Data Driven Car Following Models:

KNN Wins the Battle,
Random Forest will win War

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Free Driving:

Not Influenced by Lead Vehicle

Car Following:

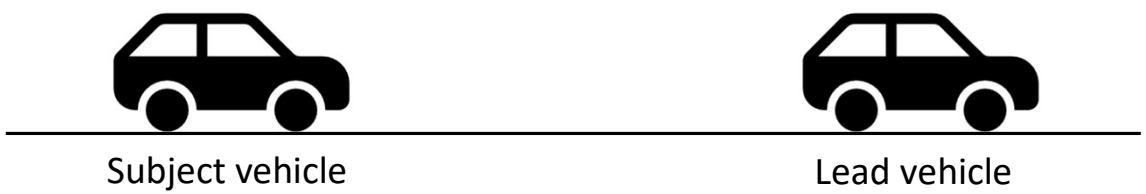
Lead Vehicle Influences Acceleration, Deceleration(Braking), Velocity, Spacing and Jerk

Emergency Break

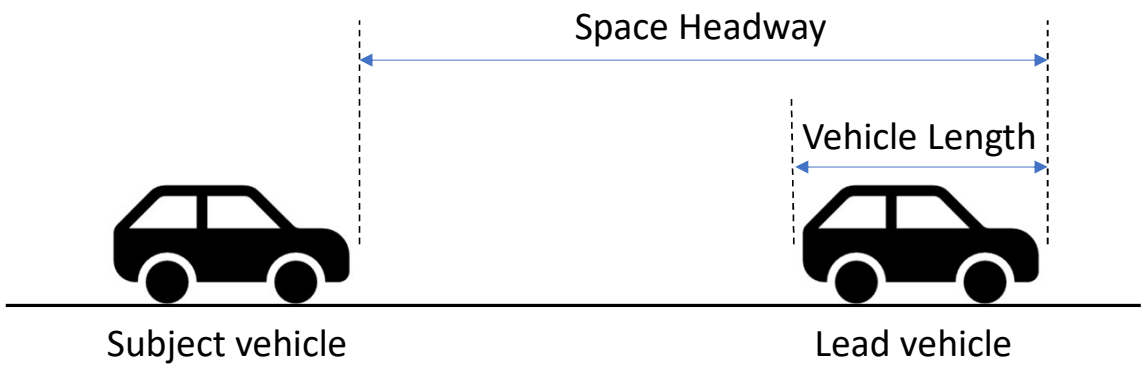
Lead vehicle too close

Avoid This, Have a Good **Car Following Model**

Car Following Model Terminology

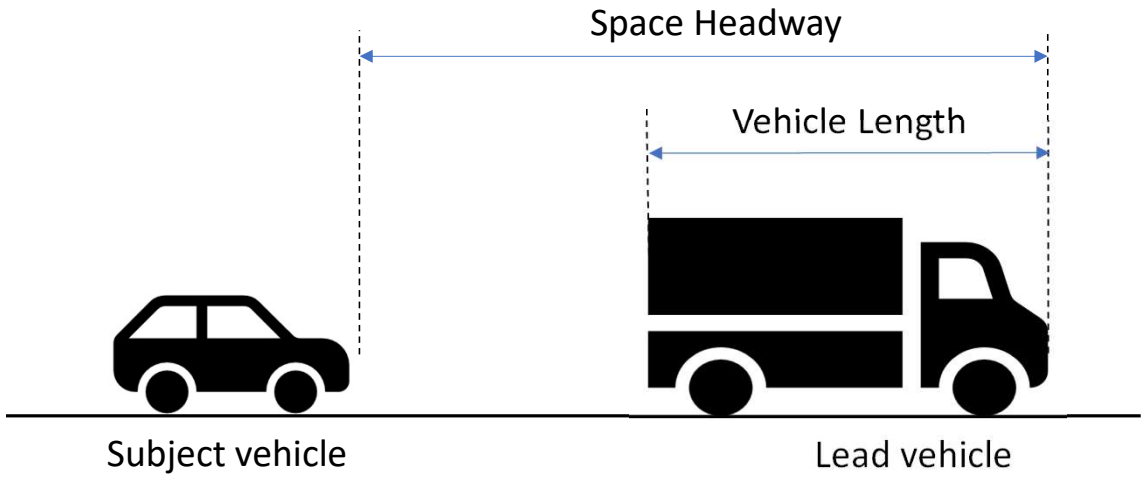


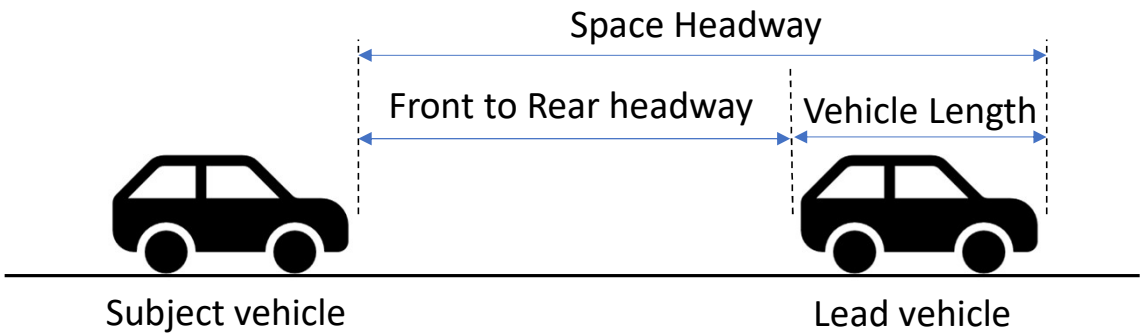
Car Following Model Terminology



Car Following Model Terminology

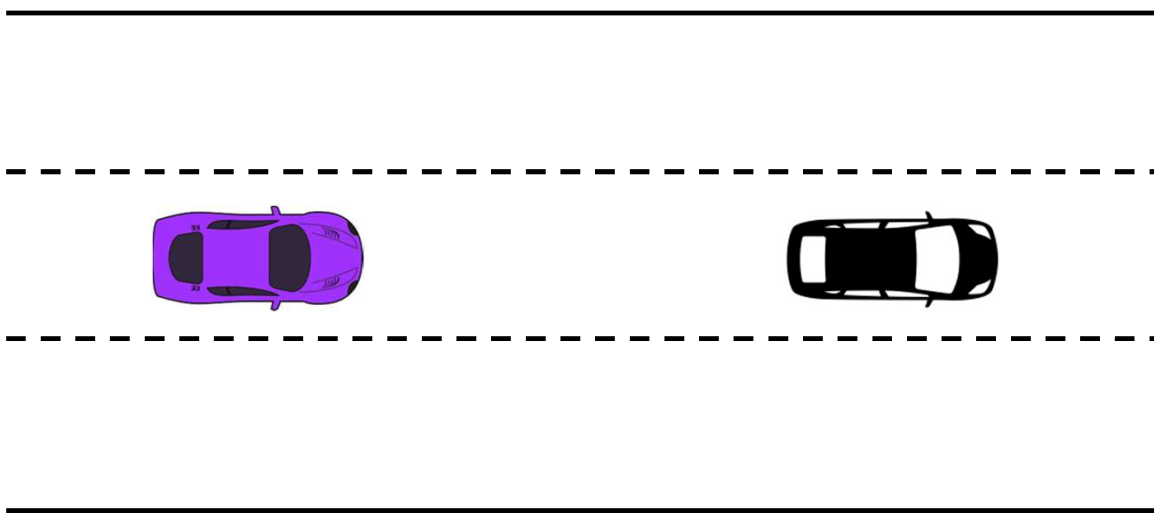
Car Following Model Terminology





Literature Review

Mesoscopic



Combination of Microscopic and Macroscopic

Literature Review

- Velocity ➔ $v = u + at$
- Position ➔ $s = ut + \frac{1}{2}at^2$
- Acceleration ➔ $a = \frac{dv}{dt}$
- Jerk ➔ $J = \frac{da}{dt}$

u = initial velocity
v = final velocity
t = time
a = acceleration
s = distance
j = jerk
dv = change in velocity
dt = change in time
da = change in acceleration

Problem Statement

- **Problem:**
  - Very few data driven models predict acceleration accurately.
  - Even with good RMSE scores, the trajectories do not match or aren't displayed.
  - The papers either falsely claim good acceleration predictions or completely avoid mentioning it.

- **Proposed Solution**
  - Create and compare Data Driven car following model using NGSIM dataset.
  - Display and compare trajectories along with R^2 and RMSE.

