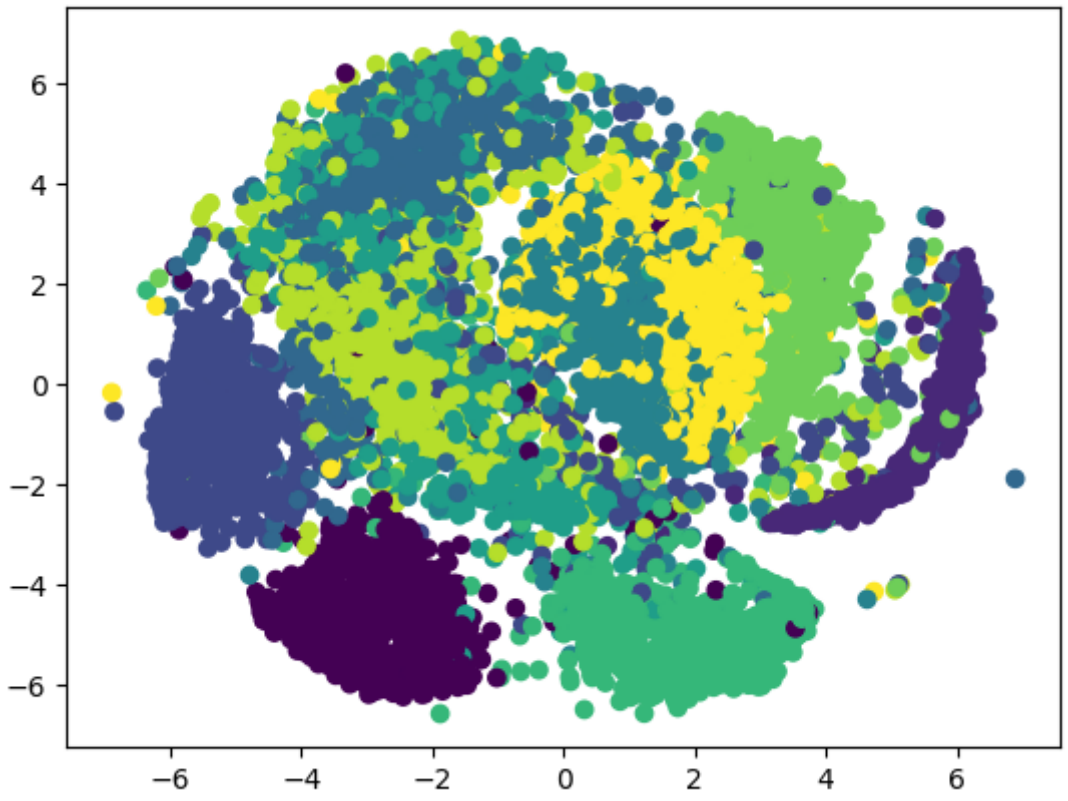

```
Iteration 40: error is nan
```



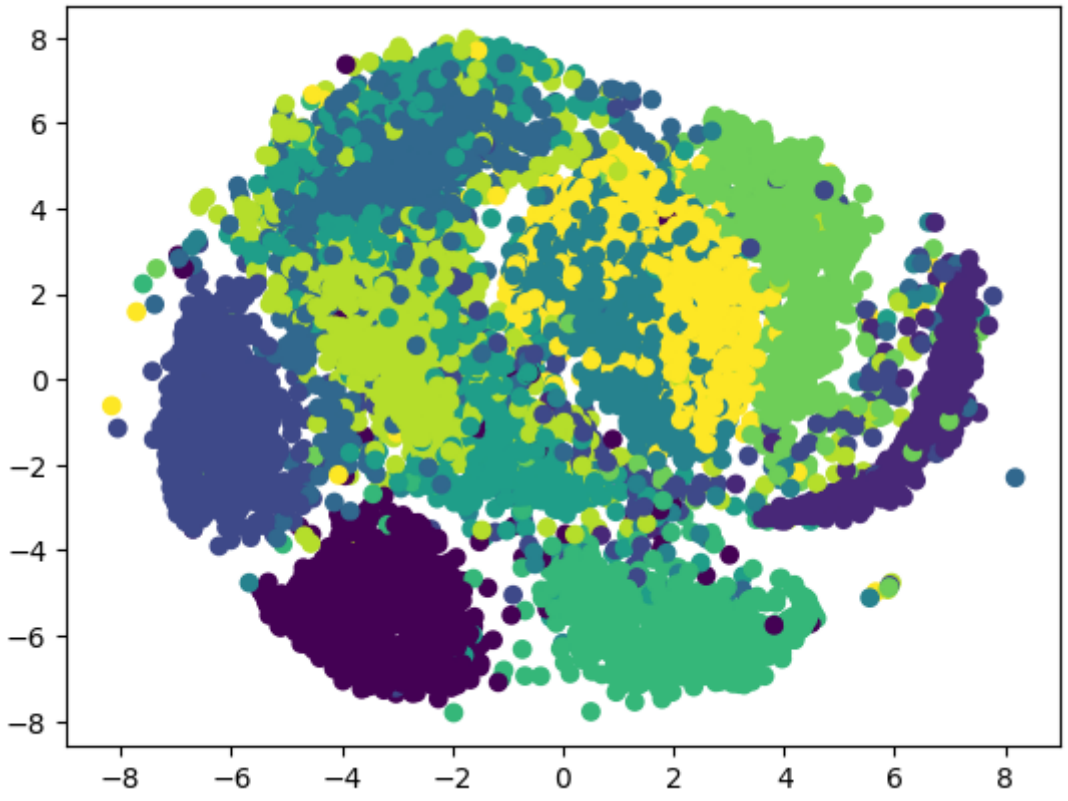

```
Iteration 50: error is nan
```



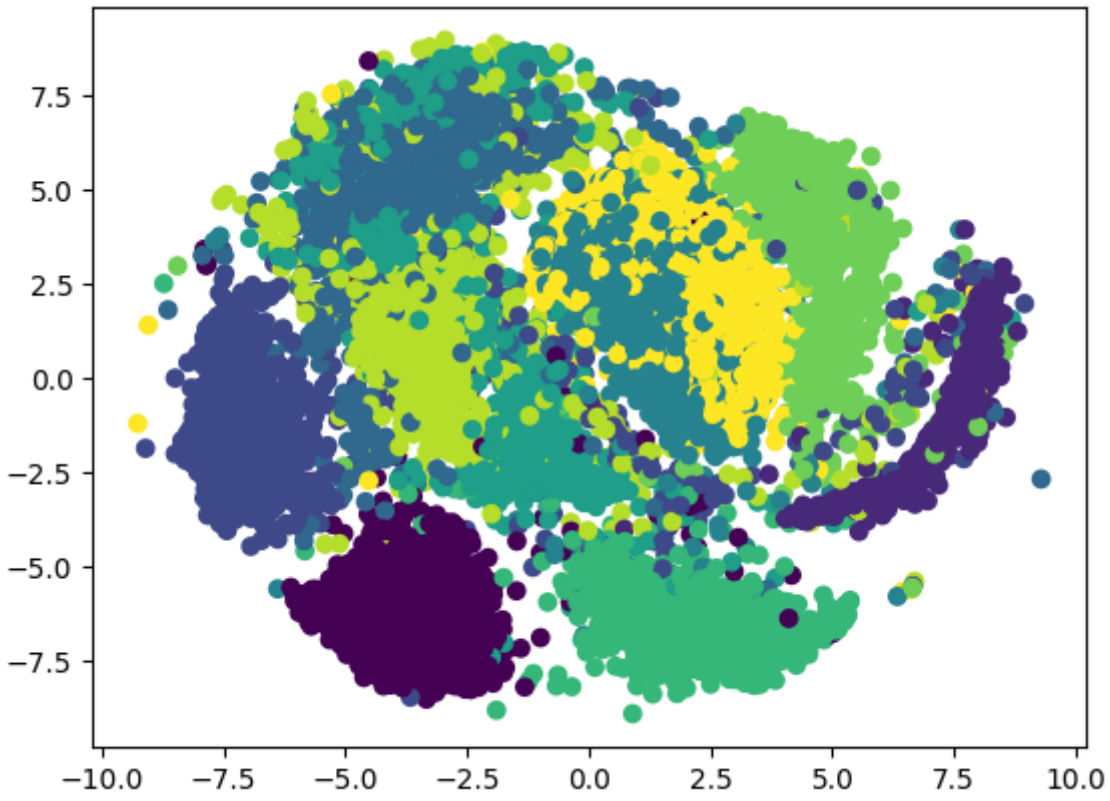

```
