In [ ]:
```
import DW_oscillator as DW
import numpy as np
from IPython.display import clear_output

from torchdiffeq import odeint
import torch
import torch.nn as nn
import torch.optim as optim
from torch.nn import functional as F
import matplotlib.pyplot as plt
```

"run_field_sequence" that randomly generates and simulates a set of fields. It returns the time, DW position and angle plus the input time sequence. field_low and field_high specify the range the fields will be generated over while N_fields is the number of fields in the sequence and T is the time period of each field.

The outputs of interest are t, y and h_t. y[0] is the DW position over time (at time points given in t) and h_t is the magnetic field (serves as input) at the same times.

In [ ]:
```
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Using device:", device)
```

```
Using device: cuda
```

In [ ]:
```
t, y, h_t, fields, periods = DW.run_field_sequence(field_low = 100, field_high = 10
```

```
[100.]
[60.]
```

In [ ]:
```
t.shape,y.shape,h_t.shape,fields.shape,periods.shape
```

Out[ ]:
```
((600,), (2, 600), (600,), (1,), (1,))
```

In [ ]:
```
fields,periods
```

Out[ ]:
```
(array([100.]), array([60.]))
```

In [ ]:
```
class DWODE(nn.Module):
    """
    neural network for learning the chaotic lorenz system
    """
    def __init__(self):
        super(DWODE, self).__init__()
        self.lin = nn.Linear(3, 128)
        self.lin2 = nn.Linear(128, 256)
        self.lin3 = nn.Linear(256,512)
        self.lin4 = nn.Linear(512,3)
        self.tanh = nn.Tanh()
        self.lrelu = nn.LeakyReLU()


    def forward(self, t,x):
```

```
        x = self.lrelu(self.lin(x))
        x = self.lrelu(self.lin2(x))
        x = self.tanh(self.lin3(x))
        x = self.lin4(x)
        return x
```

In [ ]:
```
time = torch.tensor(t).to(device)
```

In [ ]:
```
time.shape
```

Out[ ]:
```
torch.Size([600])
```

In [ ]:
```
time_train = torch.tensor(t).to(device)
```

In [ ]:
```
time_test = torch.tensor(t[300:]).to(device)
```

In [ ]:
```
time_train.shape,time_test.shape
```

Out[ ]:
```
(torch.Size([600]), torch.Size([300]))
```

In [ ]:
```
h_t_ = torch.tensor(h_t, dtype=torch.float64)  # Converting to column vector
y_0_ = torch.tensor(y[0], dtype=torch.float64)  # Converting to column vector
y_1_ = torch.tensor(y[1], dtype=torch.float64)  # Converting to column vector

# Stack the tensors horizontally
data = torch.stack((torch.div(h_t_, 1000.),torch.div(y_0_, 1000.),y_1_)).to(device)
```

In [ ]:
```
data.shape
```

Out[ ]:
```
torch.Size([3, 600])
```

In [ ]:
```
train = data[:,:].transpose(0,1)
```

In [ ]:
```
test = data[:,300:].transpose(0,1)
```

In [ ]:
```
train.shape,test.shape
```

Out[ ]:
```
(torch.Size([600, 3]), torch.Size([300, 3]))
```

In [ ]:
```
model = DWODE().double().to(device)
```

In [ ]:
```
optimizer = optim.AdamW(model.parameters(), lr=1e-3)
```

In [ ]:
```
def get_batch(true_y,time, batch_size):
    num_samples = len(true_y)
    indices = np.random.choice(np.arange(num_samples - batch_size, dtype=np.int64),
    indices.sort()
    #print(indices)
    batch_y0 = true_y[indices]  # (batch_size, D)
    batch_t = time[:batch_size]  # (batch_size)
```

