Predicting Machine Failures with Temperature, Noise, and Vibrations Data

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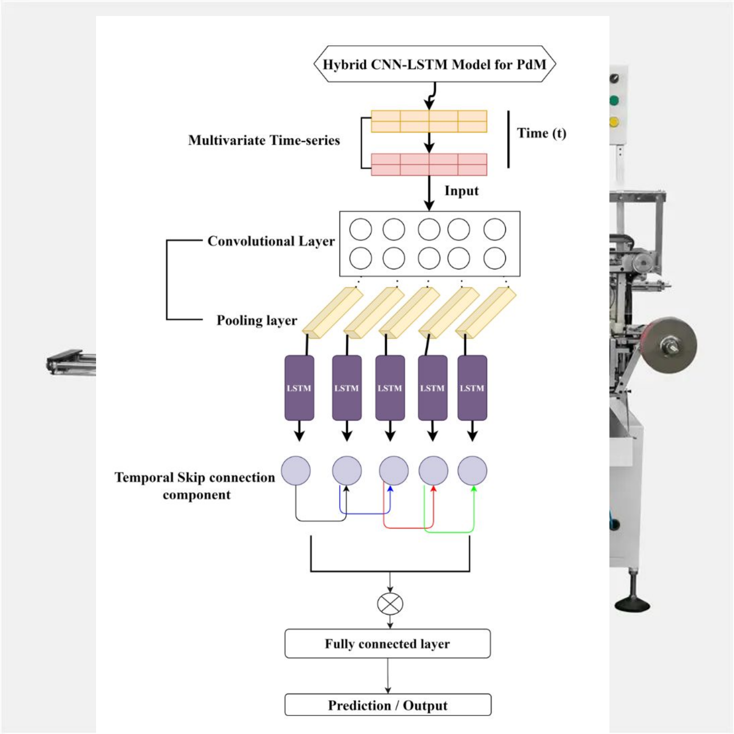
DS598 Final Project

Background

- Toothbrush tufting machines
  - Dental Industry
  - Large-scale, automated manufacturing
- Current practice
  - Replace after damage
  - Manual checkups
- Goal
  - Common architectures (LSTMs Jansen et al, CNN-LSTMs Wahid et al.)
  - Alert prior to failure
  - Reduce repair and labor costs