Iteration 60: error is nan
```



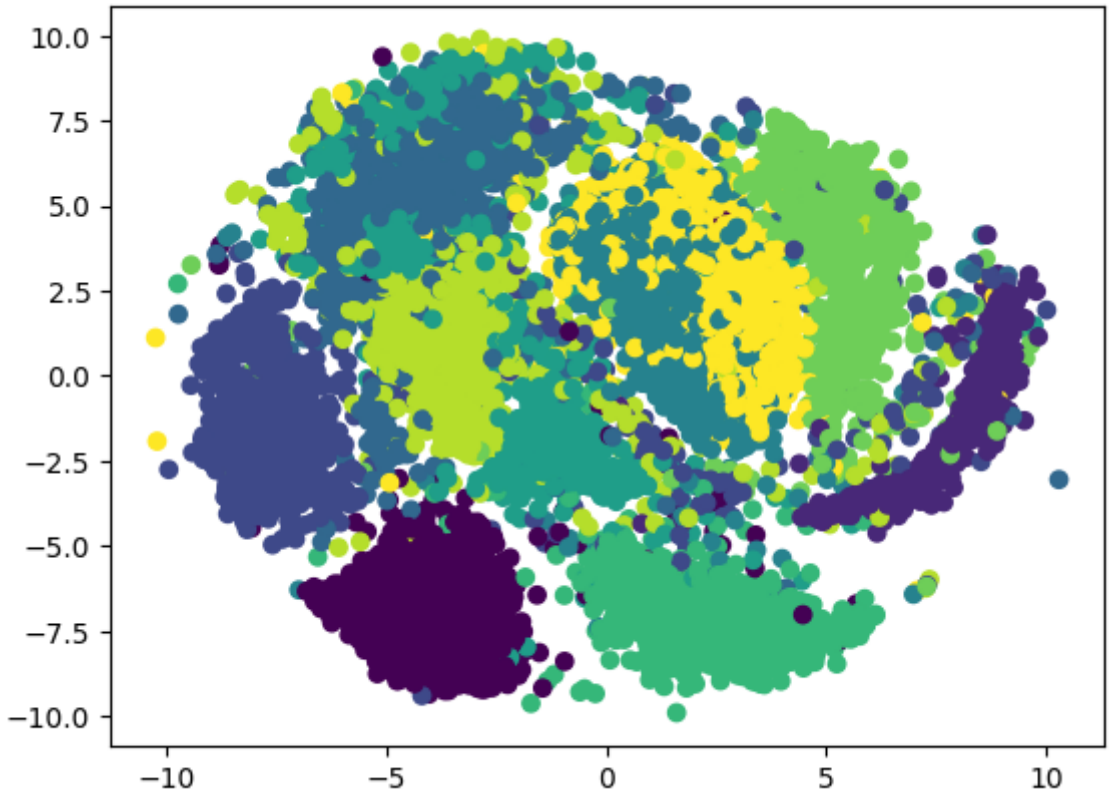

```
Iteration 70: error is nan
```



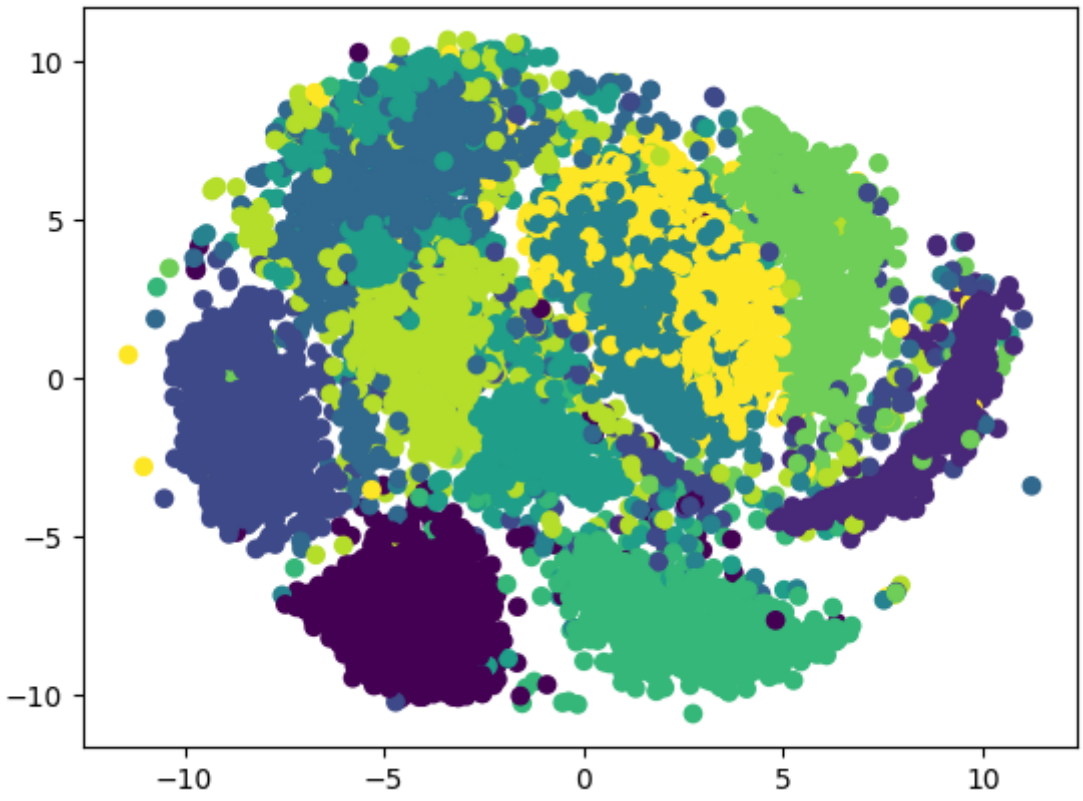

```
Iteration 80: error is nan
```