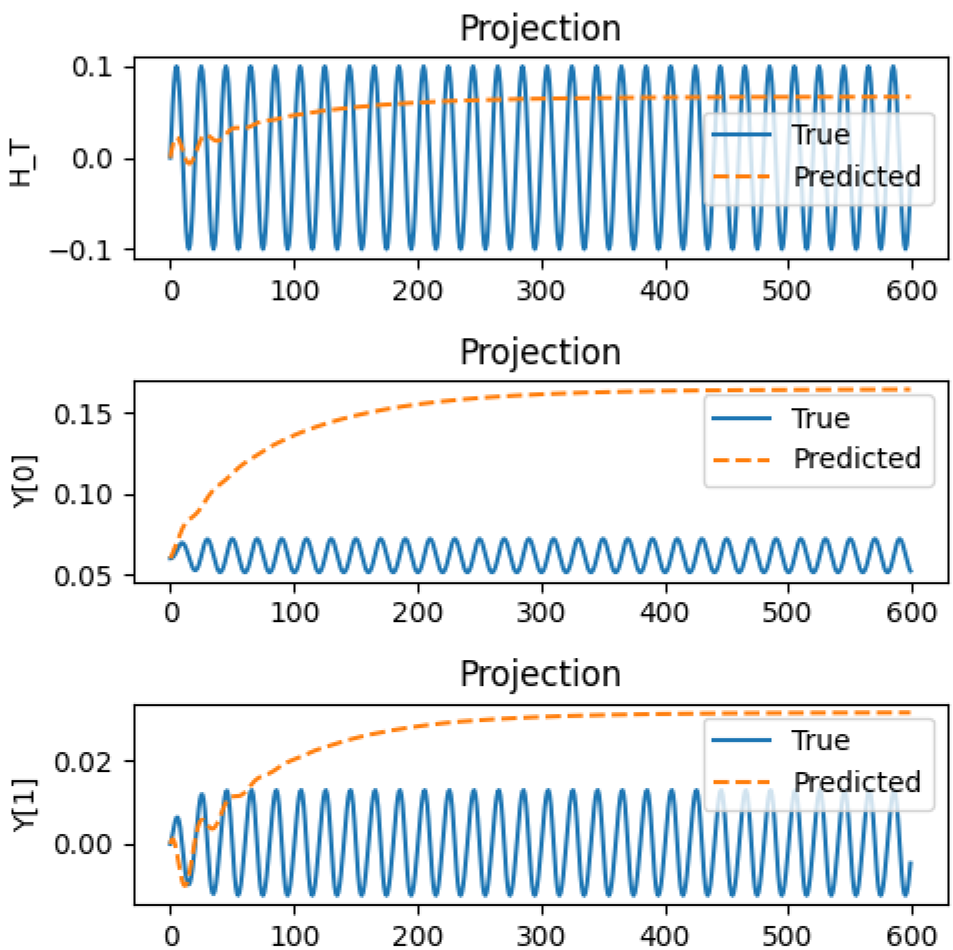
```
    batch_y = torch.stack([true_y[indices + i] for i in range(batch_size)], dim=0)
    return batch_y0,batch_t,batch_y
```

In [ ]:
```
from torchdiffeq import odeint_adjoint as adjoint
```

In [ ]:
```
losses = []
whole_losses = []
best_loss = 100.0
for i in range(500):

    optimizer.zero_grad()

    init,batch_t,truth = get_batch(train,time_train,16)
    #print(init,batch_t,truth)
    pred_y = adjoint(model,init,batch_t,method='dopri5')
    loss = F.mse_loss(pred_y, truth)
    loss.backward()
    losses.append(loss.item())
    optimizer.step()
    if loss.item() < best_loss:
                best_loss = loss.item()
                torch.save(model.state_dict(), 'saved_models/domain_best_single_fie
    if i % 100 == 0:

        with torch.no_grad():
            pred_y = adjoint(model, train[0], time_train,method='dopri5')
            loss = F.mse_loss(pred_y, train)
            whole_losses.append(loss.item())

            print('Iter {:04d} | Total Loss {:.6f}'.format(i, loss.item()))
            x_pred = pred_y[:,0].cpu()
            y_pred = pred_y[:,1].cpu()
            z_pred = pred_y[:,2].cpu()

            # Extract the x, y, z coordinates from X_train_plt
            x_train = train[:,0].cpu()
            y_train = train[:,1].cpu()
            z_train = train[:,2].cpu()

            fig, ax = plt.subplots(3, 1, figsize=(5, 5))
            ax[0].plot(x_train, label='True')
            ax[0].plot(x_pred, label='Predicted', linestyle='--')
            ax[0].set_ylabel('H_T')
            ax[0].set_title('Projection')
            ax[0].legend()

            ax[1].plot(y_train, label='True')
            ax[1].plot(y_pred, label='Predicted',linestyle='--')
            ax[1].set_ylabel('Y[0]')
            ax[1].set_title('Projection')
            ax[1].legend()

            ax[2].plot(z_train, label='True')
            ax[2].plot(z_pred, label='Predicted',linestyle='--')
            ax[2].set_ylabel('Y[1]')
```

```
        ax[2].set_title('Projection')
        ax[2].legend()

        plt.tight_layout()
        plt.show()
        clear_output(wait=True)
```