NGSIM Dataset

25

Columns

11.8M

Rows

Transportation.gov
U.S. Department of Transportation

Dataset Source

4

Locations

3

Vehicle Type

(Car, Motorcycle, Heavy Vehicle)

0.1

Preciseness

NGSIM Dataset

More than **75%**

Data on I-80 and US 101

NGSIM Dataset

45 Min Data

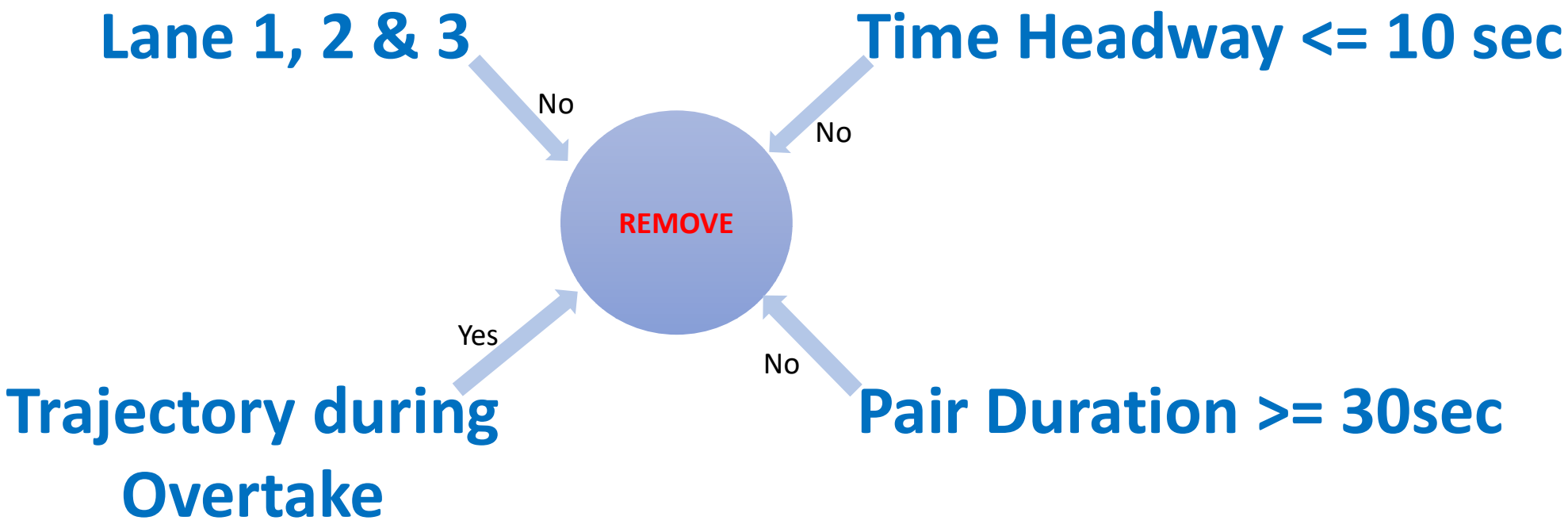
using **7** Cameras

NGSIM Dataset

45 Min Data

using **8** Cameras

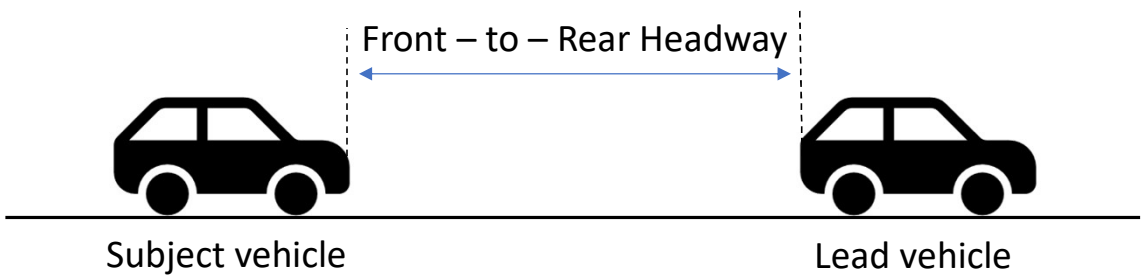
Data Cleaning



Data Transformation

Units Used: **SI** unit/**Metric** System

Space Headway: Front – to – Front ➔ **Front – to – Rear**



Model Information

Details of the model	
Features	Lead Vehicle Rear to Subject Vehicle Front Space Headway, Lead Vehicle Class, Subject Vehicle Class , dv = Subject Vehicle Velocity – Lead Vehicle Velocity, Subject Vehicle Velocity
Target	Acceleration
Train /Validate/Test Split	80/10/10
Random Forest	*30 Estimators*
K-Nearest Neighbours	*5 N-Neighbours*
Neural Network	*Conv1D X 3 Blocks + Dense X 3 ; activators=tanh, sigmoid, elu*

Results and Stats

delta_time	r_square_acc_cnn	r_square_acc_knn	r_square_acc_rf	r_square_vel_cnn	r_square_vel_knn	r_square_vel_rf	r_square_spacing_cnn	r_square_spacing_knn	r_square_spacing_rf	r_square_jerk_cnn	r_square_jerk_knn	r_square_jerk_rf
0.1	0.0686	-0.1207	-0.1180	0.2386	0.7018	0.8086	-11137.4	-9920.7	-10684.3	-0.0006	-0.1640	-0.1720
0.2	0.0648	-0.1273	-0.1128	0.8201	-3.9708	0.8366	-10157.1	-12612.5	-10636.5	-0.0024	-0.1635	-0.1746
0.3	0.0706	-0.2358	-0.0849	0.7103	-38.5791	0.8323	-10896.3	-23754.8	-10627.0	-0.0023	-0.1504	-0.1496
0.5	0.0737	-0.1305	-0.0487	0.4998	-11.9569	-0.0912	-11036.3	-14430.9	-11323.3	-0.0009	-0.1408	-0.1138
1	0.0619	-0.1118	-0.0561	0.6013	0.7099	0.4898	-10998.5	-11067.9	-11065.9	-0.0002	-0.1329	-0.0975
2	0.0278	-0.2742	-0.1029	0.7470	0.1554	-0.0215	-10937.9	-10911.9	-11196.1	0.0013	-0.1188	-0.1135
4	-0.0036	-0.3136	-0.1206	0.1016	-53.0816	-0.3483	-11438.0	-32316.3	-11452.6	0.0000	-0.0678	-0.1151

delta_time	rmse_acc_cnn	rmse_acc_knn	rmse_acc_rf	rmse_vel_cnn	rmse_vel_knn	rmse_vel_rf	rmse_spacing_cnn	rmse_spacing_knn	rmse_spacing_rf	rmse_jerk_cnn	rmse_jerk_knn	rmse_jerk_rf
0.1	1.33	1.46	1.46	3.45	2.16	1.73	987.54	932.04	967.24	19.43	20.96	21.03
0.2	1.33	1.46	1.45	1.68	8.82	1.60	943.15	1050.97	965.15	19.45	20.95	21.05
0.3	1.33	1.53	1.44	2.13	24.90	1.62	976.94	1442.42	964.79	19.44	20.83	20.82
0.5	1.33	1.46	1.41	2.80	14.25	4.14	983.34	1124.44	996.05	19.42	20.73	20.49
1	1.33	1.45	1.41	2.50	2.13	2.83	982.05	985.14	985.05	19.40	20.64	20.32
2	1.35	1.55	1.44	2.00	3.65	4.01	980.15	978.99	991.65	19.34	20.47	20.42
4	1.37	1.57	1.45	3.78	29.29	4.62	1003.84	1687.28	1004.48	19.30	19.95	20.38

