Experimental study of forecasting of fall using RNN and simulated data.

By

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Advised by

Dr. Ngu

Context

- Stick Balancing
  - Experimental Setup
- Inverted pendulum - cart model

Control at stability's edge minimizes energetic costs: expert stick balancing
Milton, et al.,

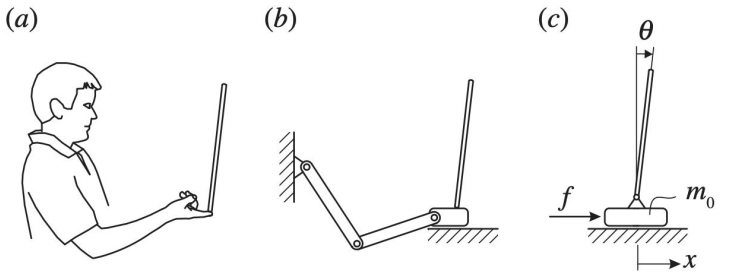


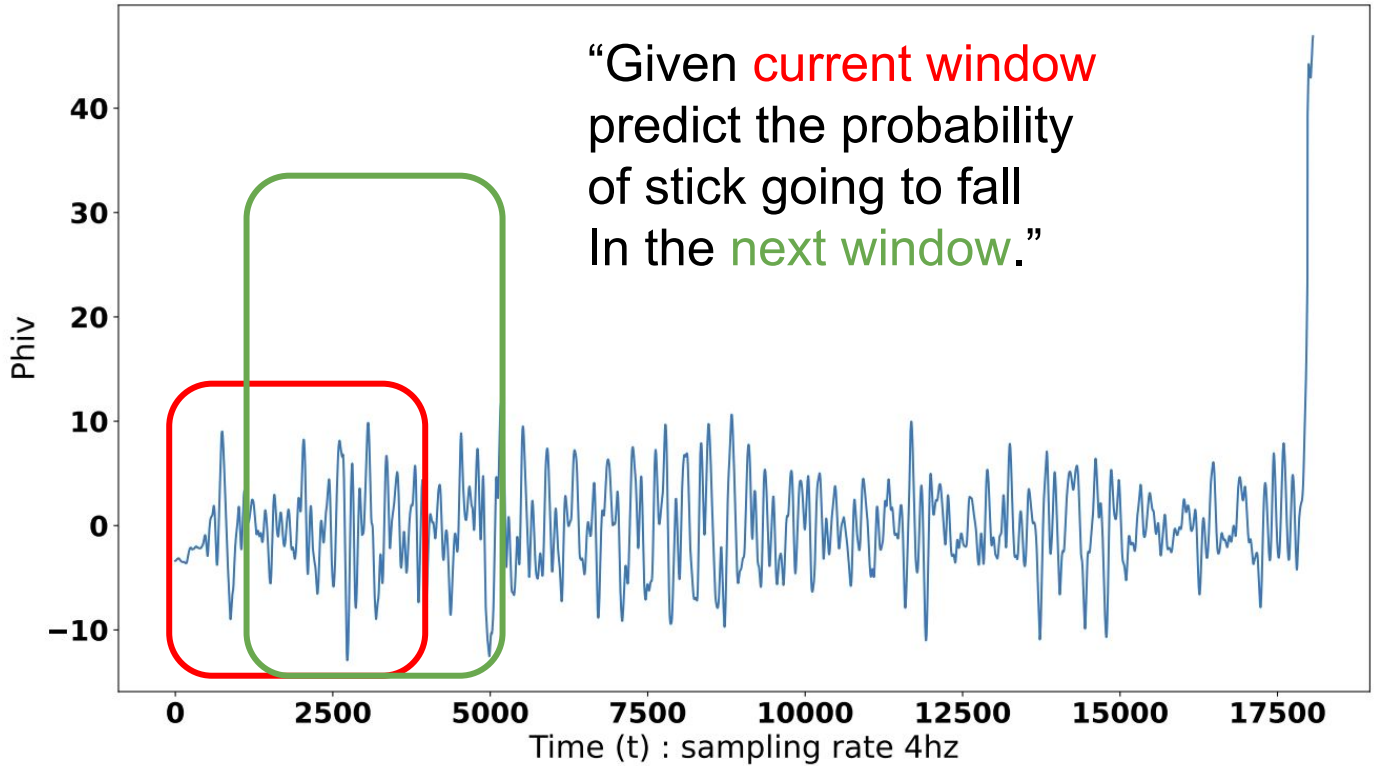
Figure 1. (*a*) Subject balancing stick on fingertip. (*b*) Slider crank model of the arm used to estimate the equivalent mass of the cart for the pendulum–cart model. (*c*) Pendulum–cart model for stick balancing with equivalent mass.

Delayed state feedback

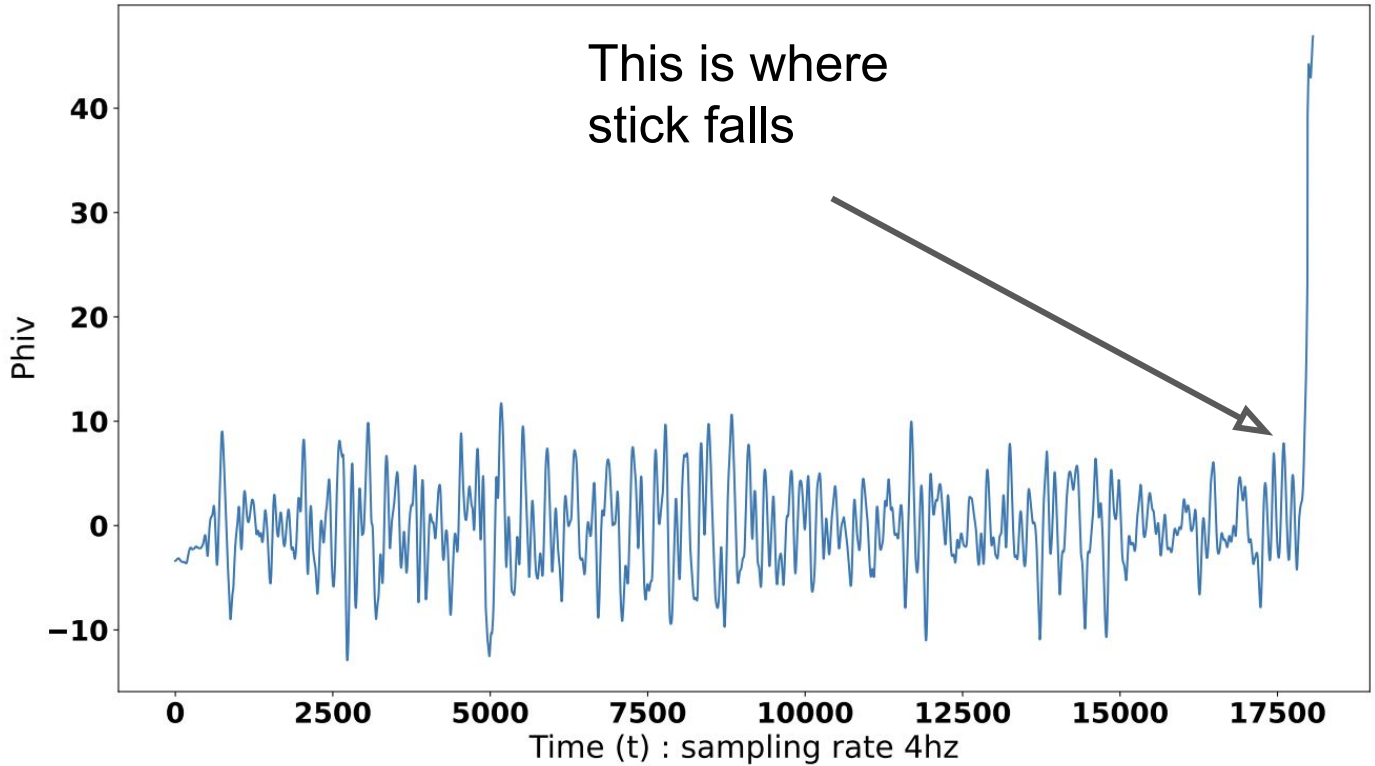
$$f_{\mathrm{PD}}(t) = k_{\mathrm{p},\theta}\theta(t-\tau) + k_{\mathrm{d},\theta}\dot{\theta}(t-\tau) + k_{\mathrm{p},x}x(t-\tau) + k_{\mathrm{d},x}\dot{x}(t-\tau),$$