Iter 0400 | Total Loss 0.005946



In [ ]:
```
print(best_loss)
```

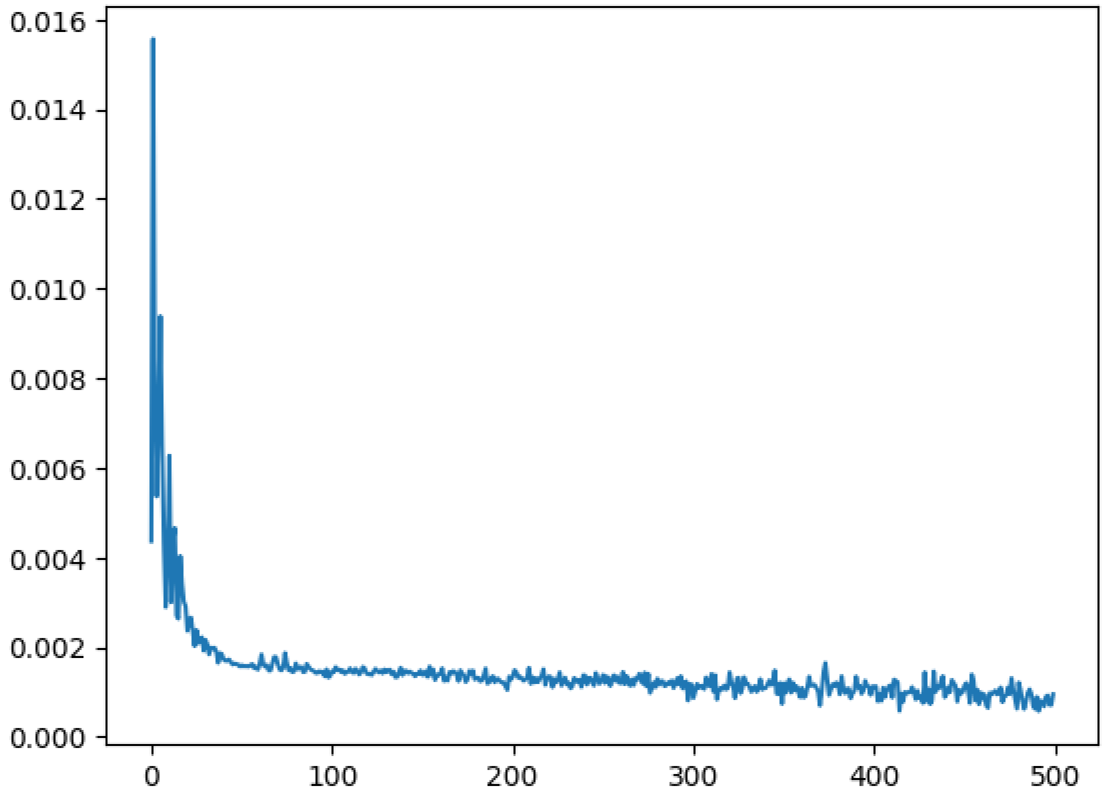
0.0005760219379882456

In [ ]:
```
test_model = DWODE().double().to(device)
```

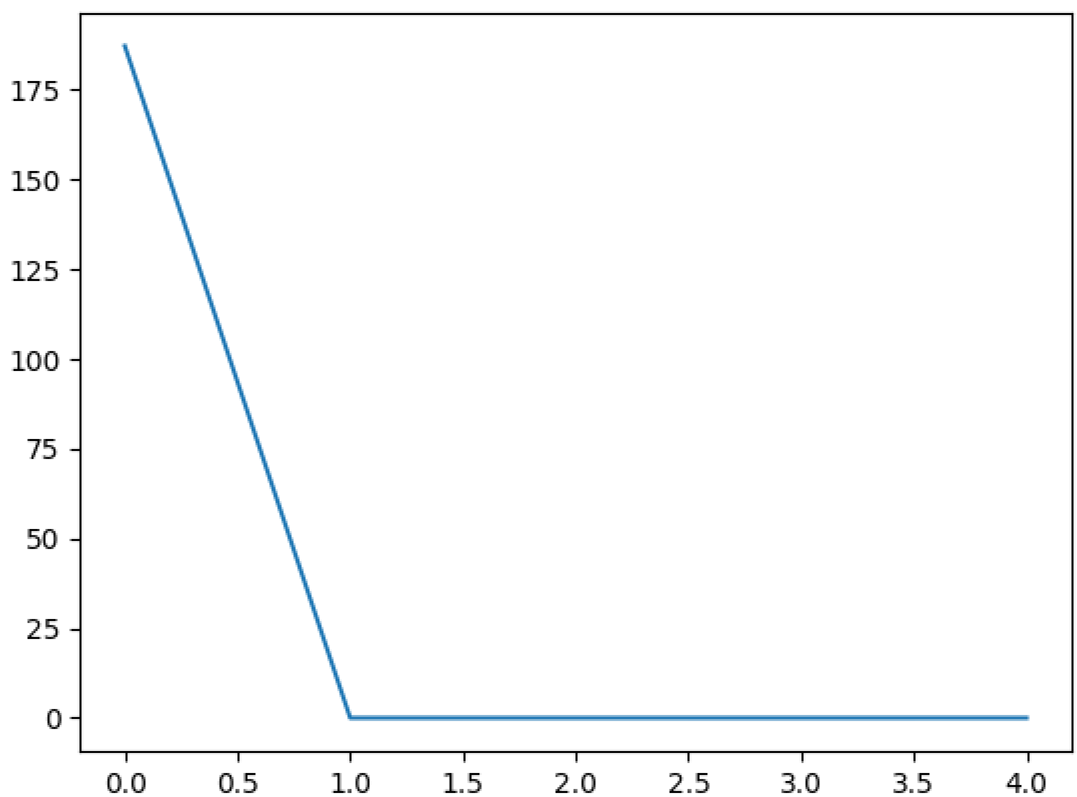
In [ ]:
```
test_model.load_state_dict(torch.load('saved_models\domain_best_single_field_onlylr
```

Out[ ]: <All keys matched successfully>

In [ ]:
```
plt.plot(losses)
plt.show()
```



In [ ]:
```
plt.plot(whole_losses)
plt.show()
```



In [ ]:
```
with torch.no_grad():
    pred = adjoint(test_model, train[0], time,method='dopri5')
```