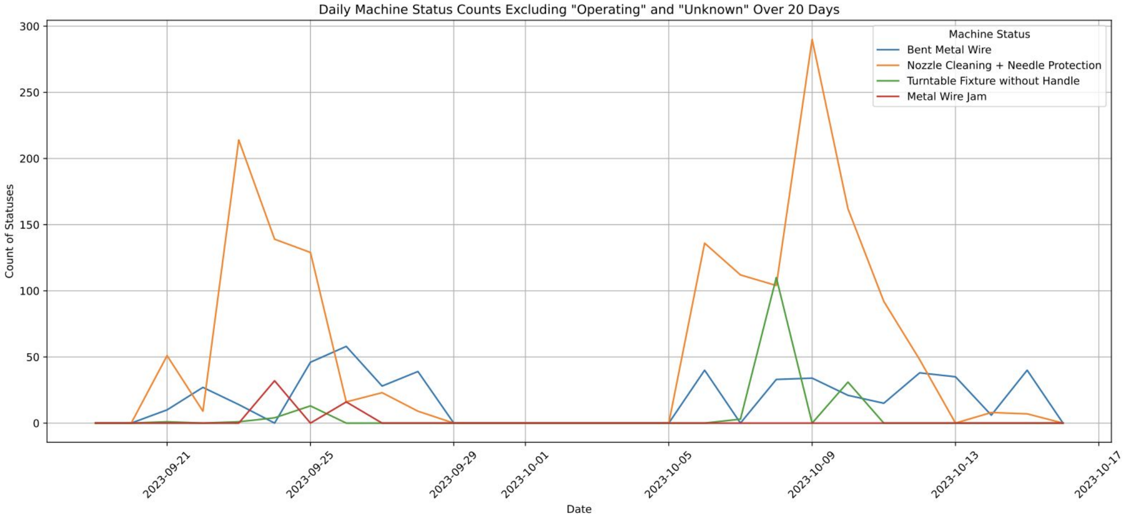


Data

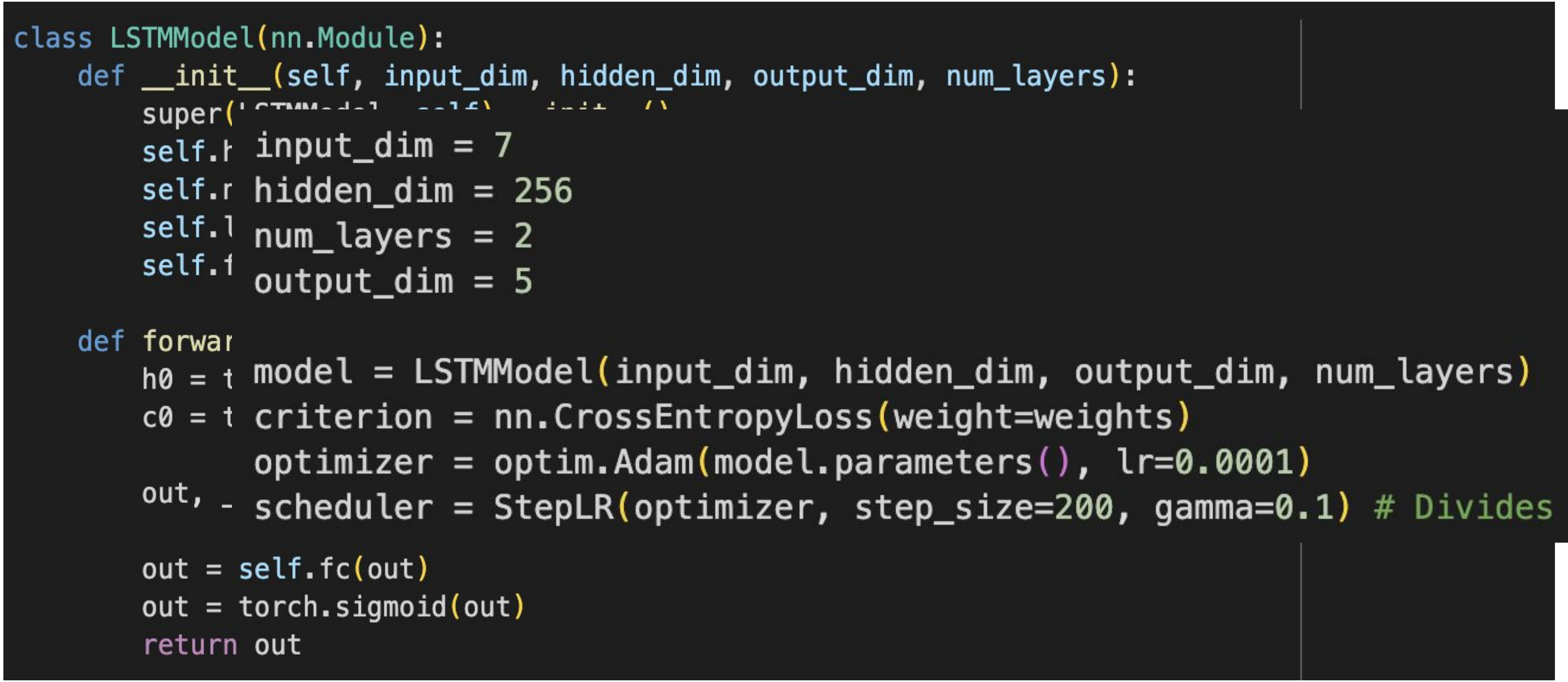
- From 09-19-23 to 10-16-23
- Sensor generated temperature (celsius), 3-dimensional vRMS vibration velocity (m/s), and shock/noise frequency data (Hz)
- Machine statuses (Operating, Nozzle Cleaning + Needle Protection, Unknown, Bent Metal Wire, Turntable Fixture without Handle)
- Collected for on ~10-second intervals
- Parts of the data is missing (nan)
- Gap between 09-29-23 to 10-08-23 without any new data, no machine status data until 09-21-23

Data Preprocessing

- Resample data to ensure 10-second intervals between data points
- Address gap by separating data into two datasets
- Remove and replace nan values (column mean for numeric, “Unknown” for machine status)