Ref: https://doi.org/10.1098/rsif.2016.0212

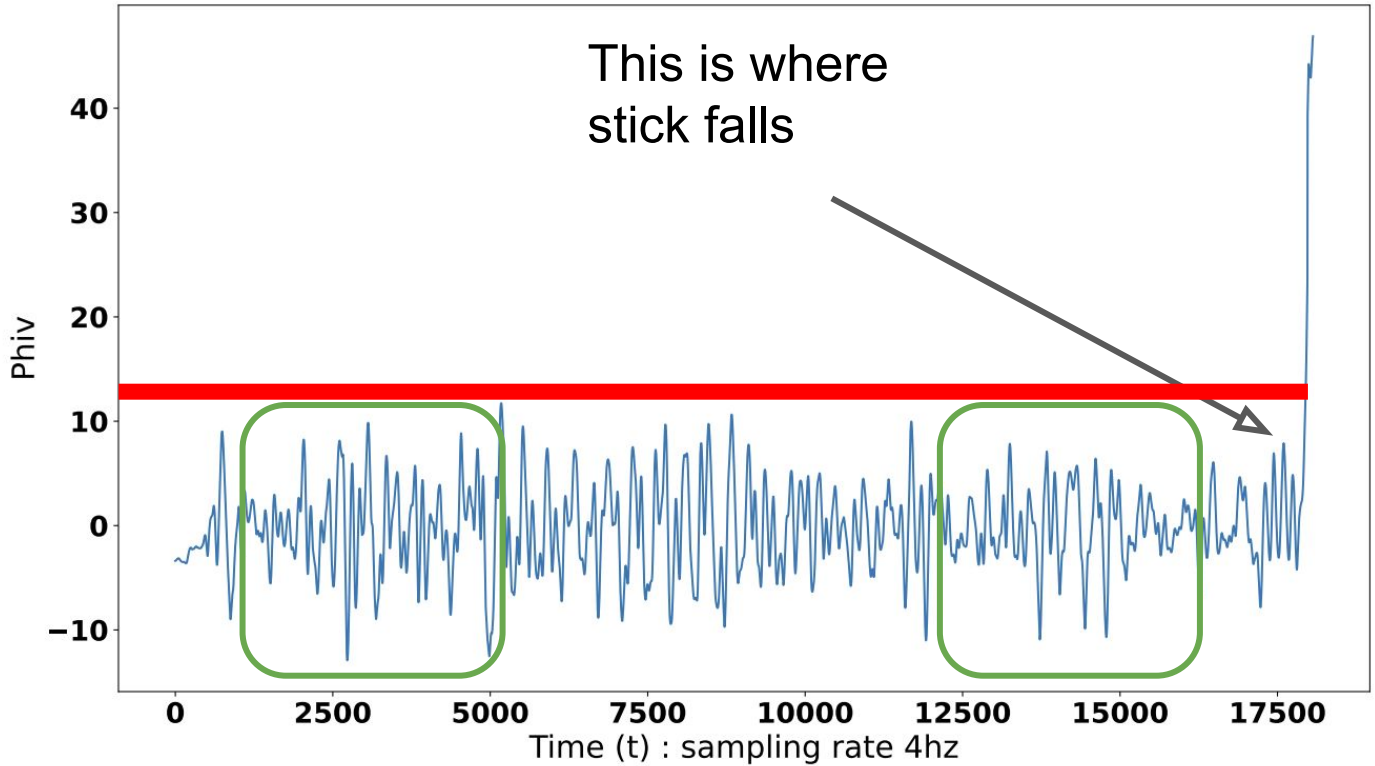
Objective


"Given current window
predict the probability
of stick going to fall
In the next window."
Phiv
40
30
20
10
0
−10
0
2500
5000
7500
10000
12500
15000
17500
Time (t) : sampling rate 4hz

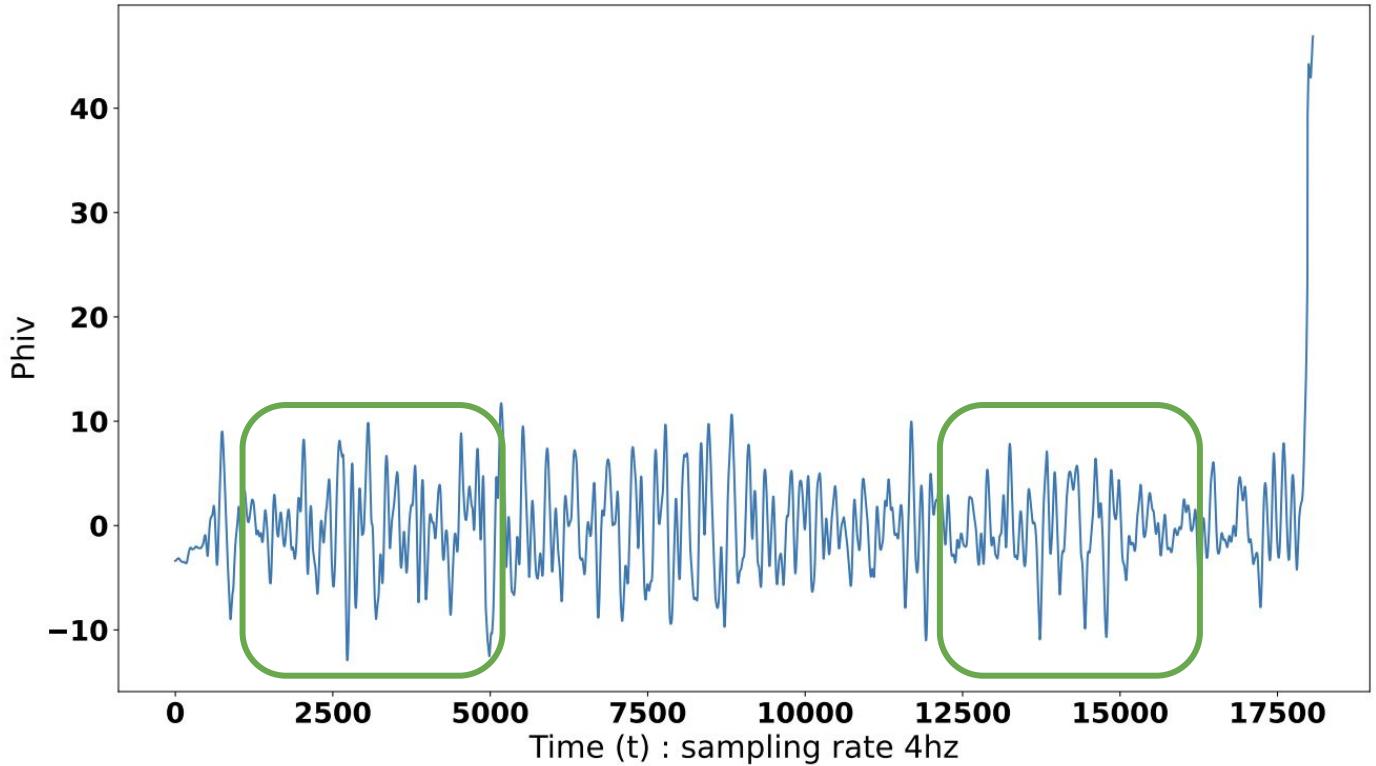
Complexity


This is where
stick falls
Phiv
40
30
20
10
0
−10
0
2500
5000
7500
10000
12500
15000
17500
Time (t) : sampling rate 4hz