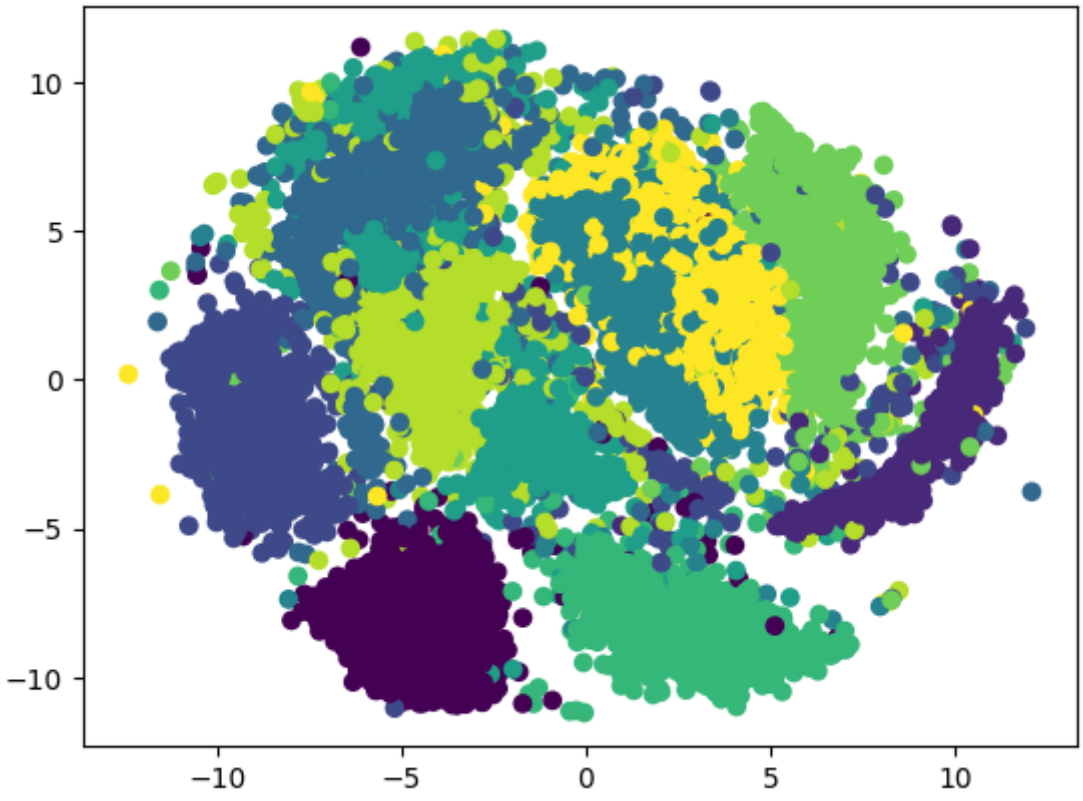

```
Iteration 90: error is nan
```



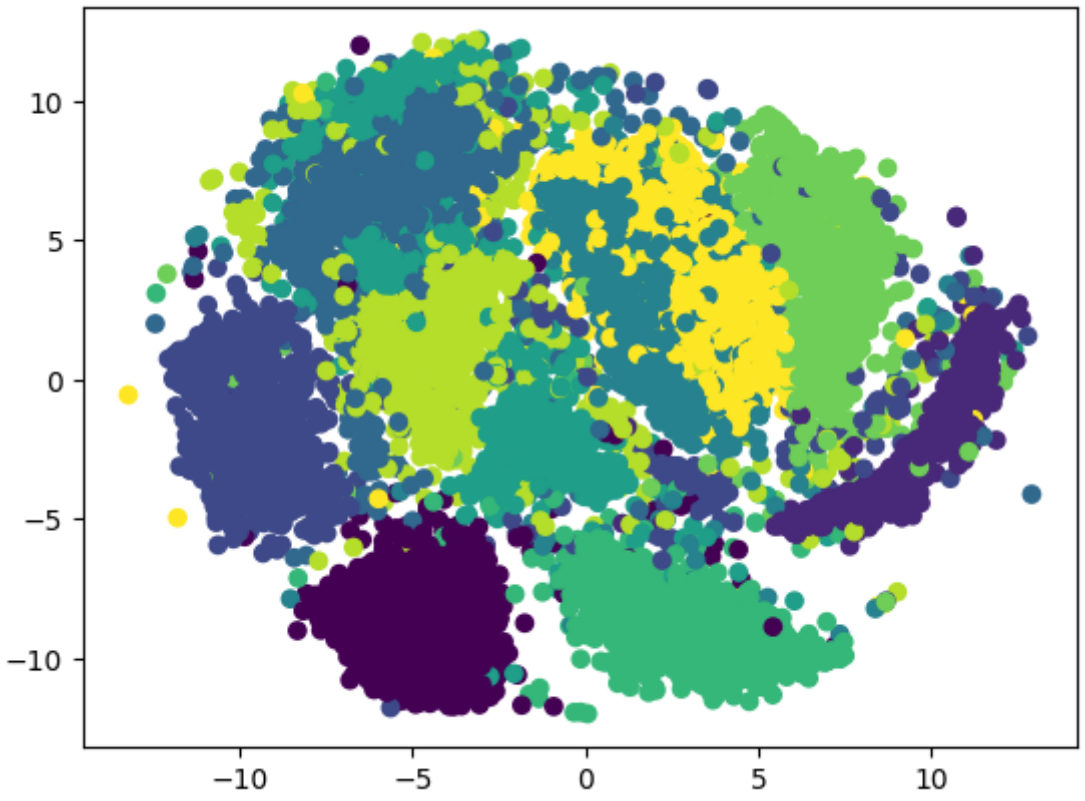

```
Iteration 100: error is nan
```



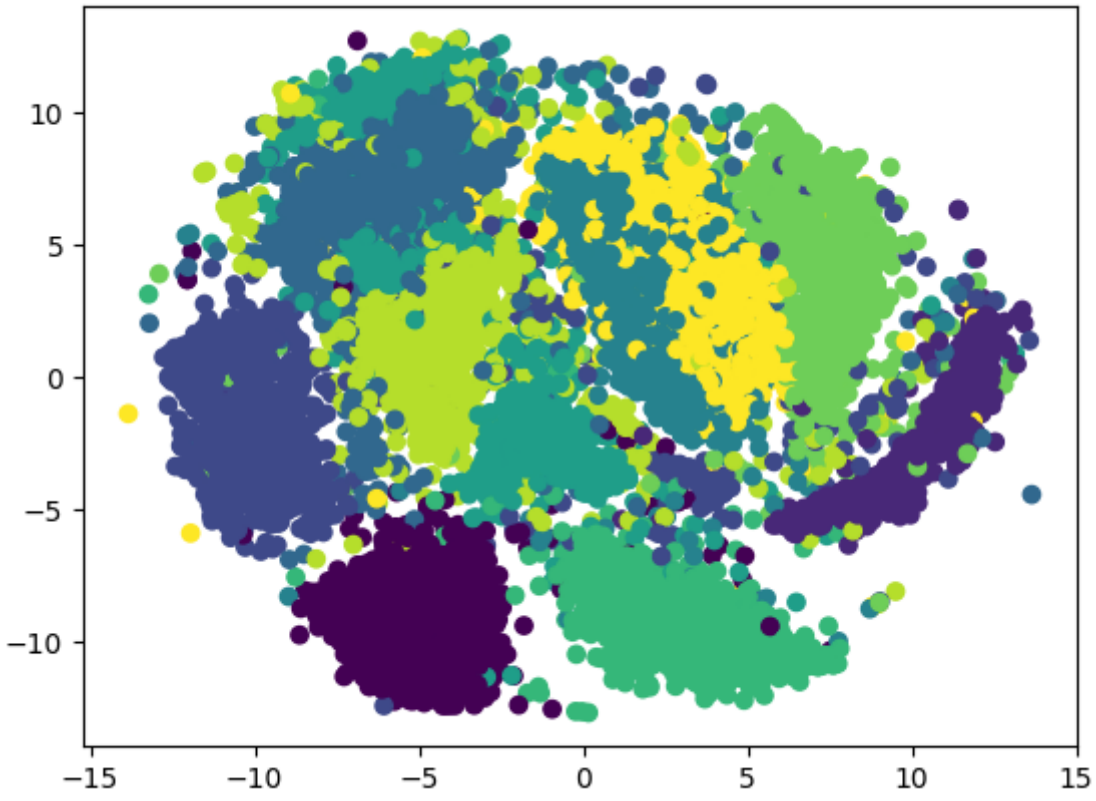

```