Results and Stats

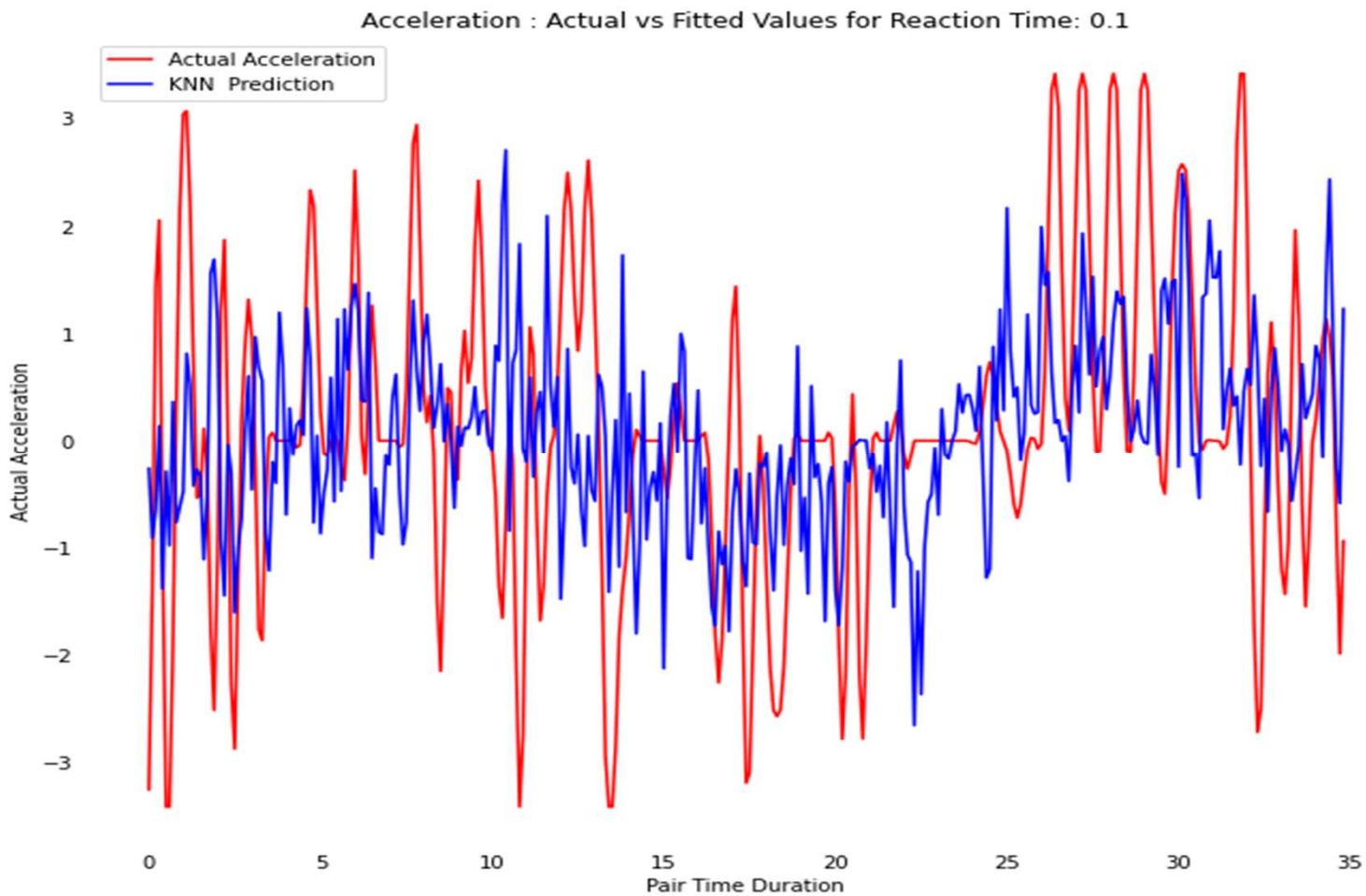
Model Name	Random Forest	KNN	CNN
Time to Fit	150 s	25 s	~1 hr
Time to Preprocess and Predict 1 Pair	31 s	12 s	68.2 s
Only Predict	20 s	2.4 s	57 s
Time to Load Model	3 s	0.1 s	0.4 s
Dataset division(train/Validate/test) in %	83 /8 /9	83 /8 /9	83 /8 /9
Train/cal/Test Car Pairs Count	4365 / 432 / 480	4365 / 432 / 480	4365 / 432 / 480
Time to Predict Test Pairs(per Reaction Time)	40 Min	12 Min	161 min
Complete Test Set	308 Min	70 Min	1291 Min
Size of Model on Disk	3.5 GB	100 MB	558 KB

Above Results are based on execution in Local Machine with i7 processor and 48 GB Ram.
Recreation timings may vary.

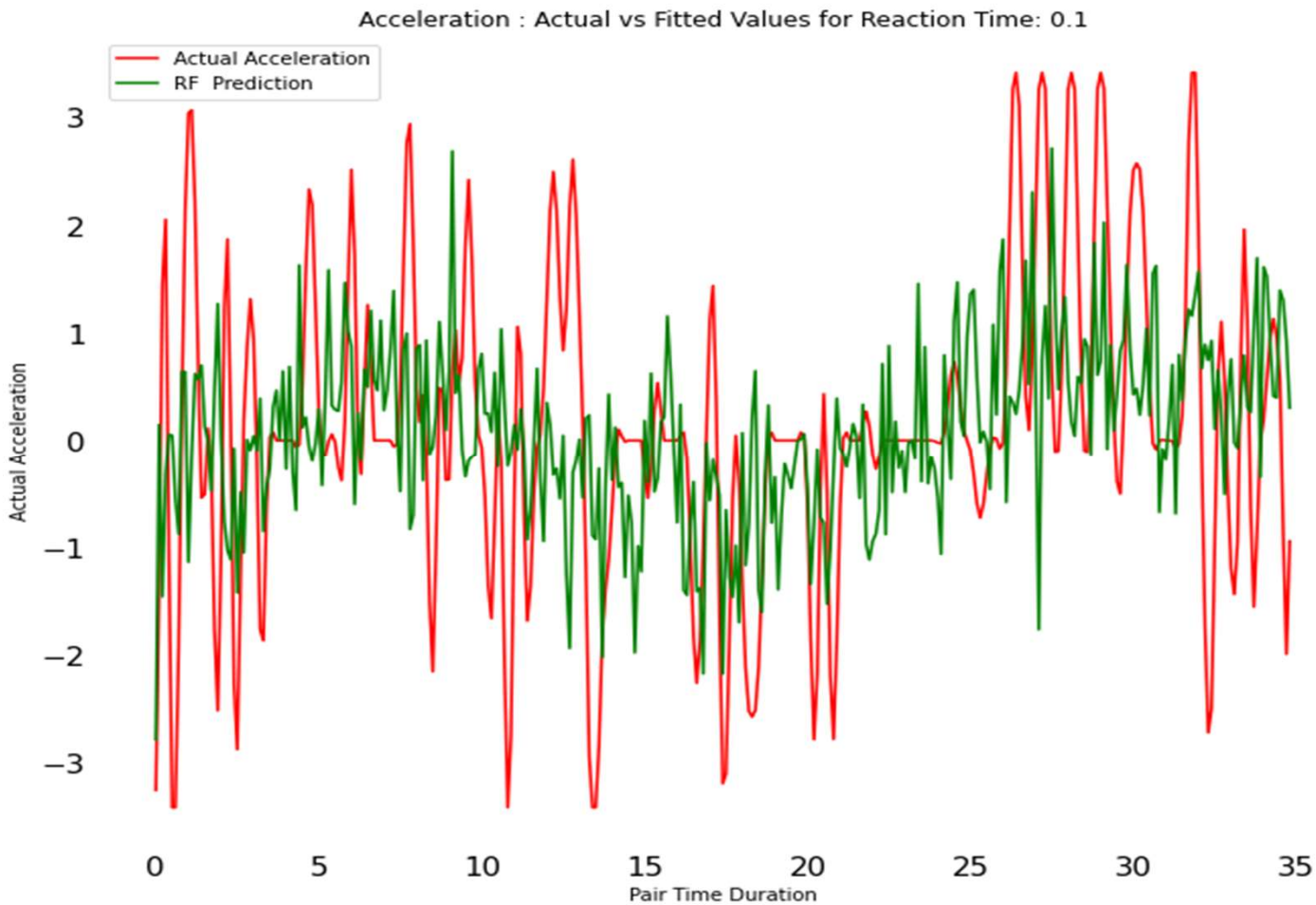
Results

- Random Forest with 150 Regressors had the best Trajectory.
- KNN has the best results at hand with limited resources i.e. Local Machine.
- CNN has best R2 and RMSE but bad trajectories and missed prediction scales.
- All three models are able to meet the trajectory oscillations.