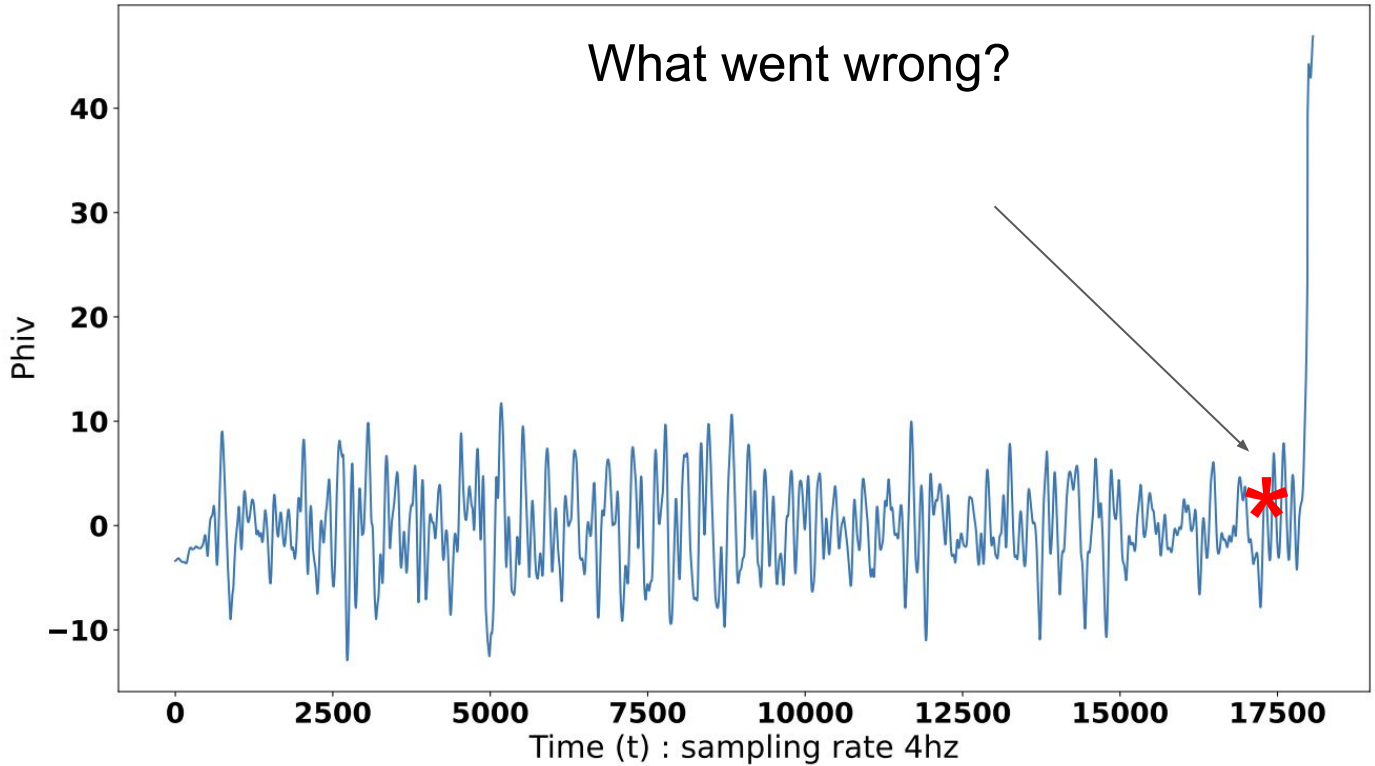
Complexity


This is where
stick falls
Phiv
40
30
20
10
0
−10
0
2500
5000
7500
10000
12500
15000
17500
Time (t) : sampling rate 4hz

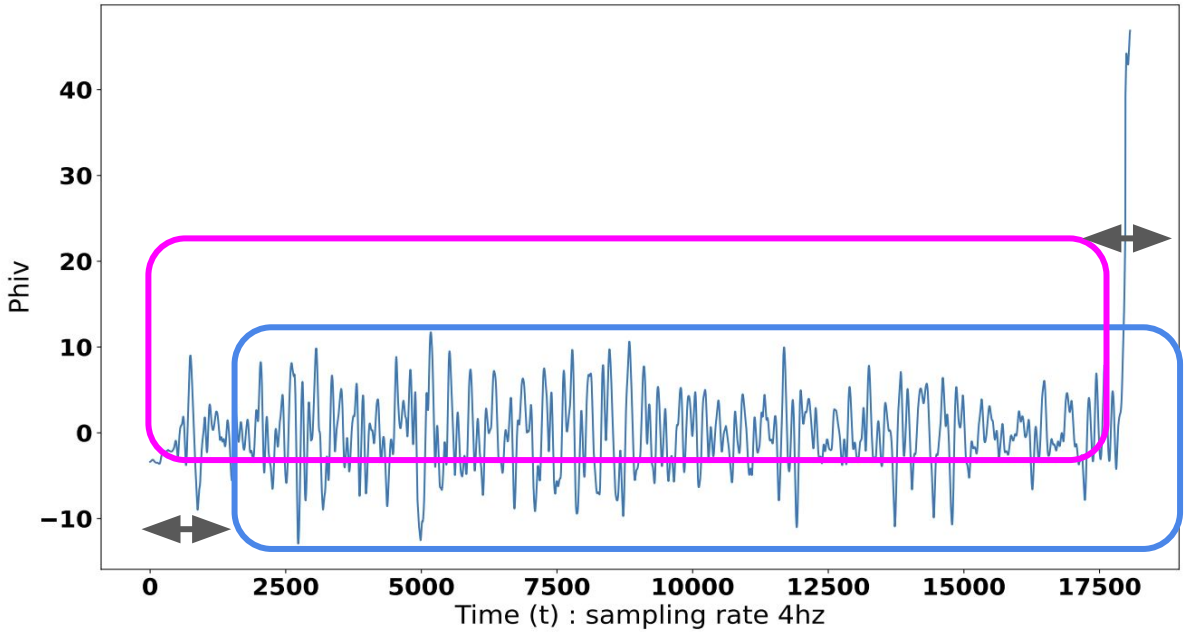
Complexity

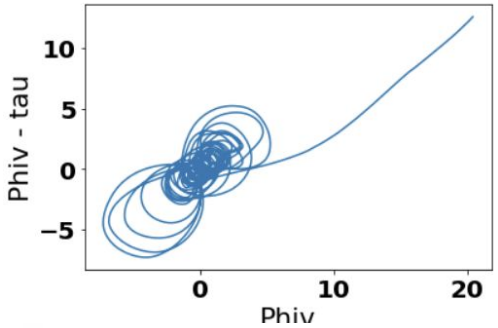

Phiv
40
30
20
10
0
−10
0
2500
5000
7500
10000
12500
15000
17500
Time (t) : sampling rate 4hz