Iteration 110: error is nan
```



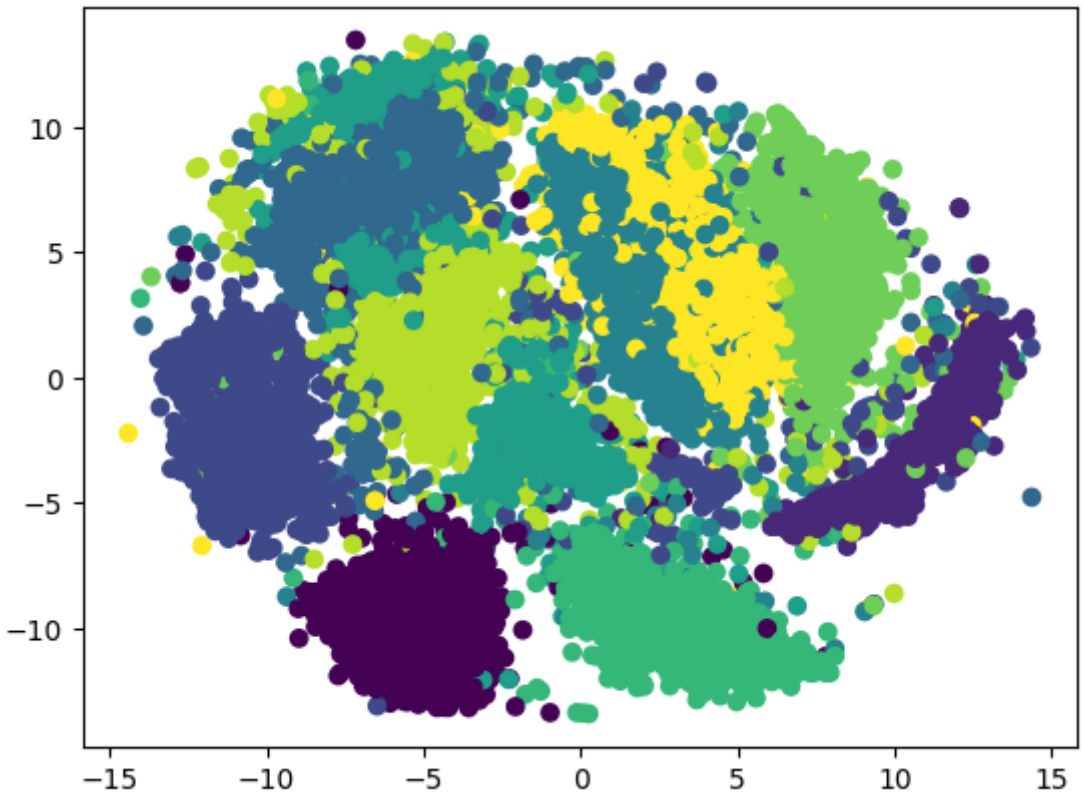

```
Iteration 120: error is nan
```



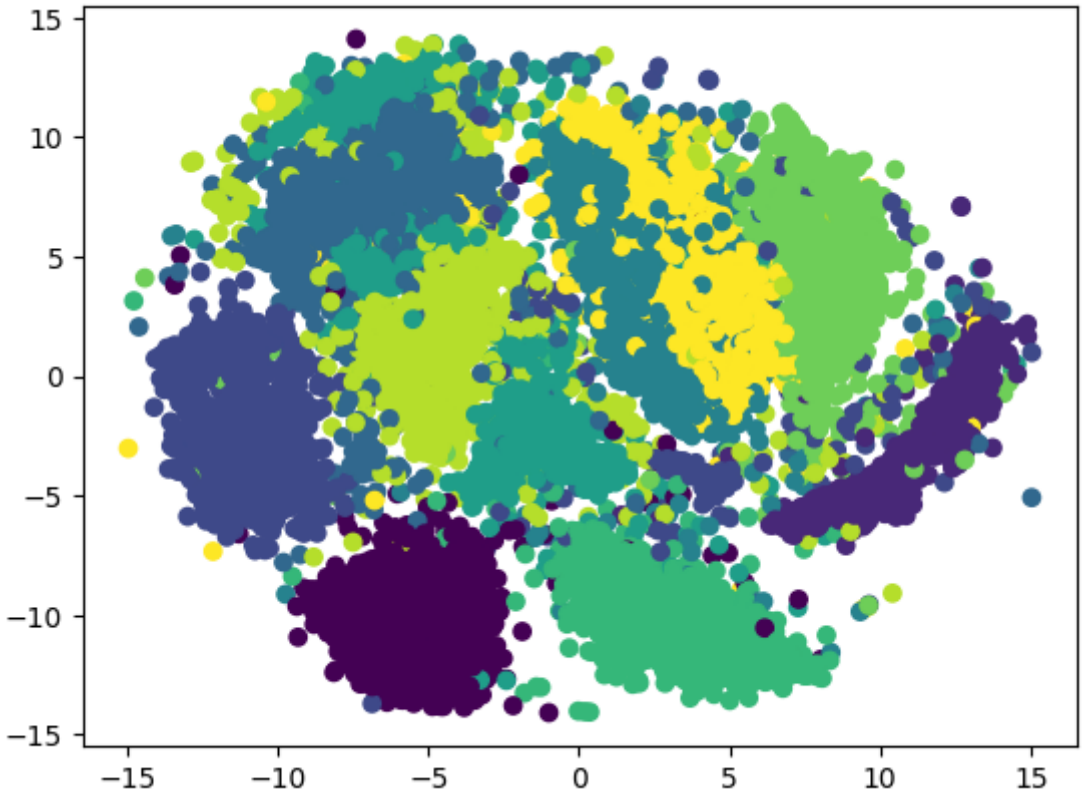

```
Iteration 130: error is nan
```