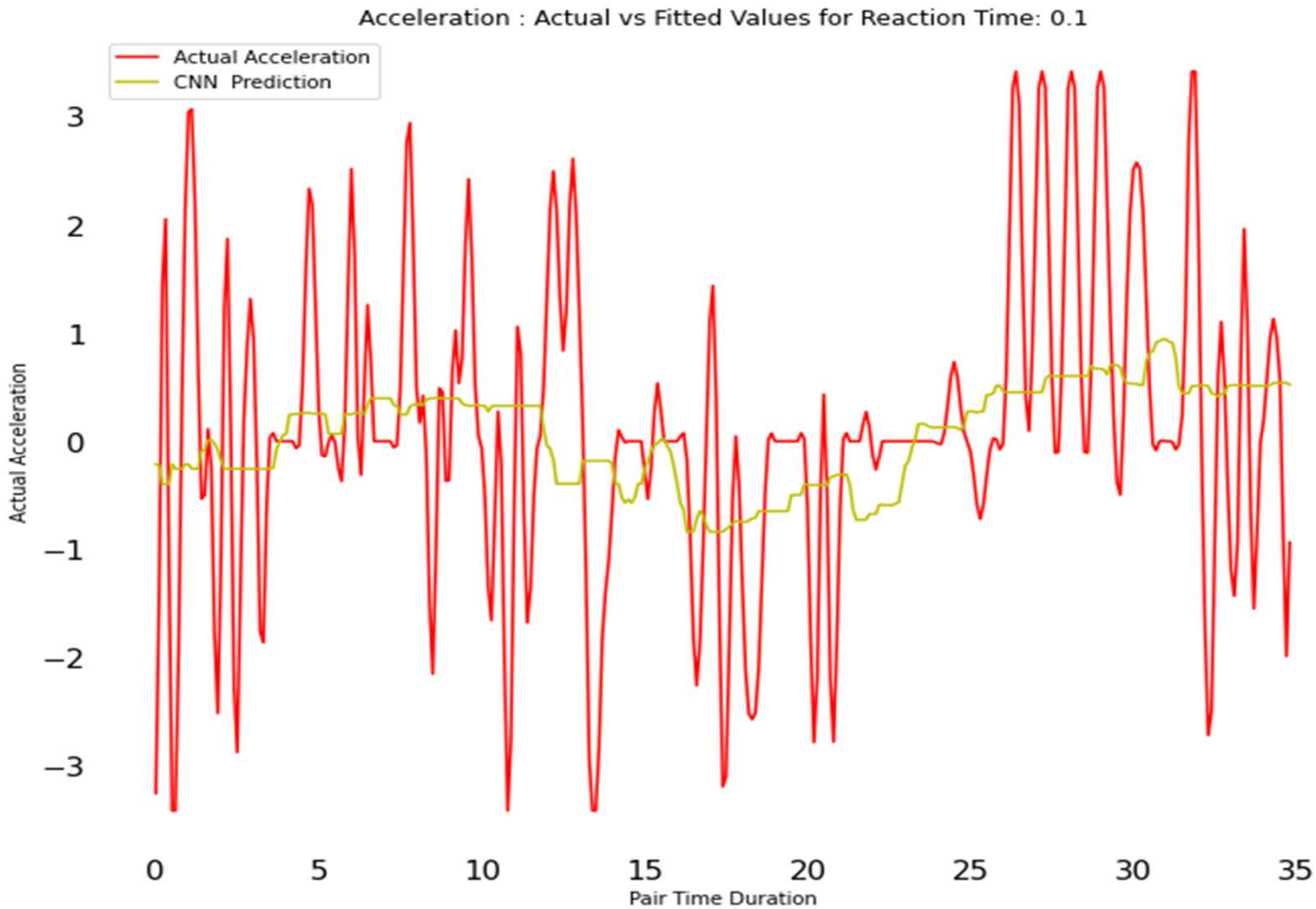
Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.1
Actual Acceleration
KNN Prediction
Actual Acceleration
Pair Time Duration
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
30
35

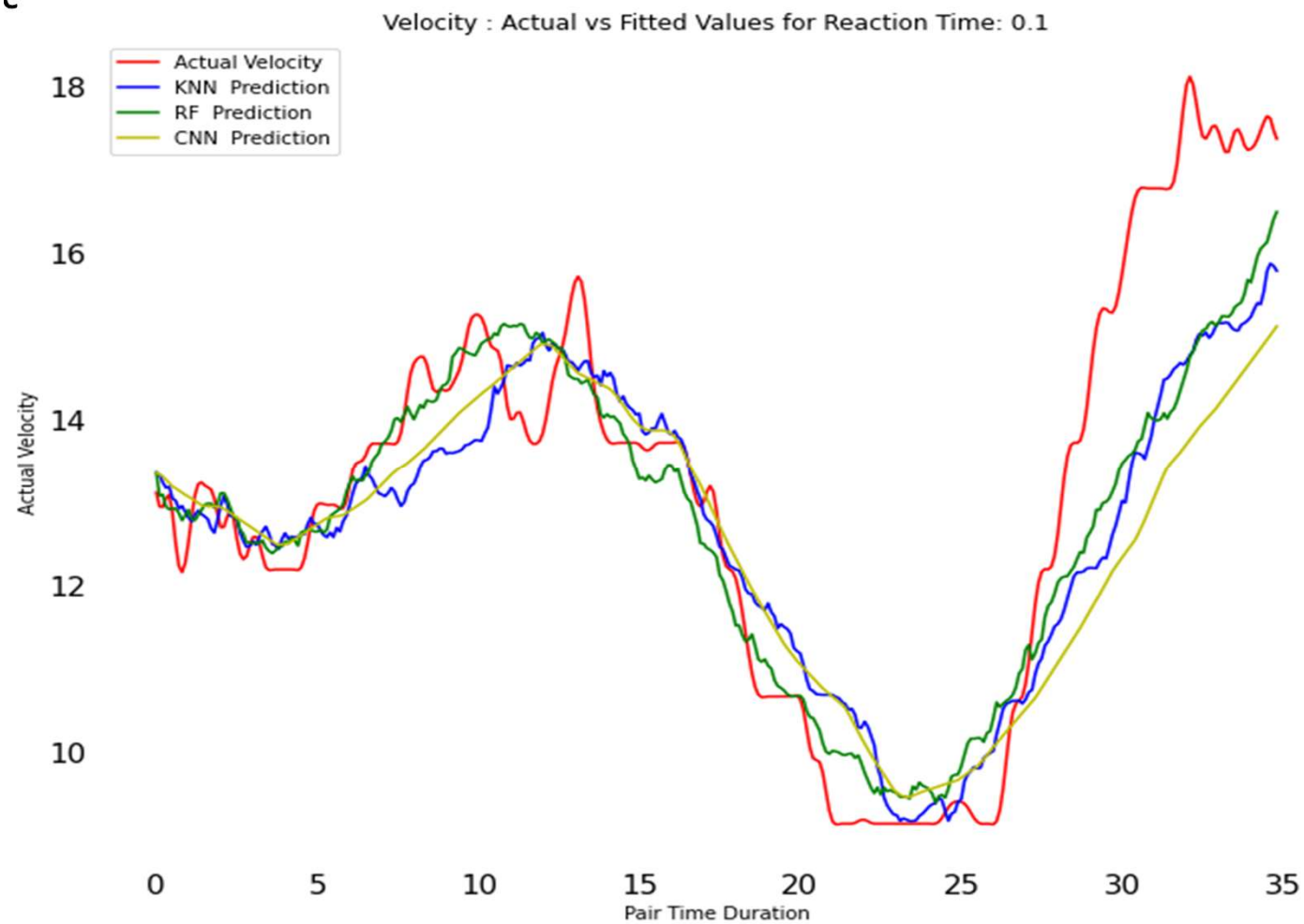
Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.1
Actual Acceleration
RF Prediction
3
2
1
0
−1
−2
−3
Actual Acceleration
0
5
10
15
20
25
30
35
Pair Time Duration

Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.1
Actual Acceleration
CNN Prediction
Actual Acceleration
Pair Time Duration
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
30
35