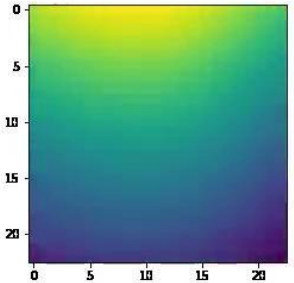
Complexity


What went wrong?
Phiv
40
30
20
10
0
−10
0
2500
5000
7500
10000
12500
15000
17500
Time (t) : sampling rate 4hz

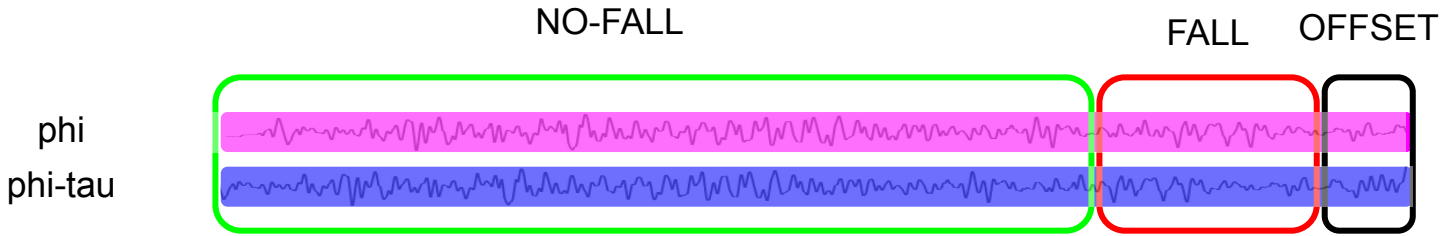
Understanding Feed-Back



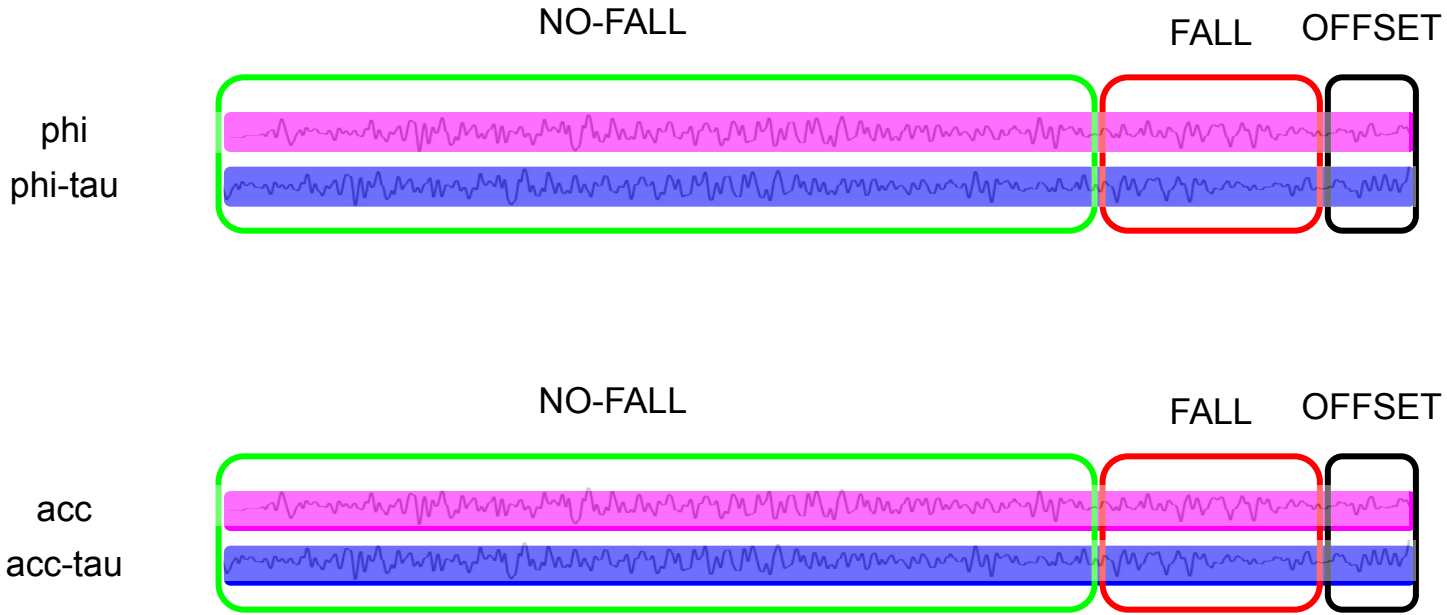




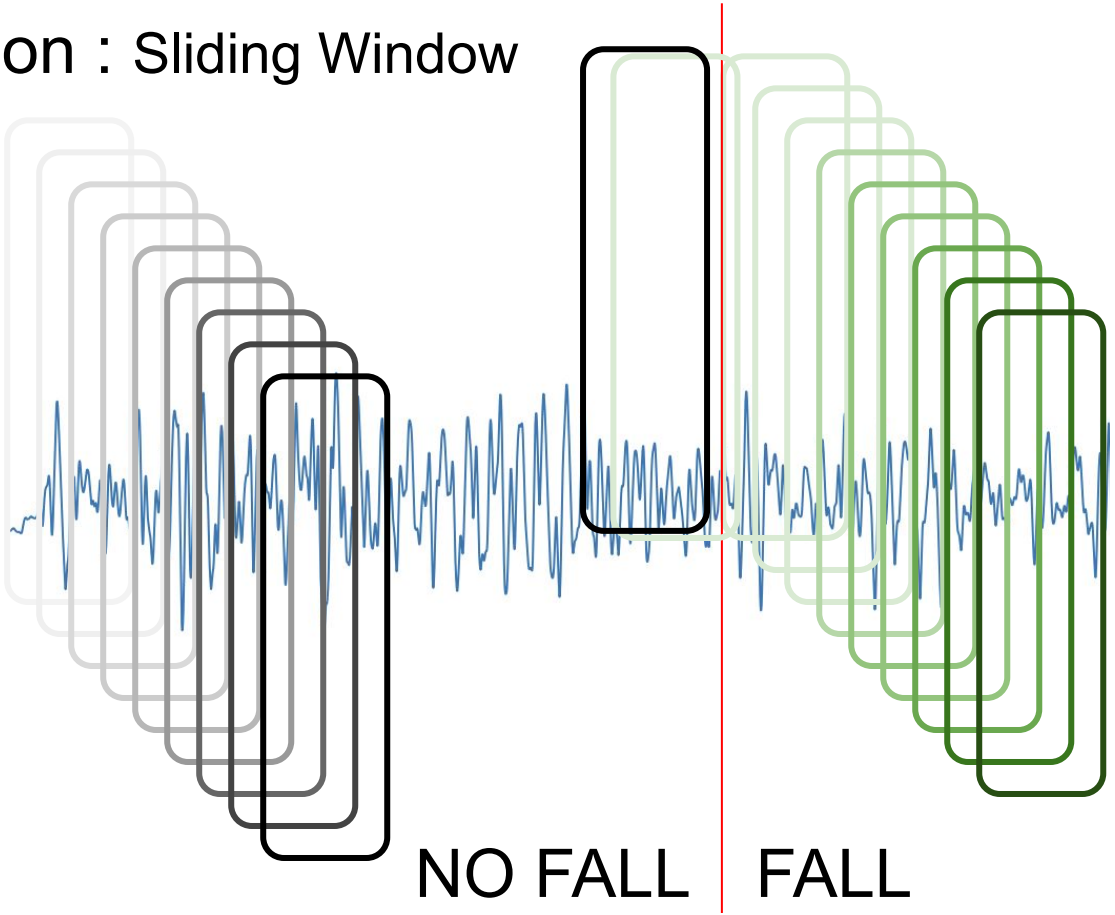
Assumption : Features