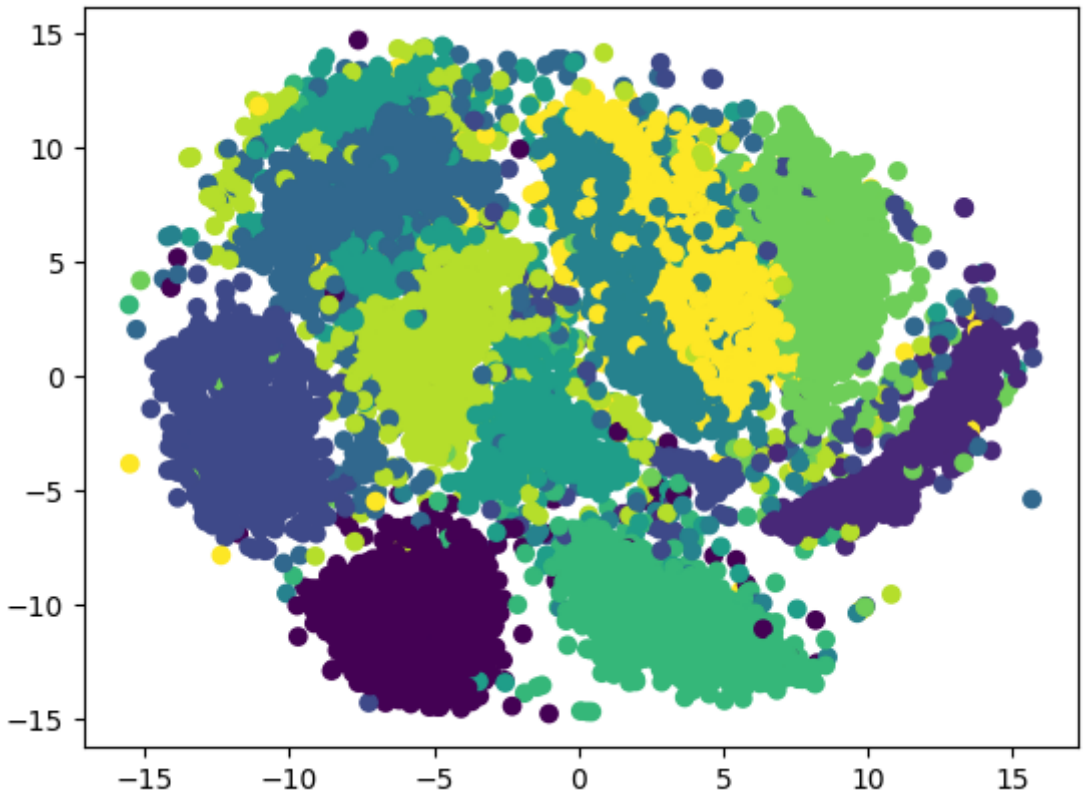

```
Iteration 140: error is nan
```



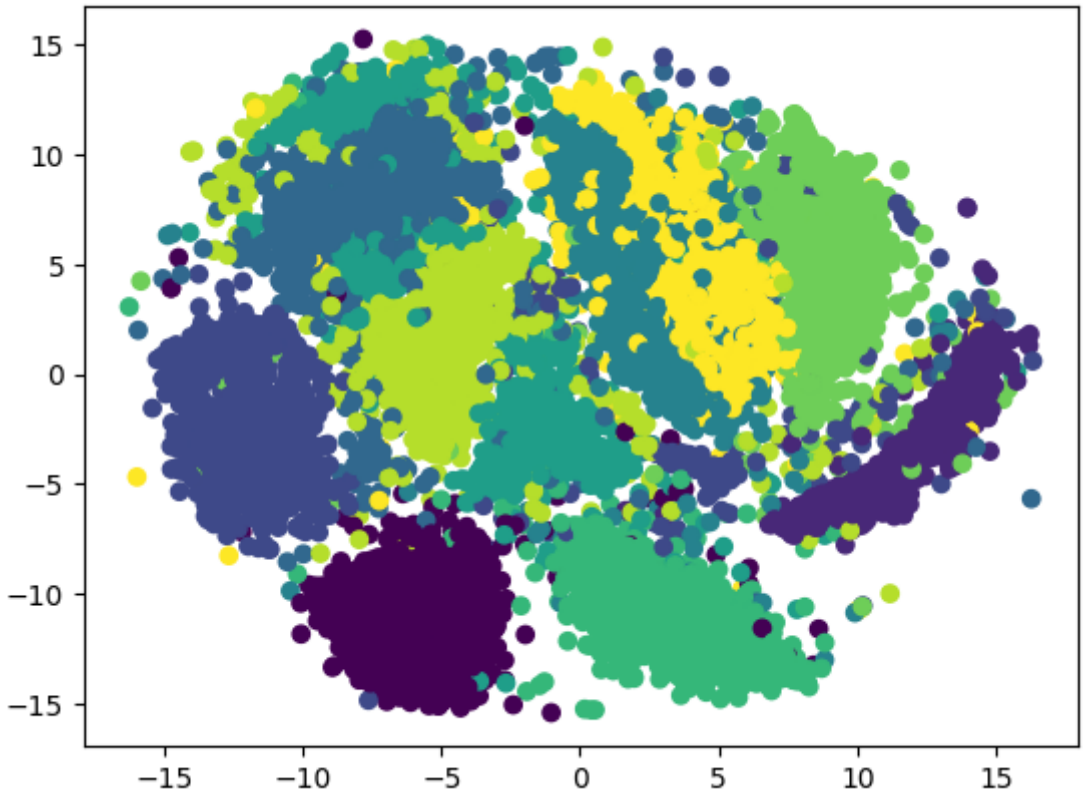

```
Iteration 150: error is nan
```



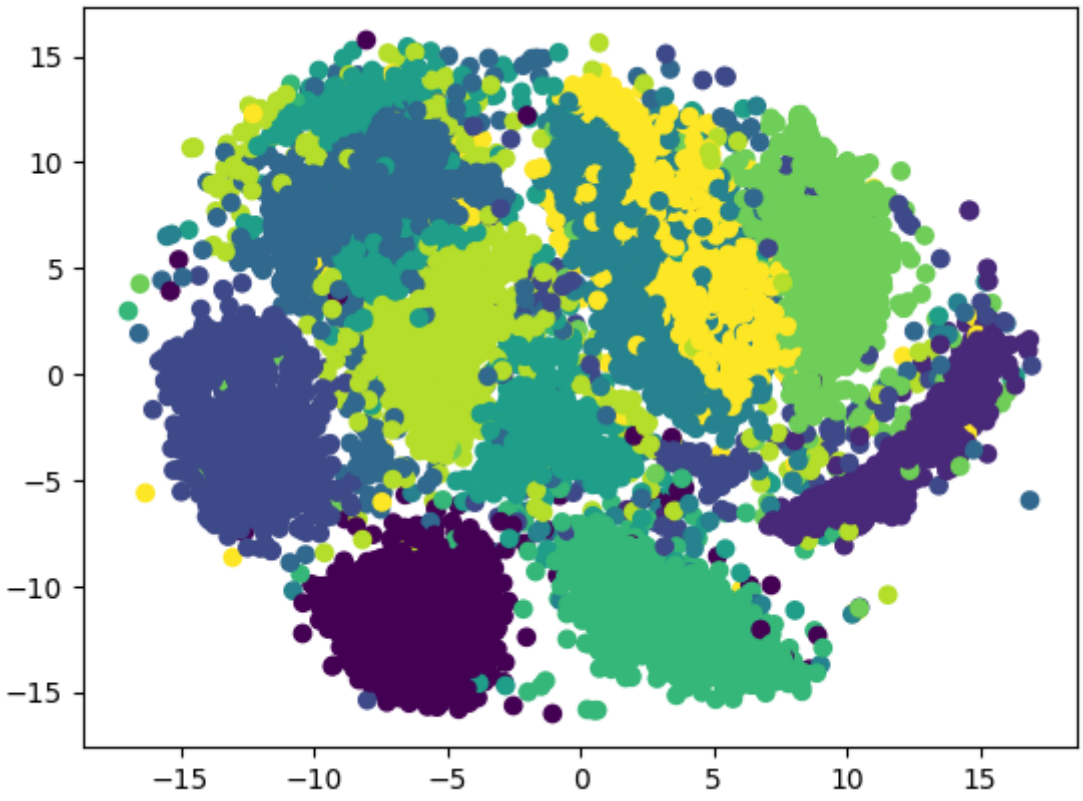

```
Iteration 160: error is nan