In [ ]:
```
pred = pred.cpu().detach().numpy()
```

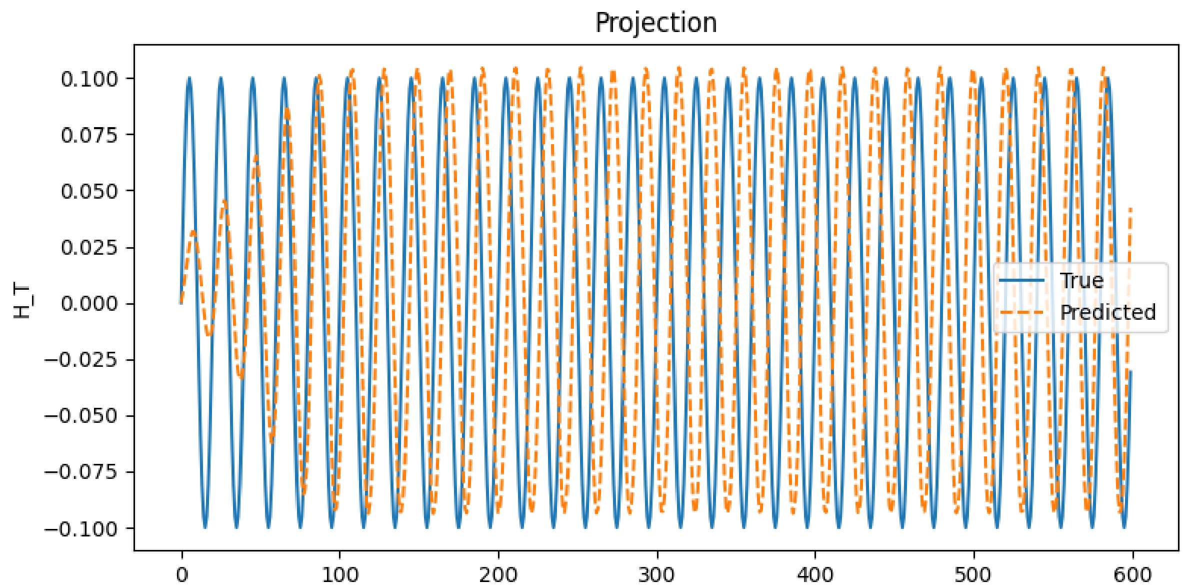
In [ ]:

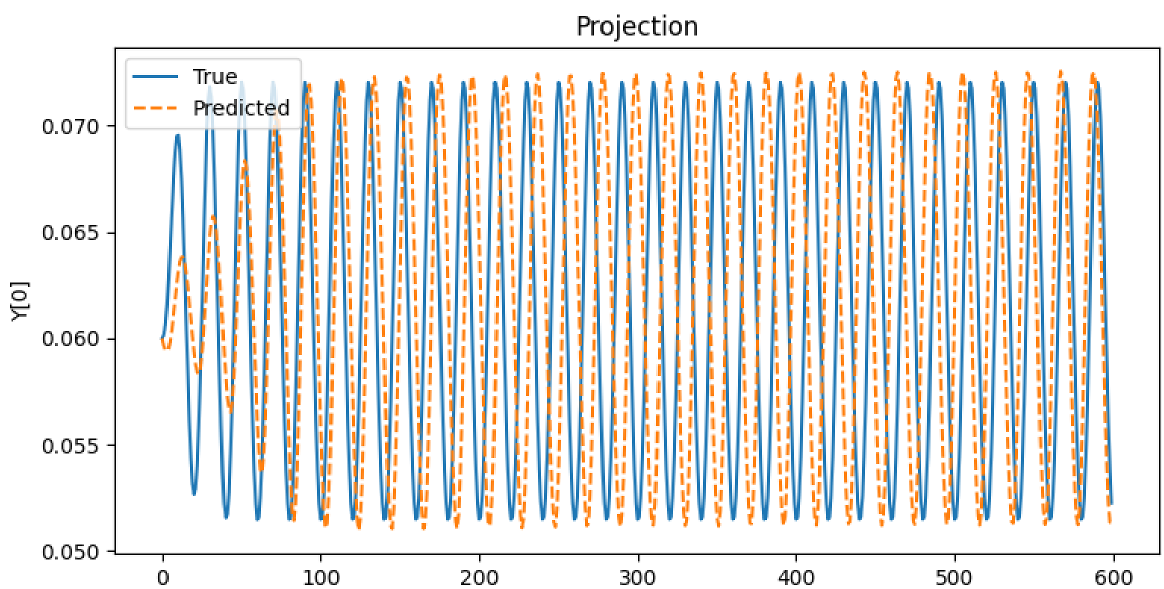
In [ ]:
```
pred.shape,data.shape
```

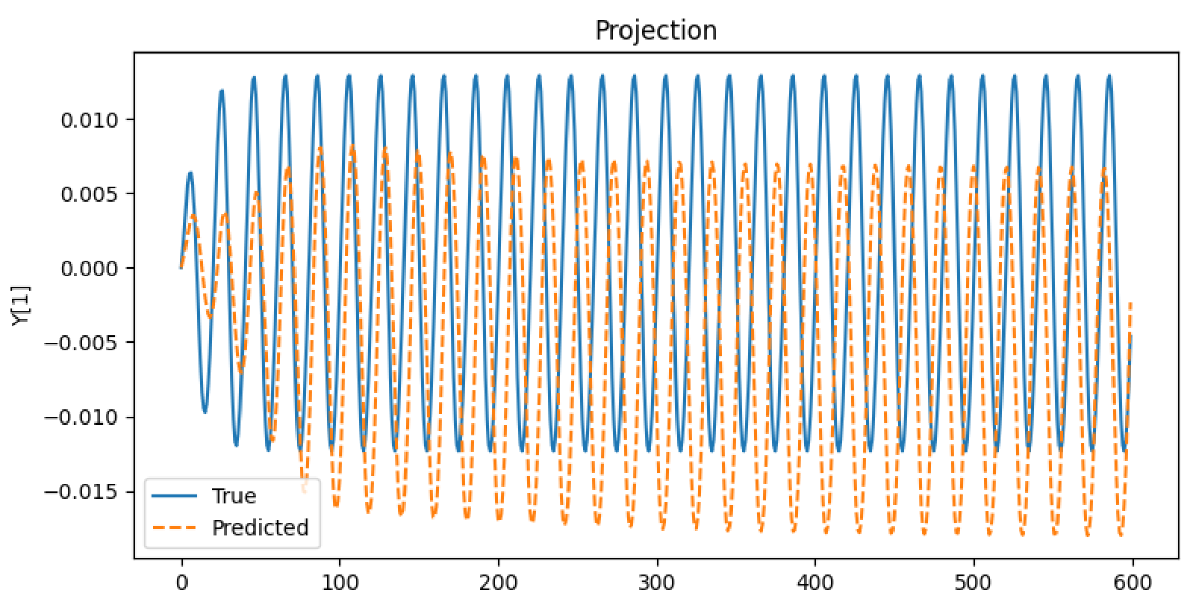
Out[ ]:
```
((600, 3), torch.Size([3, 600]))
```

In [ ]:
```
data = data.transpose(0,1)
```

In [ ]:
```
# Extract the x, y, z coordinates from predictions_plt
x_pred = pred[:,0]
y_pred = pred[:,1]
z_pred = pred[:,2]

# Extract the x, y, z coordinates from X_train_plt
x_train = data[:,0].cpu()
y_train = data[:,1].cpu()
z_train = data[:,2].cpu()

fig, ax = plt.subplots(3, 1, figsize=(8, 12))
ax[0].plot(x_train, label='True')
ax[0].plot(x_pred, label='Predicted',linestyle='--')
ax[0].set_ylabel('H_T')
ax[0].set_title('Projection')
ax[0].legend()

ax[1].plot(y_train, label='True')
ax[1].plot(y_pred, label='Predicted',linestyle='--')
ax[1].set_ylabel('Y[0]')
ax[1].set_title('Projection')

ax[1].legend()

ax[2].plot(z_train, label='True')
ax[2].plot(z_pred, label='Predicted',linestyle='--')
ax[2].set_ylabel('Y[1]')
ax[2].set_title('Projection')
ax[2].legend()
plt.savefig('projection_full_1_batch_lrelu_5thrun_60pos_start_2.png')
plt.tight_layout()
plt.show()
```


Projection
H_T
True
Predicted
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100
0
100
200
300
400
500
600


Projection
Y[0]
True
Predicted
0.070
0.065
0.060
0.055
0.050
0
100
200
300
400
500
600


Projection
Y[1]
True
Predicted
0.010
0.005
0.000
−0.005
−0.010
−0.015
0
100
200
300
400
500
600