Result


Velocity : Actual vs Fitted Values for Reaction Time: 0.1
Actual Velocity
KNN Prediction
RF Prediction
CNN Prediction
18
16
14
12
10
Actual Velocity
0
5
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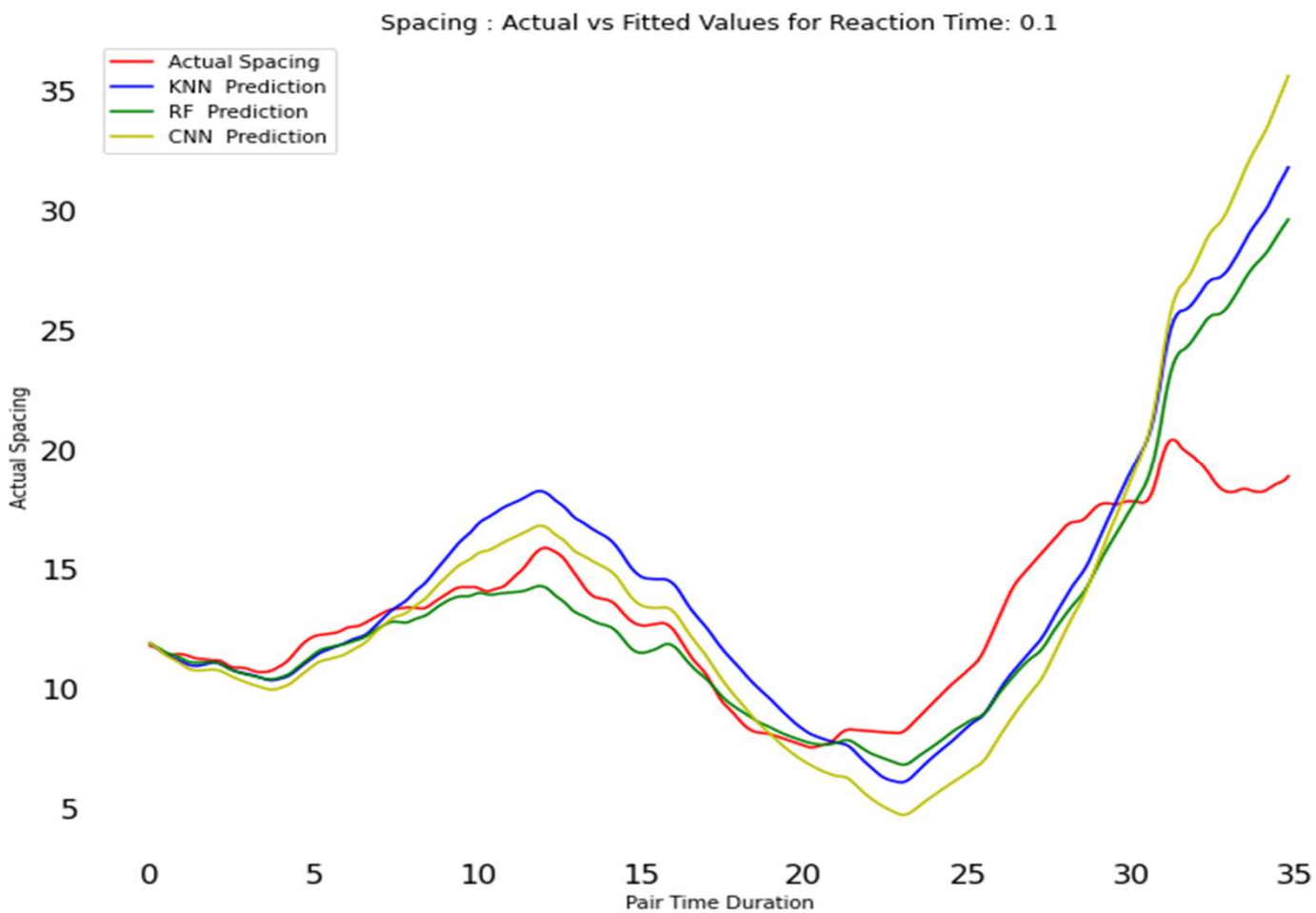
20
25
30
35
Pair Time Duration