```



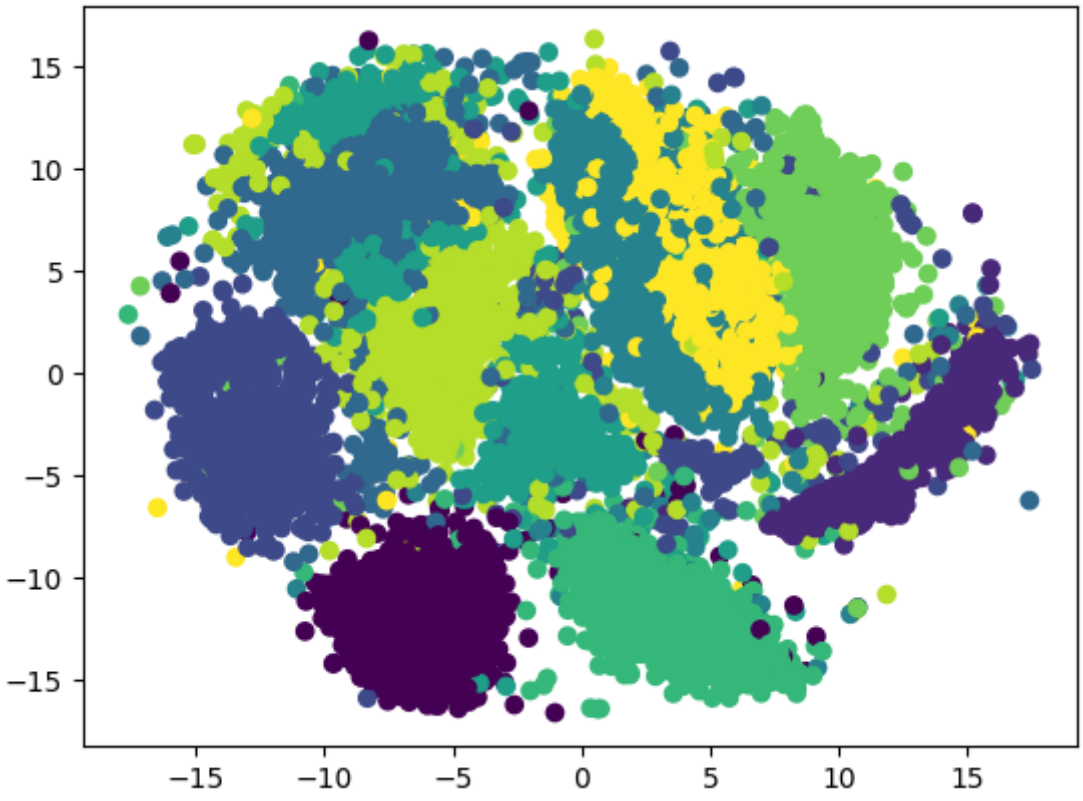

```
Iteration 170: error is nan
```



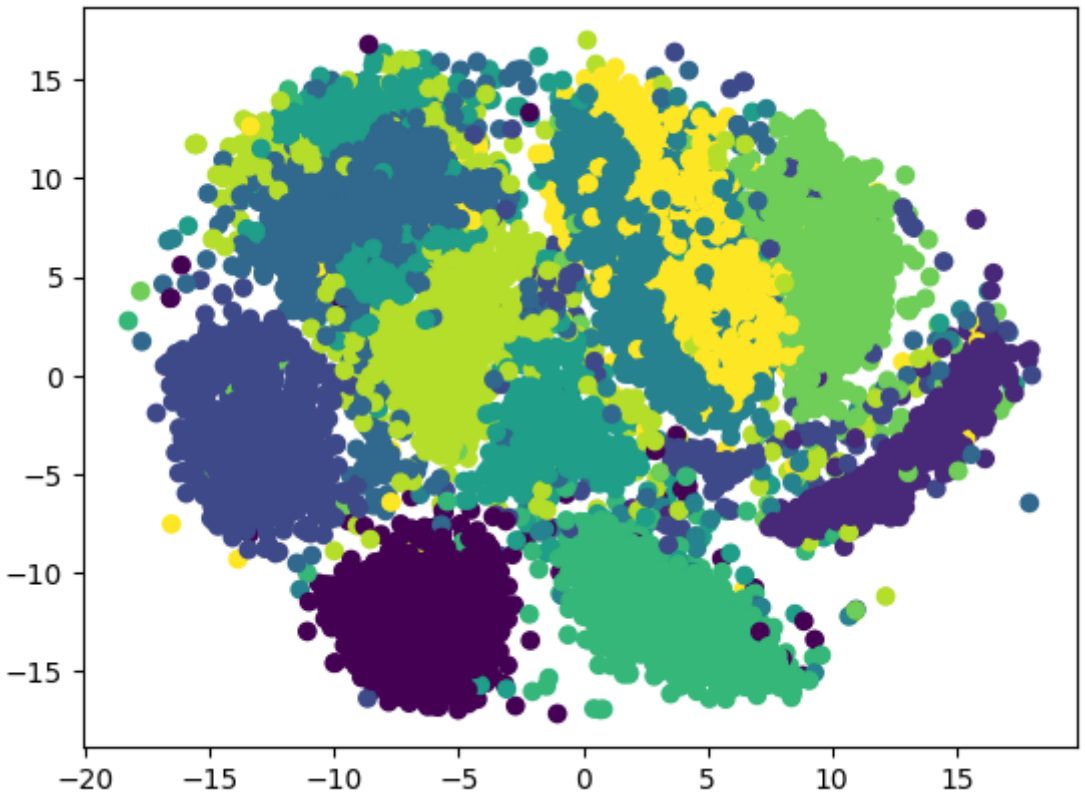

```
Iteration 180: error is nan
```



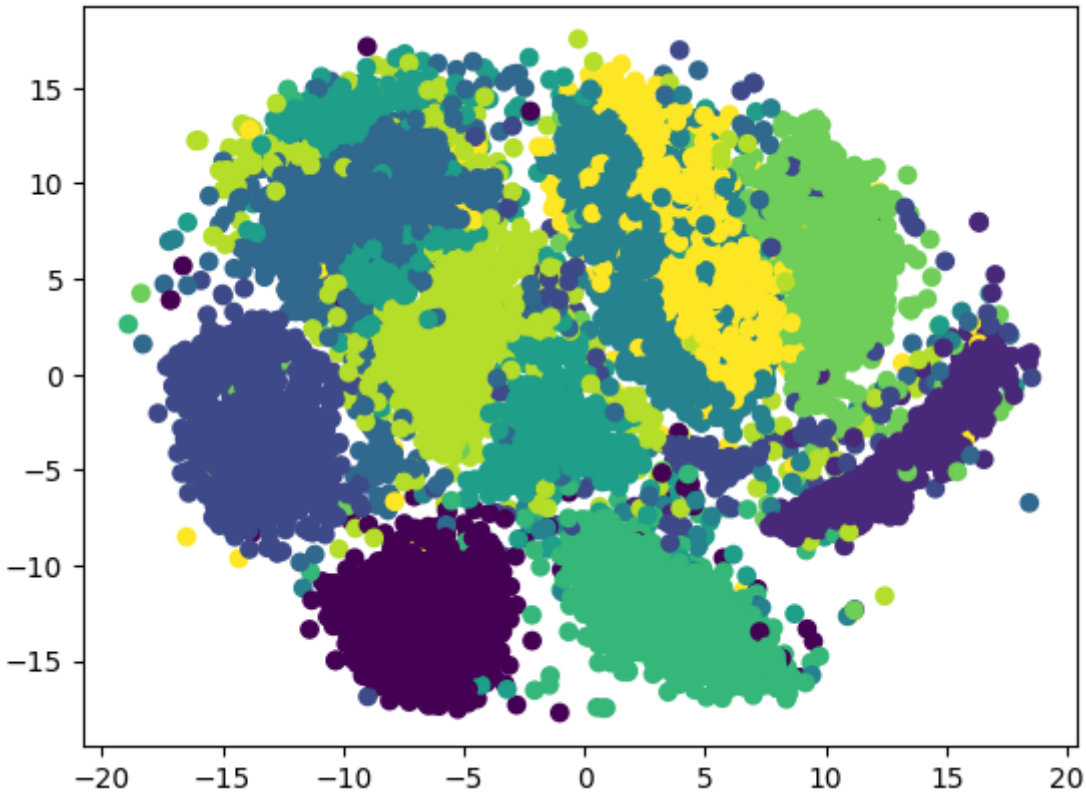