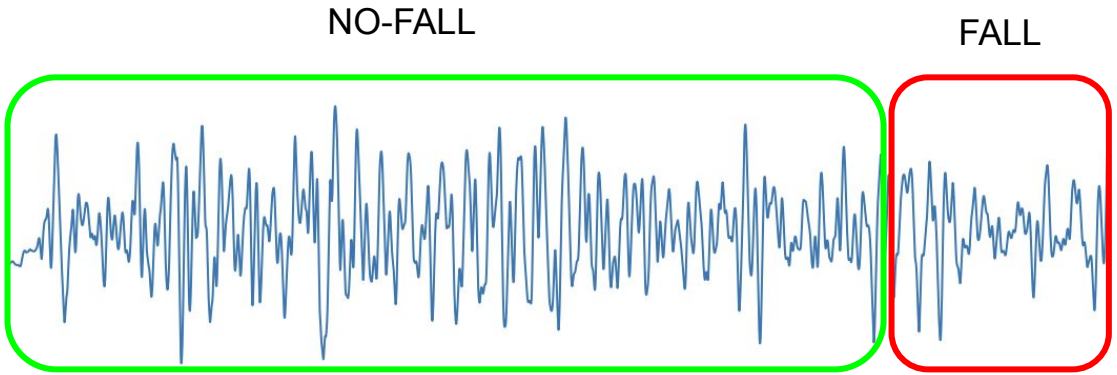
Assumption : Features



Assumption : Sliding Window

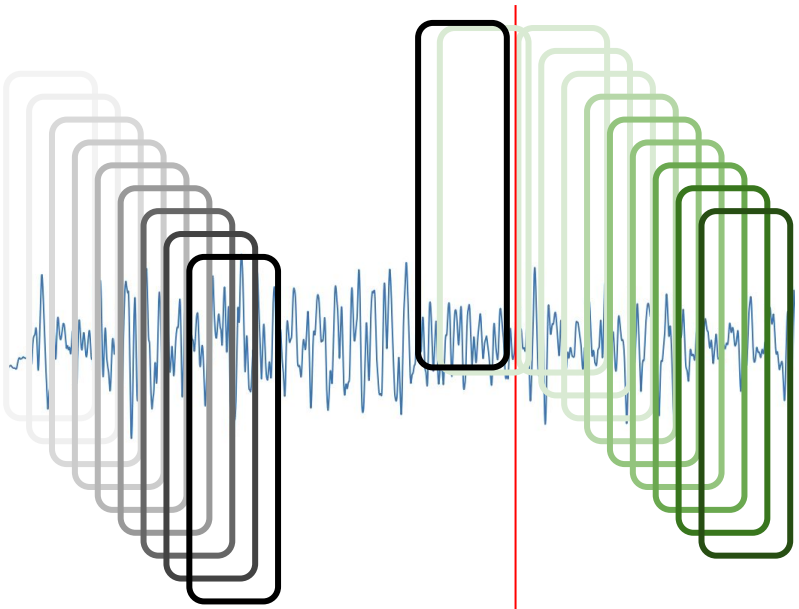


Challenge | Imbalance



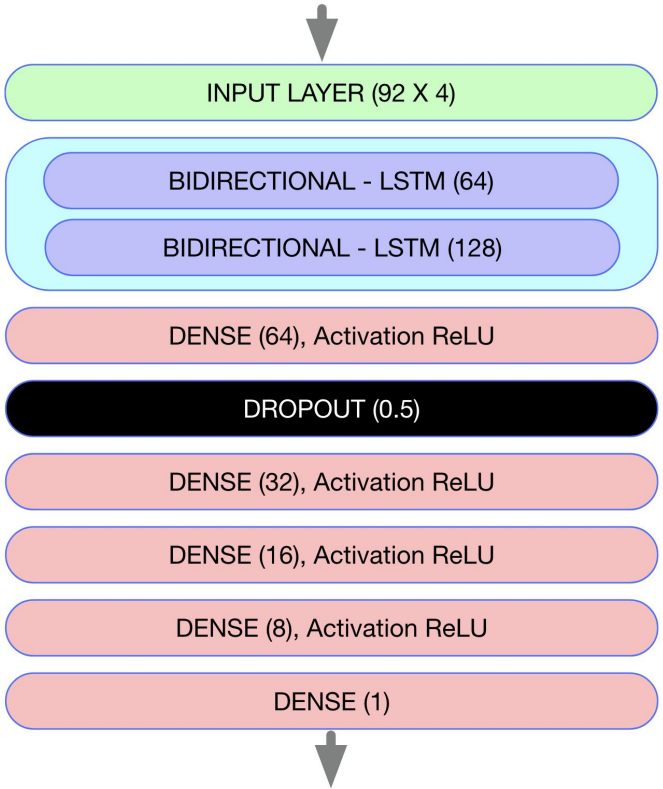
0 : 1 = 100:5

Solving | Imbalance



Run n simulation	Keep N no-fall classes	Keep w*n fall classes
Run (N - w*n)/w simulation		keep only fall classes