Model Architecture/Sequence Selection

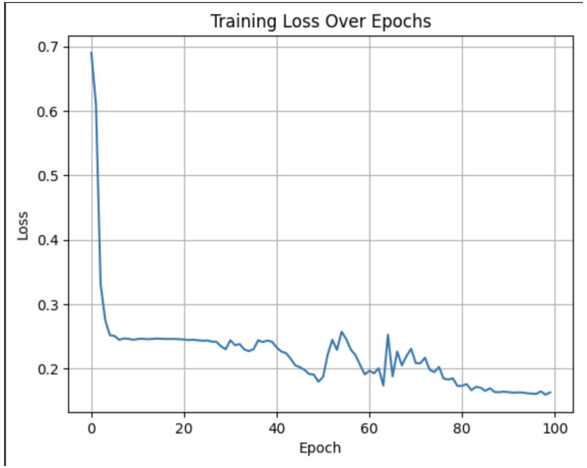


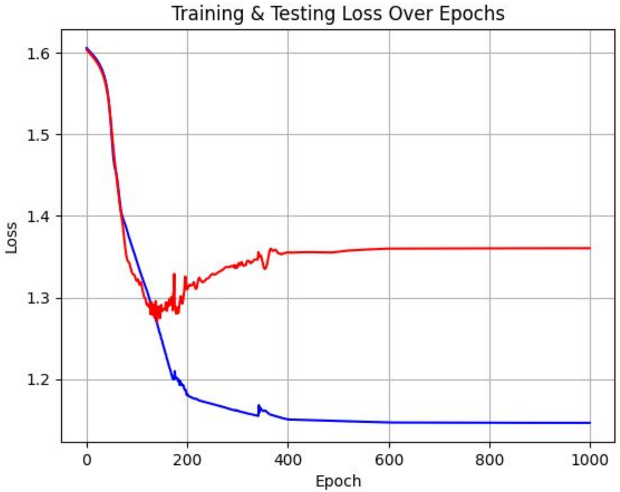
```
class LSTMModel(nn.Module):
    def __init__(self, input_dim, hidden_dim, output_dim, num_layers):
        super(
        self.h
        self.r
        self.l
        self.f

    def forwar
        h0 = t
        c0 = t

        out, -

        out = self.fc(out)
        out = torch.sigmoid(out)
        return out
```

```
input_dim = 7
hidden_dim = 256
num_layers = 2
output_dim = 5

model = LSTMModel(input_dim, hidden_dim, output_dim, num_layers)
criterion = nn.CrossEntropyLoss(weight=weights)
optimizer = optim.Adam(model.parameters(), lr=0.0001)
scheduler = StepLR(optimizer, step_size=200, gamma=0.1) # Divides
```

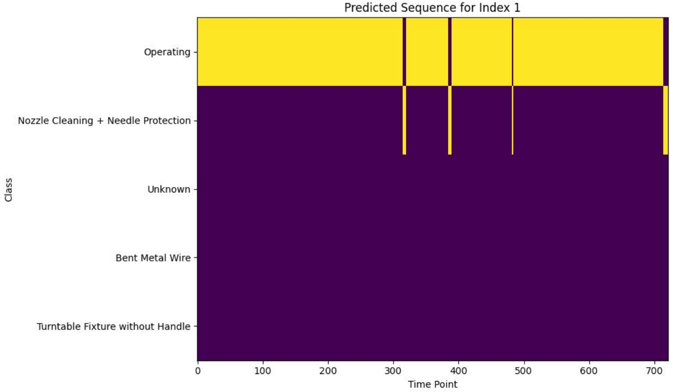
Results

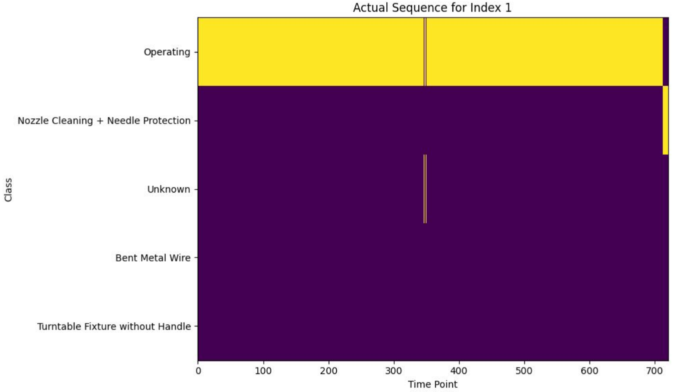
- 0.1629 Binary cross entropy loss (100 Epochs)
- 1.1462 Cross entropy loss with class weights (1000 Epochs with scheduling)

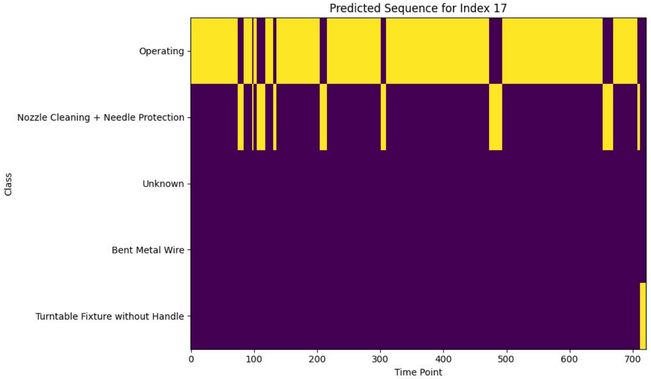


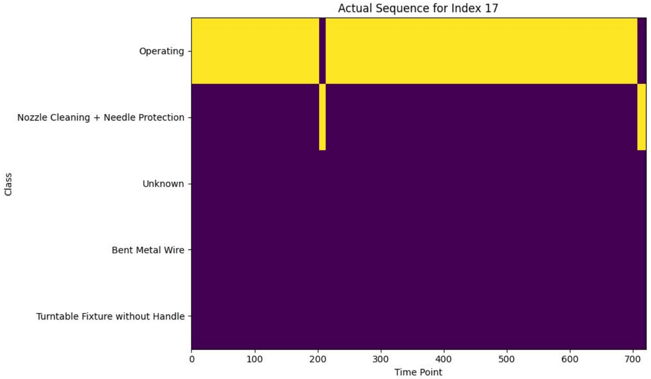


Predictions









Next Steps

- Debug cross entropy loss training
- Experiment with stacked LSTMs
- Evaluate model accuracy
- Experiment with different model types (CNN-LSTMs, TCNs Hsu et al., transformers)