```
Iteration 190: error is nan
```



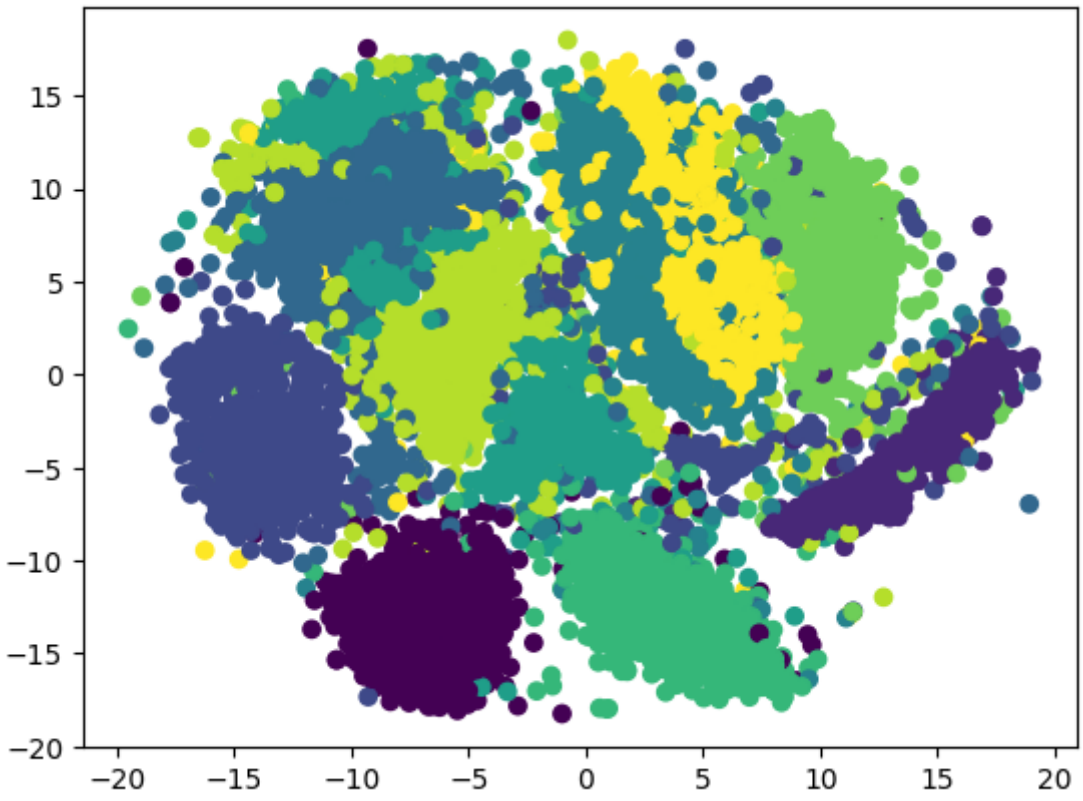

```
Iteration 200: error is nan
```



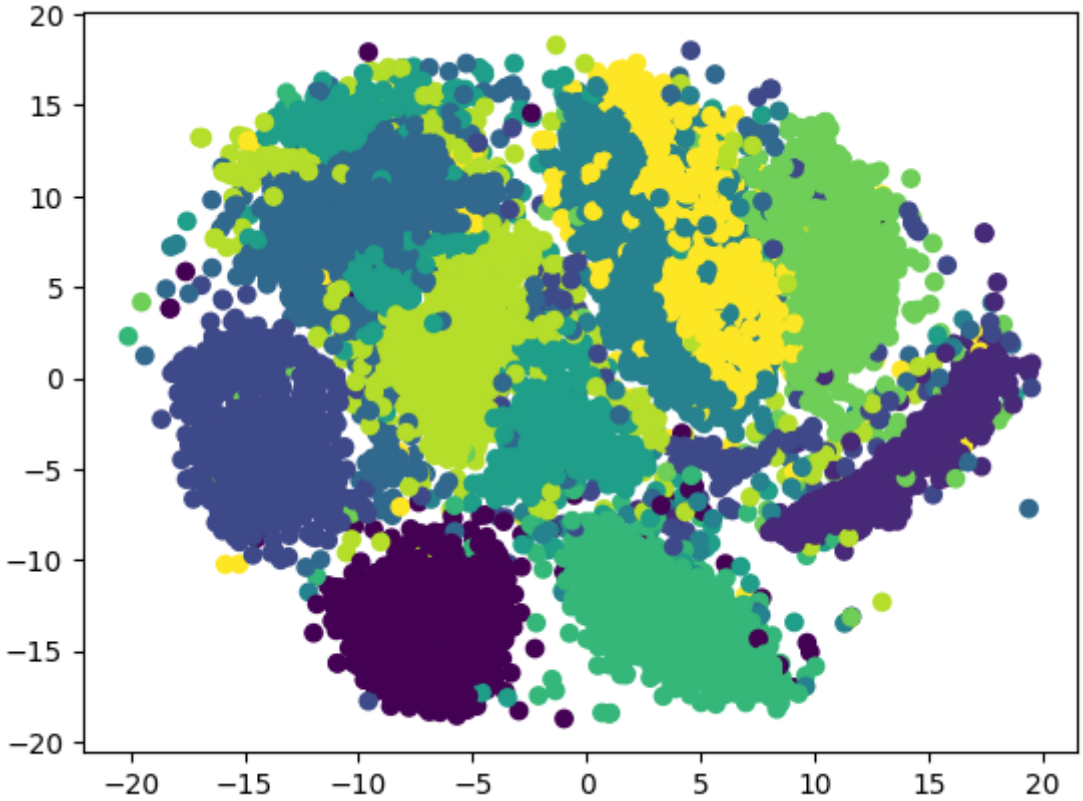

```
Iteration 210: error is nan