Model



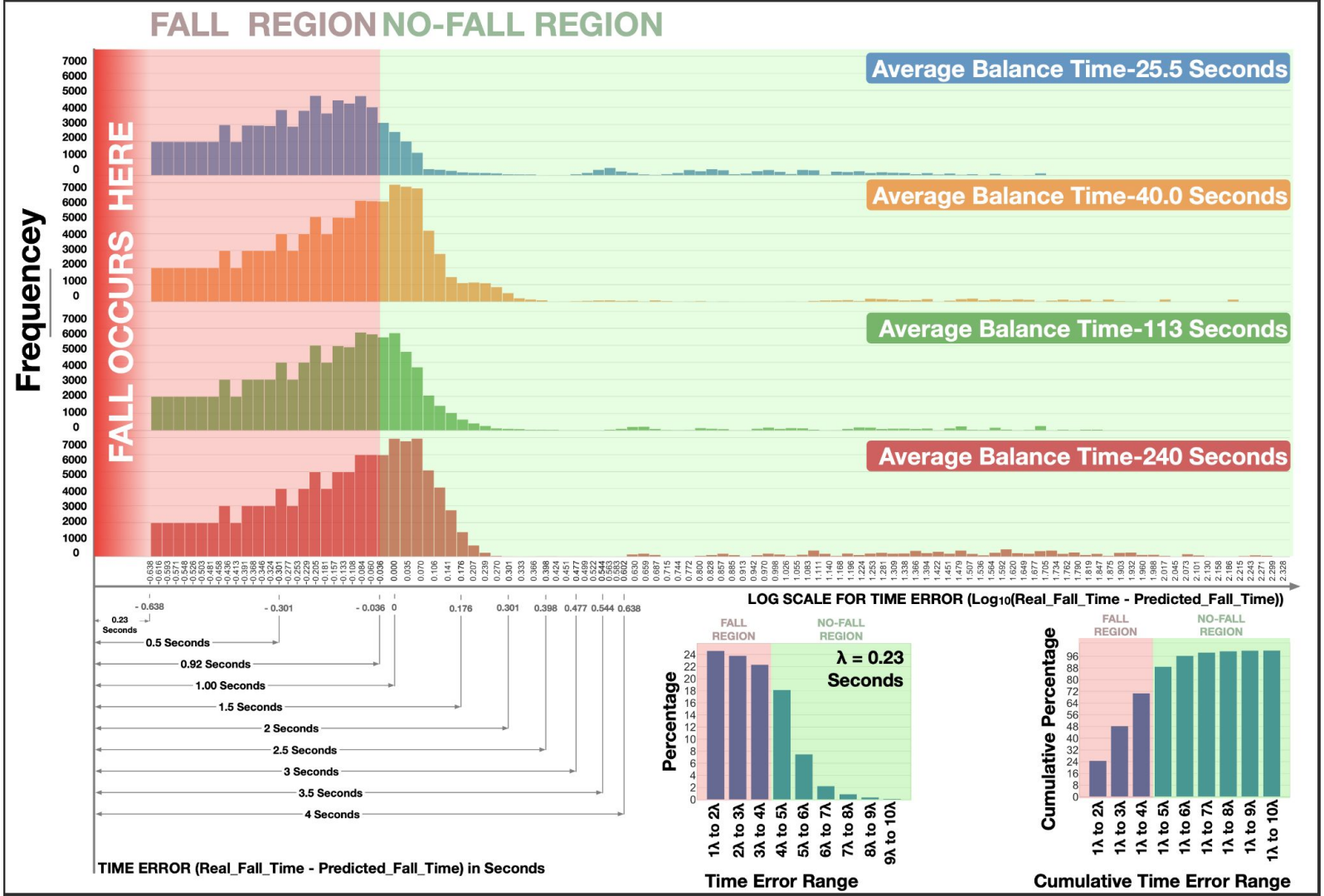
Loss: Binary Cross Entropy

Initial Experiment

- AVG BT Considered: 25,40,113,240 Seconds
- Offset 23
- Window 92

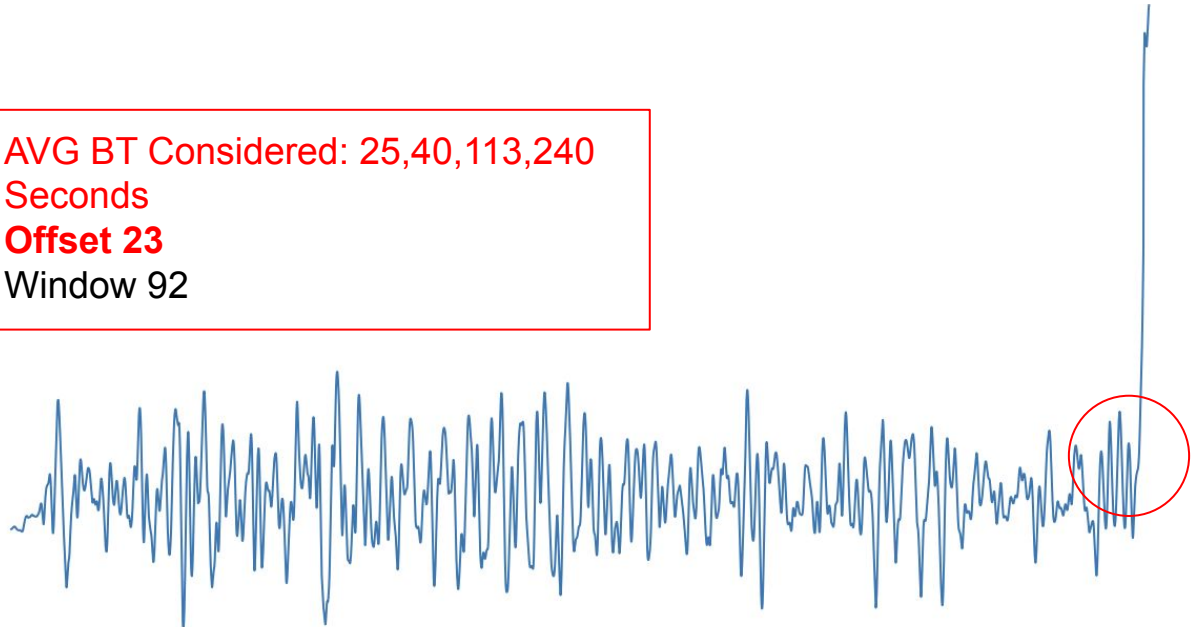
Precision	Recall	Accuracy	F1-Score
0.85	0.92	0.96	0.89

On Validation Set


FALL REGION
NO-FALL REGION
FALL OCCURS HERE
Frequencey
Average Balance Time-25.5 Seconds
Average Balance Time-40.0 Seconds
Average Balance Time-113 Seconds
Average Balance Time-240 Seconds
LOG SCALE FOR TIME ERROR (Log10(Real_Fall_Time - Predicted_Fall_Time))
0.23 Seconds
0.5 Seconds
0.92 Seconds
1.00 Seconds
1.5 Seconds
2 Seconds
2.5 Seconds
3 Seconds
3.5 Seconds
4 Seconds
TIME ERROR (Real_Fall_Time - Predicted_Fall_Time) in Seconds
FALL REGION
NO-FALL REGION
λ = 0.23 Seconds
Percentage
1λ to 2λ
2λ to 3λ
3λ to 4λ
4λ to 5λ
5λ to 6λ
6λ to 7λ
7λ to 8λ
8λ to 9λ
9λ to 10λ
Time Error Range
Cumulative Percentage
Cumulative Time Error Range

Initial Experiment : Doubts

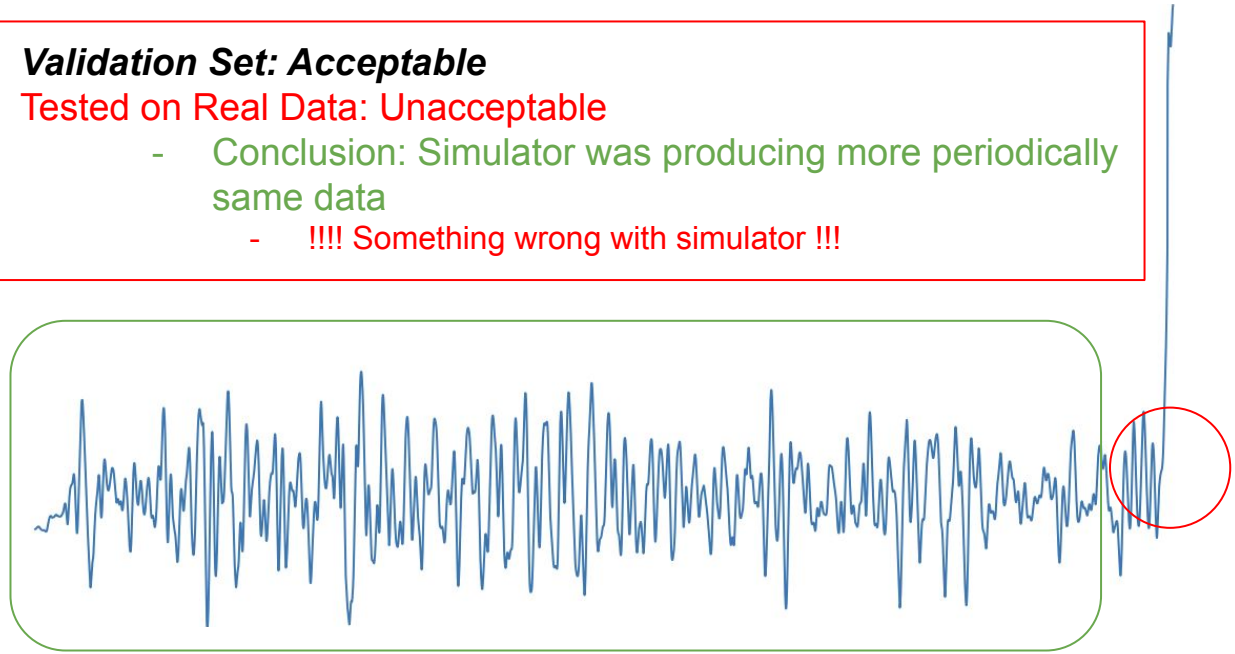
- AVG BT Considered: 25,40,113,240 Seconds
- **Offset 23**
- Window 92



An ablation study : Increased the offset to 92 or >92

Validation Set: Acceptable

- Tested on Real Data: Unacceptable
  - Conclusion: Simulator was producing more periodically same data
    - !!!! Something wrong with simulator !!!



Further Explorations

Improved Simulator

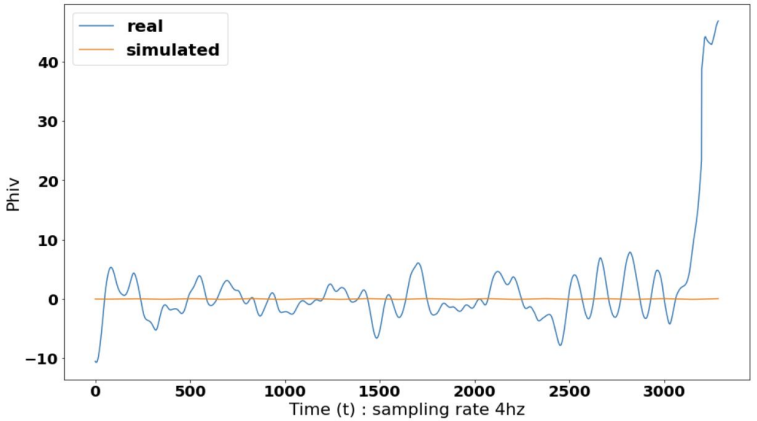
Validation Set: Acceptable

- Tested on Real Data: Unacceptable
  - Conclusion: Real data is different than simulated data
    - !!!! Something wrong with data statistics !!!

Data Augmentation Based on Real data statistics

Validation Set: Acceptable

- Tested on Real Data: Unacceptable
  - Conclusion: Limited Parameter Scope
    - !!!! But parameter scope is very complex !!!



Initial
Comparision Real and SImulated Data

Further Explorations

Improved Simulator

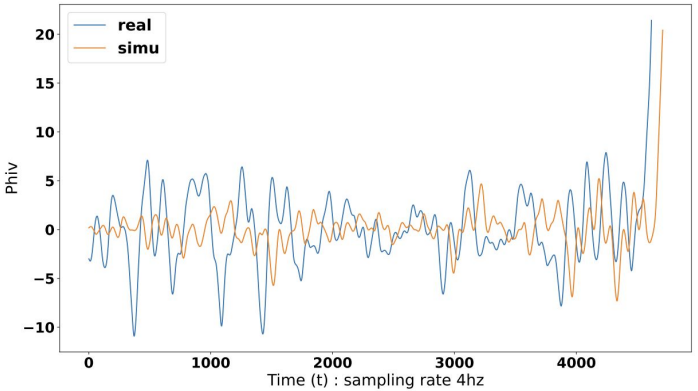
Validation Set: Acceptable

- Tested on Real Data: Unacceptable
    - Conclusion: Real data is different than simulated data
        - !!!! Something wrong with data statistics !!!

Data Augmentation Based on Real data statistics

Validation Set: Acceptable

- Tested on Real Data: Unacceptable
    - Conclusion: Limited Parameter Scope
        - !!!! But parameter scope is very complex !!!



Comparing Real and SImulated Data After augmentation

Further Explorations

Improved Simulator

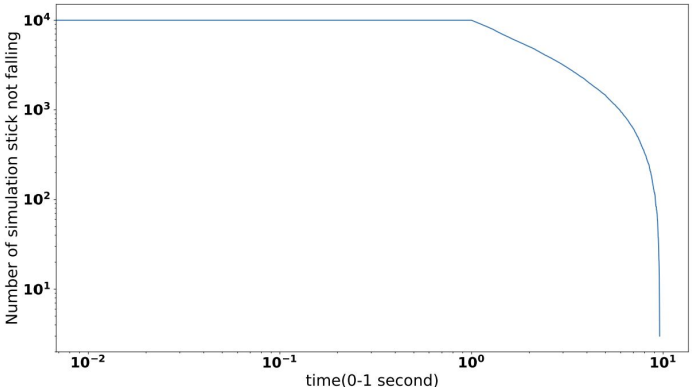
Validation Set: Acceptable

- Tested on Real Data: Unacceptable
    - Conclusion: Real data is different than simulated data
        - !!!! Something wrong with data statistics !!!

Data Augmentation Based on Real data statistics

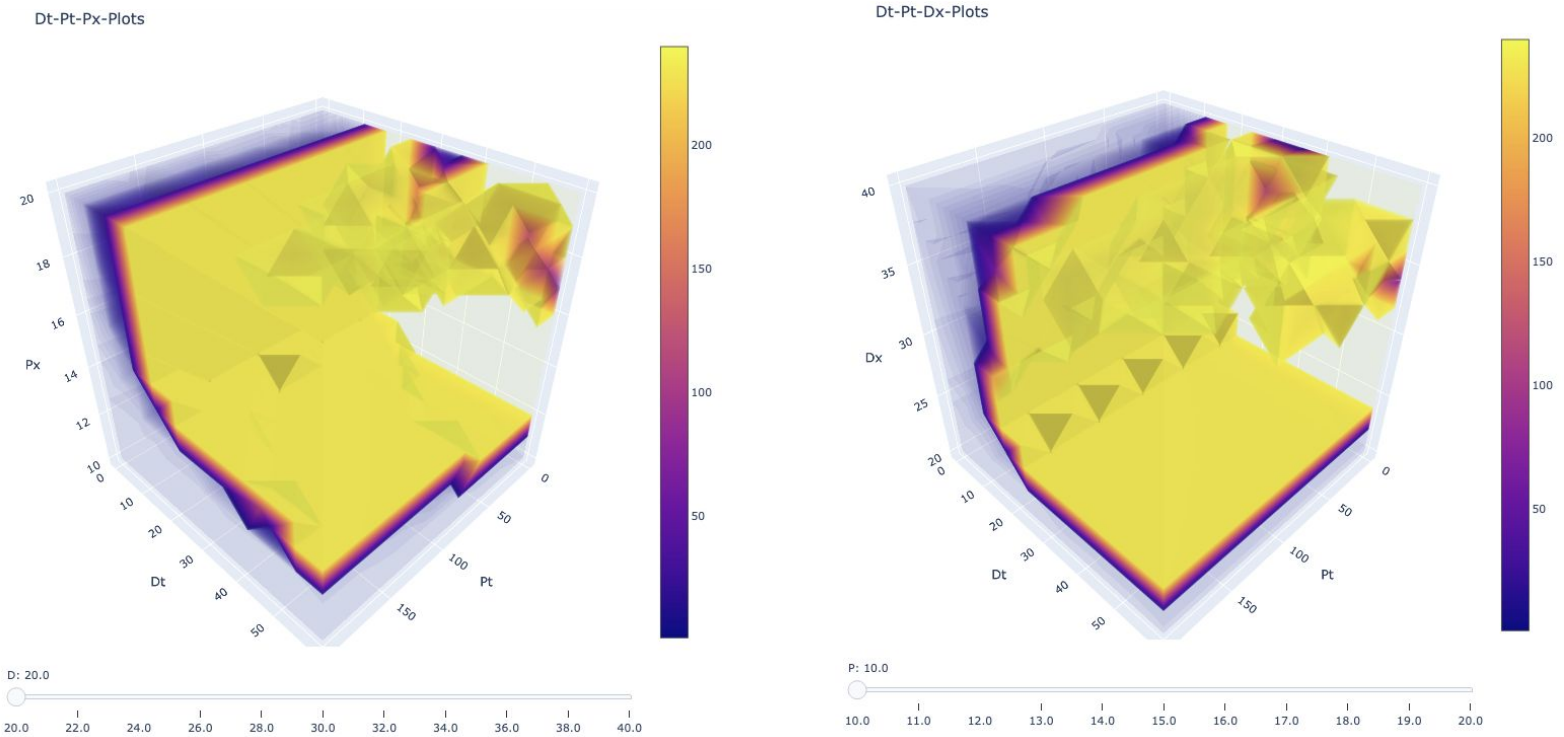
Validation Set: Acceptable

- Tested on Real Data: Unacceptable
    - Conclusion: Limited Parameter Scope
        - !!!! But parameter scope is very complex !!!