```



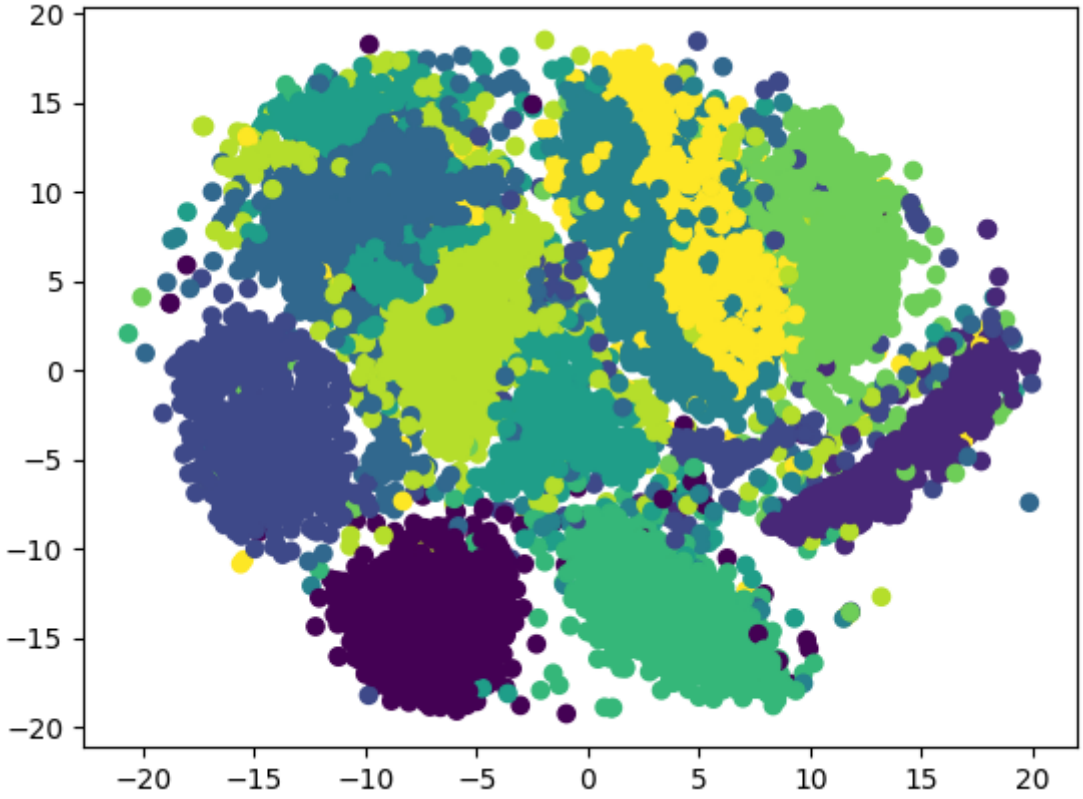

```
Iteration 220: error is nan
```




```
Iteration 230: error is nan
```




```
Iteration 240: error is nan
```




```
Iteration 250: error is nan
```