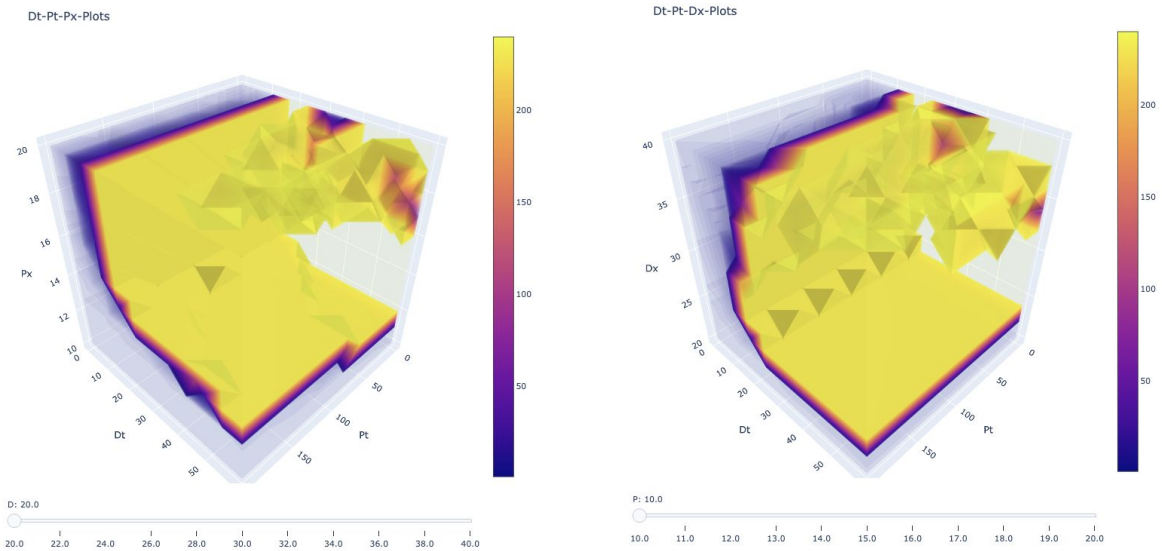
Verifying the eligibility of augmented data Based on survival curve

An ablation study : Visualizing Parameter Scope



Surface-plot showing 4 control gains: Left keeping Dx fixed, Right Keeping Px fixed

An ablation study : Visualizing Parameter Scope



Surface-plot showing 4 control gains: Left keeping Dx fixed, Right Keeping Px fixed

A tensor with dimension

11x11x11x11

Can be used to find possible Parameter for given balance times

Putting Everything together

Data Augmentation Based on Real data statistics

Validation Set: Acceptable

- Tested on Real Data: Unacceptable
  - **Comparatively good results**

	precision	recall	f1-score	support
No-Fall	1.00	0.78	0.88	2083
Fall	0.22	1.00	0.36	128
accuracy			0.80	2211
macro avg	0.61	0.89	0.62	2211
weighted avg	0.95	0.80	0.85	2211

Offset: 92

	precision	recall	f1-score	support
No-Fall	1.00	0.85	0.92	2092
Fall	0.28	0.99	0.44	128
accuracy			0.85	2220
macro avg	0.64	0.92	0.68	2220
weighted avg	0.96	0.85	0.89	2220

Offset: 23

Ablation Study: Changing Thresholds [case offset 92]

Data Augmentation Based on Real data statistics

Validation Set: Acceptable

- Tested on Real Data: Acceptable as threshold increases
  - **Good results**

	precision	recall	f1-score	support
0.0	1.00	0.78	0.88	2083
1.0	0.22	1.00	0.36	128
accuracy			0.80	2211
macro avg	0.61	0.89	0.62	2211
weighted avg	0.95	0.80	0.85	2211

threshold(default): 0.5

	precision	recall	f1-score	support
0.0	1.00	0.86	0.92	2083
1.0	0.30	0.99	0.46	128
accuracy			0.87	2211
macro avg	0.65	0.93	0.69	2211
weighted avg	0.96	0.87	0.90	2211

threshold(default): 0.9

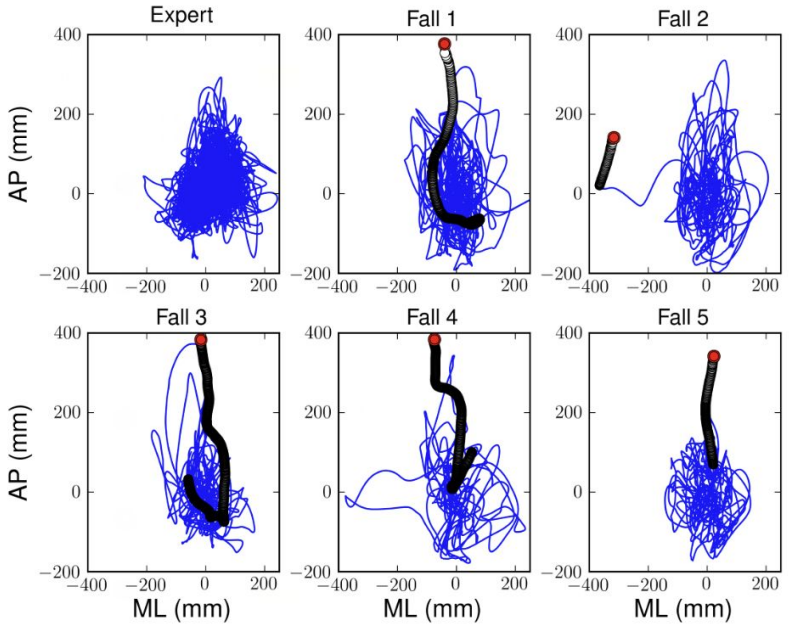
	precision	recall	f1-score	support
0.0	0.99	0.98	0.98	2083
1.0	0.70	0.90	0.79	128
accuracy			0.97	2211
macro avg	0.85	0.94	0.89	2211
weighted avg	0.98	0.97	0.97	2211

threshold(default): 0.99999

Why this is not working?

- An ablation Study is missing: See if long-term past events are responsible for the fall
- Proposed model may not be a good fit
- What is a good offset size?
- What is a good window size?
- **Most importantly : Chaotic behaviour cannot be modelled with given feature set, require more feature (eg. shown in figure)**

Milton, et al.,



Finger Movement

Possible Future Work

- Reservoir computing has shown advancement in predicting chaos
- Seq-Seq prediction
  - [1] Given current sequence predict the next sequence
    - Find anomaly in the next sequence and predict the fall
      - Exploit current advancement in NLP : Transformer Networks
  - Joint Framework
    - [1] + predict the probability of the fall
- Anomaly Detection
  - Auto-encoder based approach

May be use attention map (action+feedback)

Conclusion

- Focus on fall forecasting rather than detection
- Highlights
  - Chaos prediction
  - Dataset
  - Parameter Search