Result


Spacing : Actual vs Fitted Values for Reaction Time: 0.1
Actual Spacing
KNN Prediction
RF Prediction
CNN Prediction
Actual Spacing
Pair Time Duration
35
30
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25
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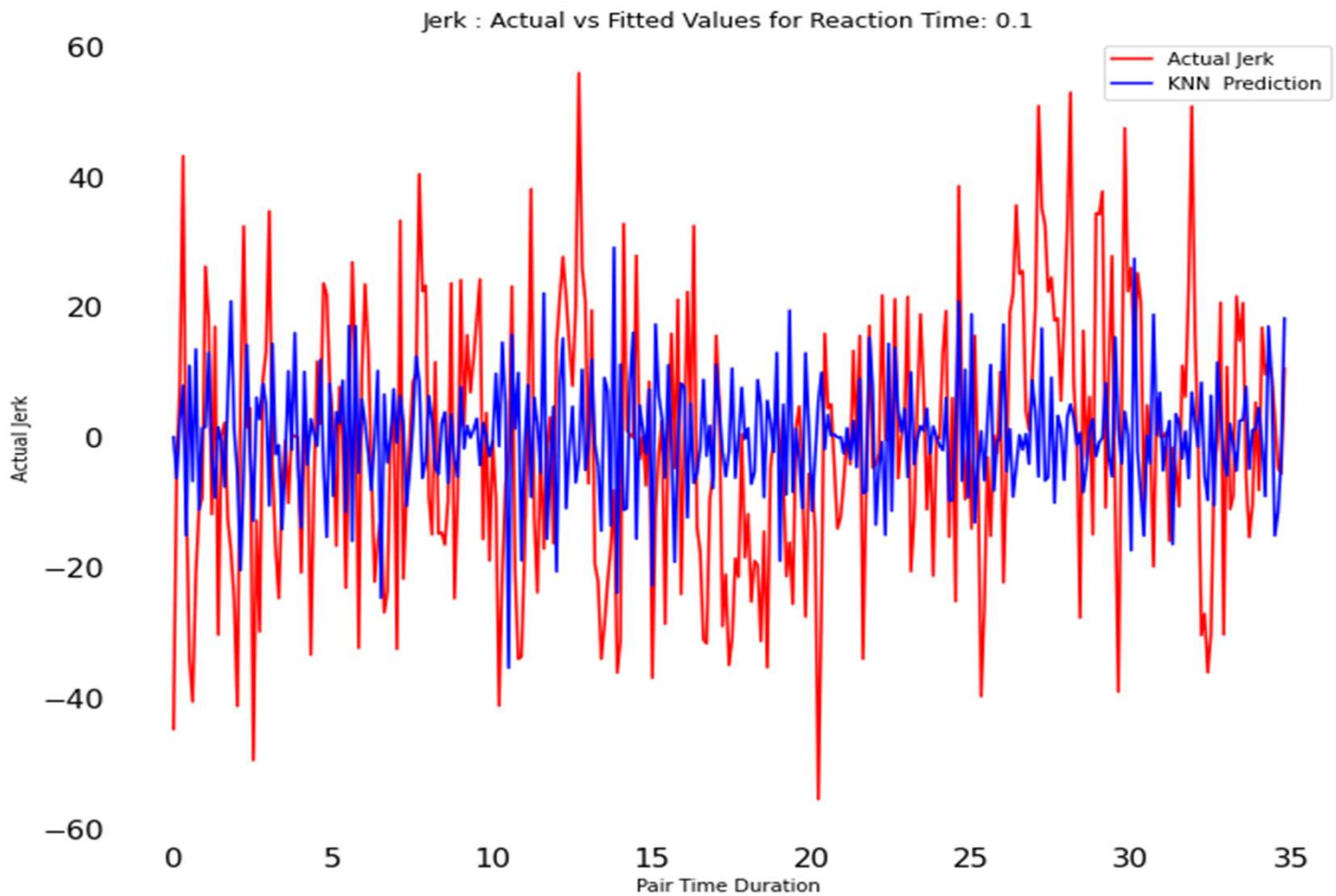
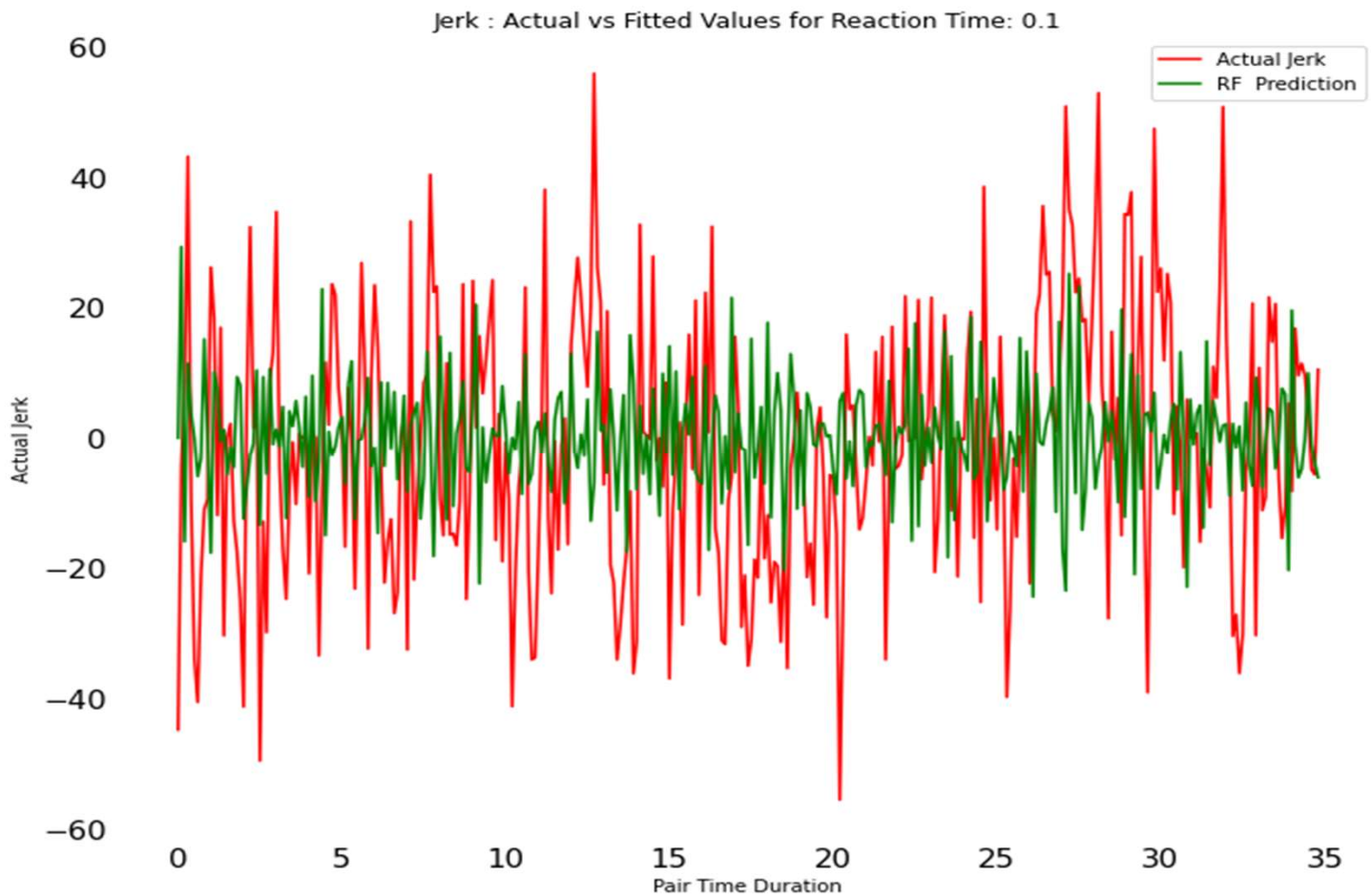
Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.1
Actual Jerk
KNN Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.1
Actual Jerk
RF Prediction
60
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0
−20
−40
−60
Actual Jerk
0
5
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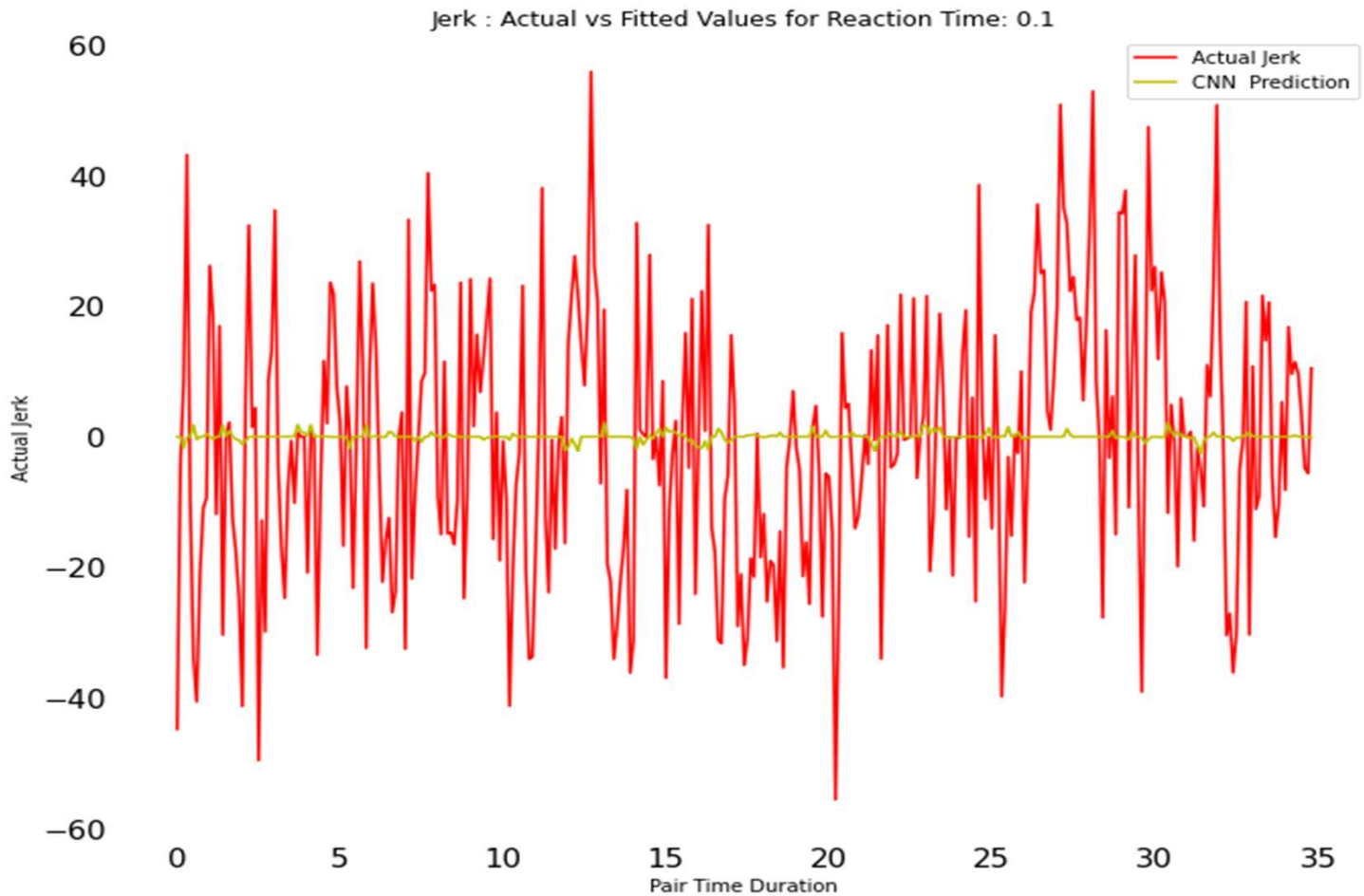
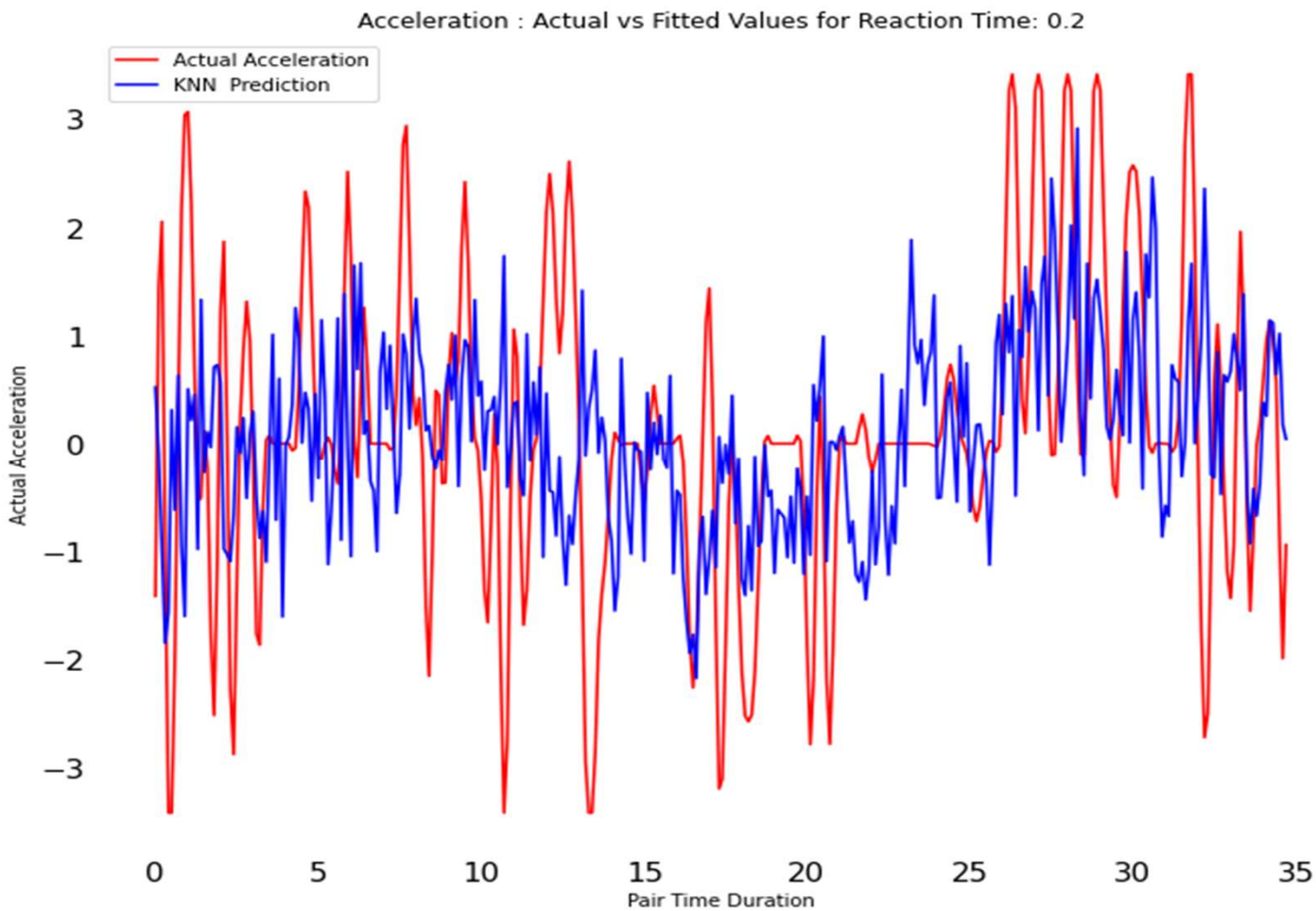
25
30
35
Pair Time Duration

Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.1
Actual Jerk
CNN Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

Result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Actual Acceleration
KNN Prediction
Actual Acceleration
Pair Time Duration
3
2
1
0
−1
−2
−3
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5
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15
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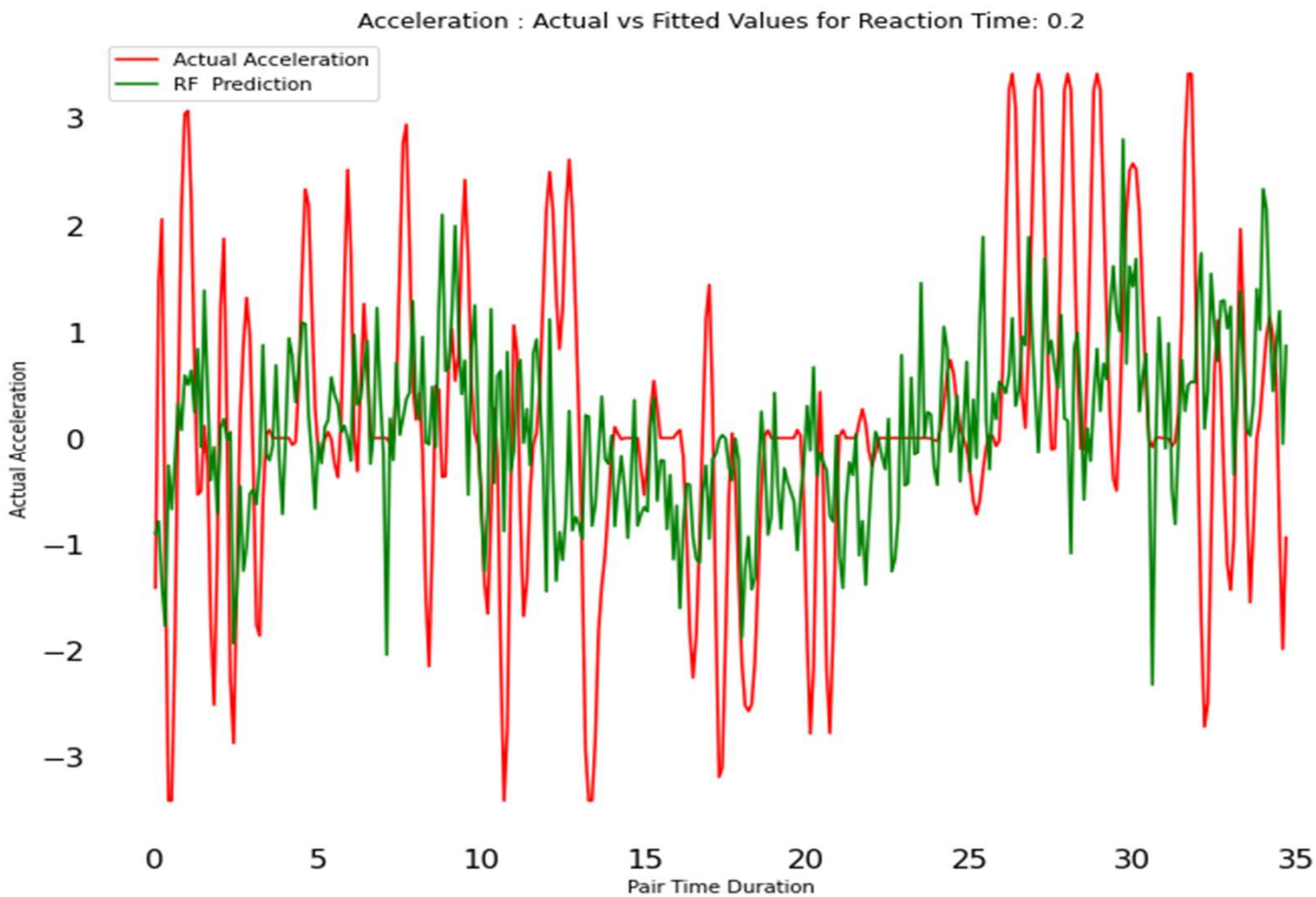
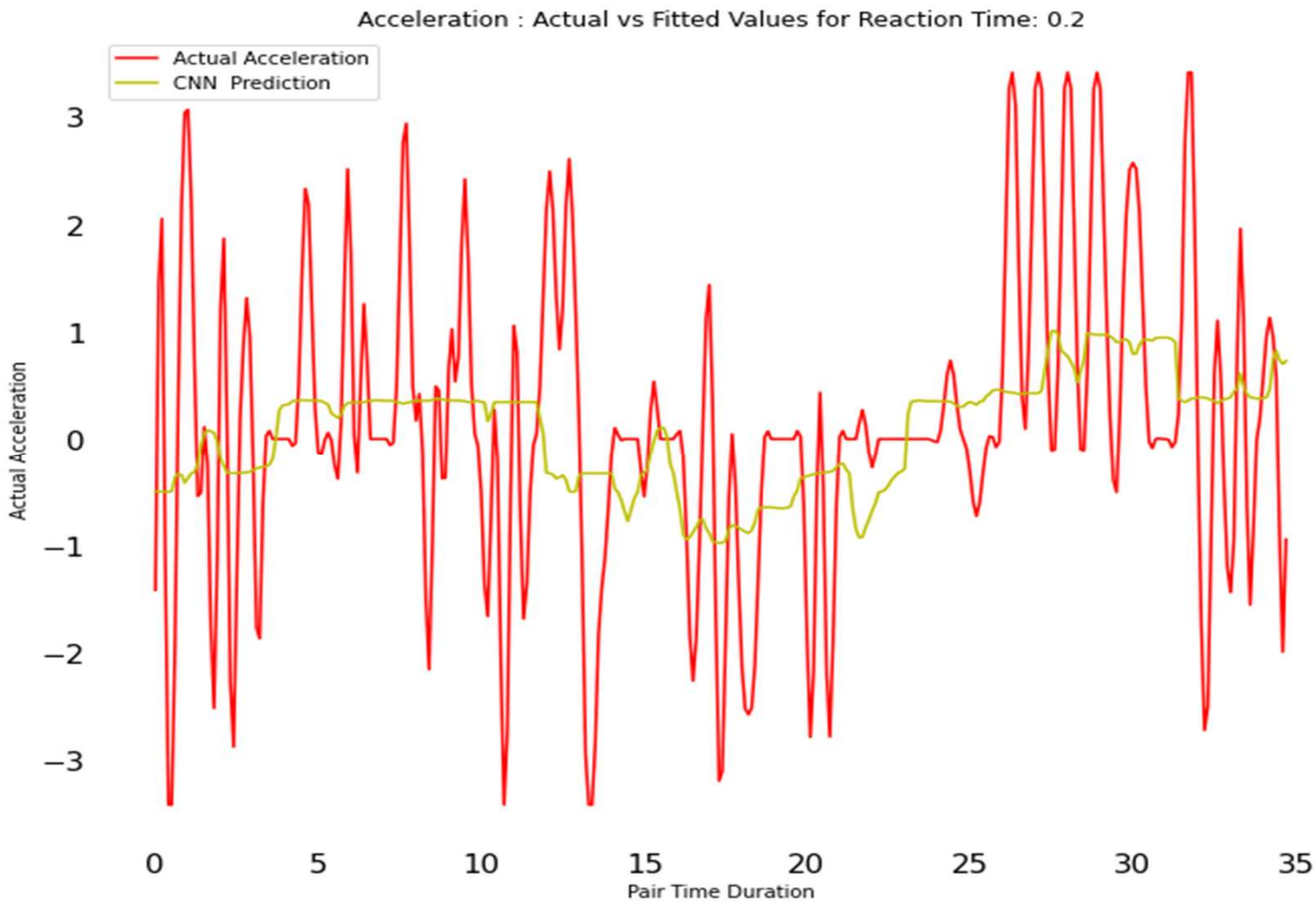
25
30
35

Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.2
Actual Acceleration
RF Prediction
3
2
1
0
−1
−2
−3
Actual Acceleration
0
5
10
15
20
25
30
35
Pair Time Duration

Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.2
Actual Acceleration
CNN Prediction
3
2
1
0
−1
−2
−3
Actual Acceleration
0
5
10
15
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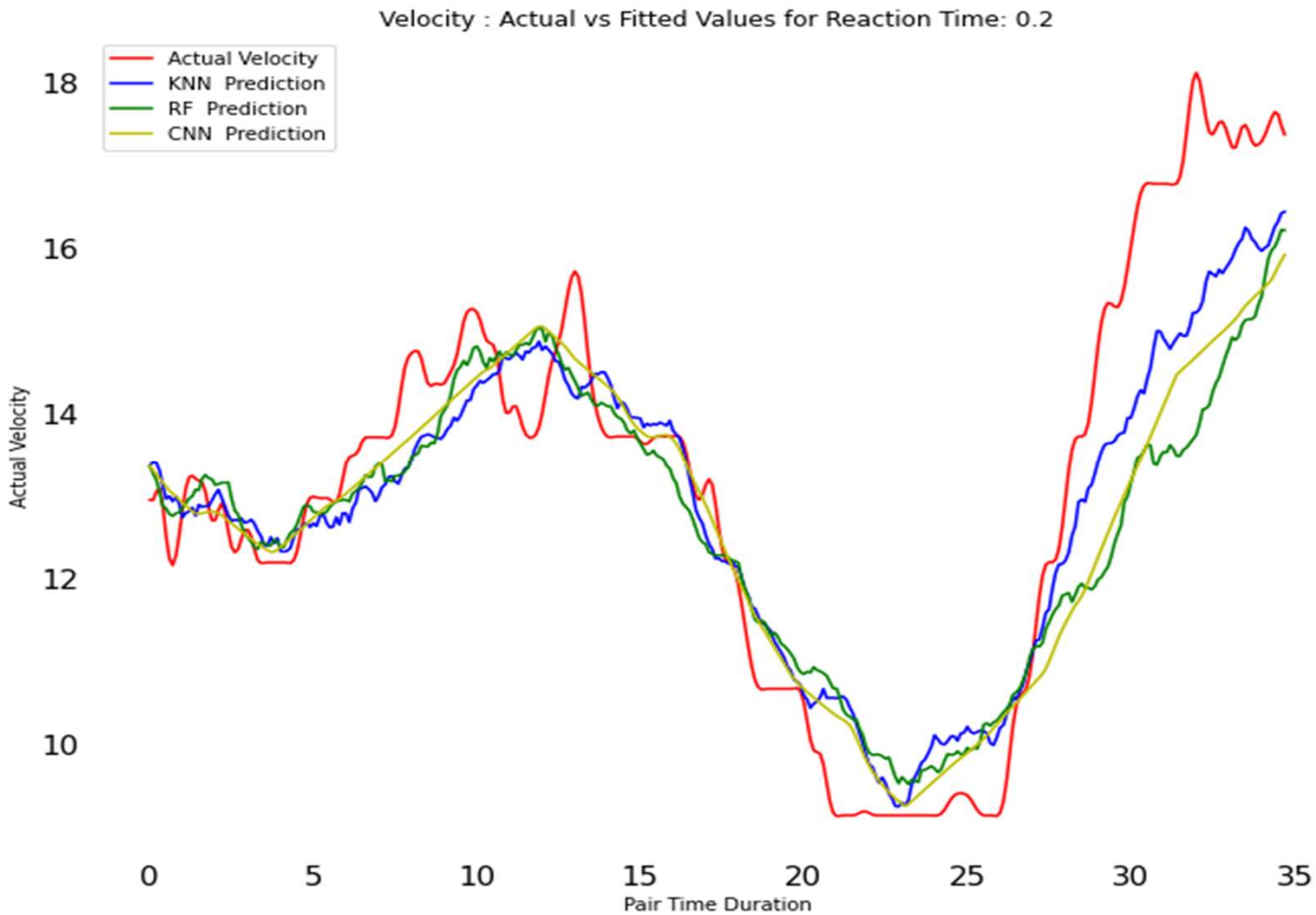
25
30
35
Pair Time Duration

Result


Velocity : Actual vs Fitted Values for Reaction Time: 0.2
Actual Velocity
KNN Prediction
RF Prediction
CNN Prediction
18
16
14
12
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Actual Velocity
0
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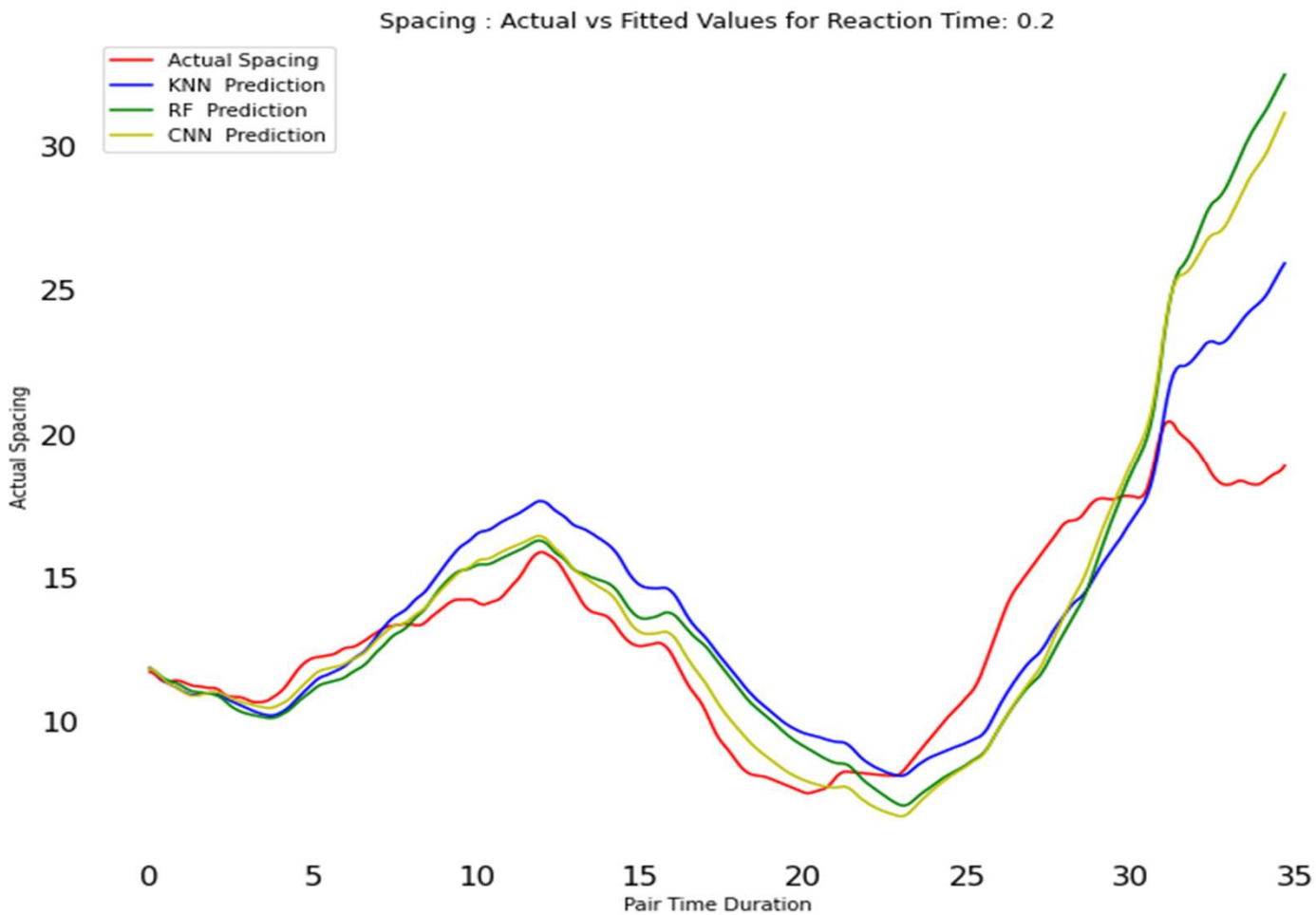
35
Pair Time Duration

Result


Spacing : Actual vs Fitted Values for Reaction Time: 0.2
Actual Spacing
KNN Prediction
RF Prediction
CNN Prediction
30
25
20
15
10
Actual Spacing
0
5
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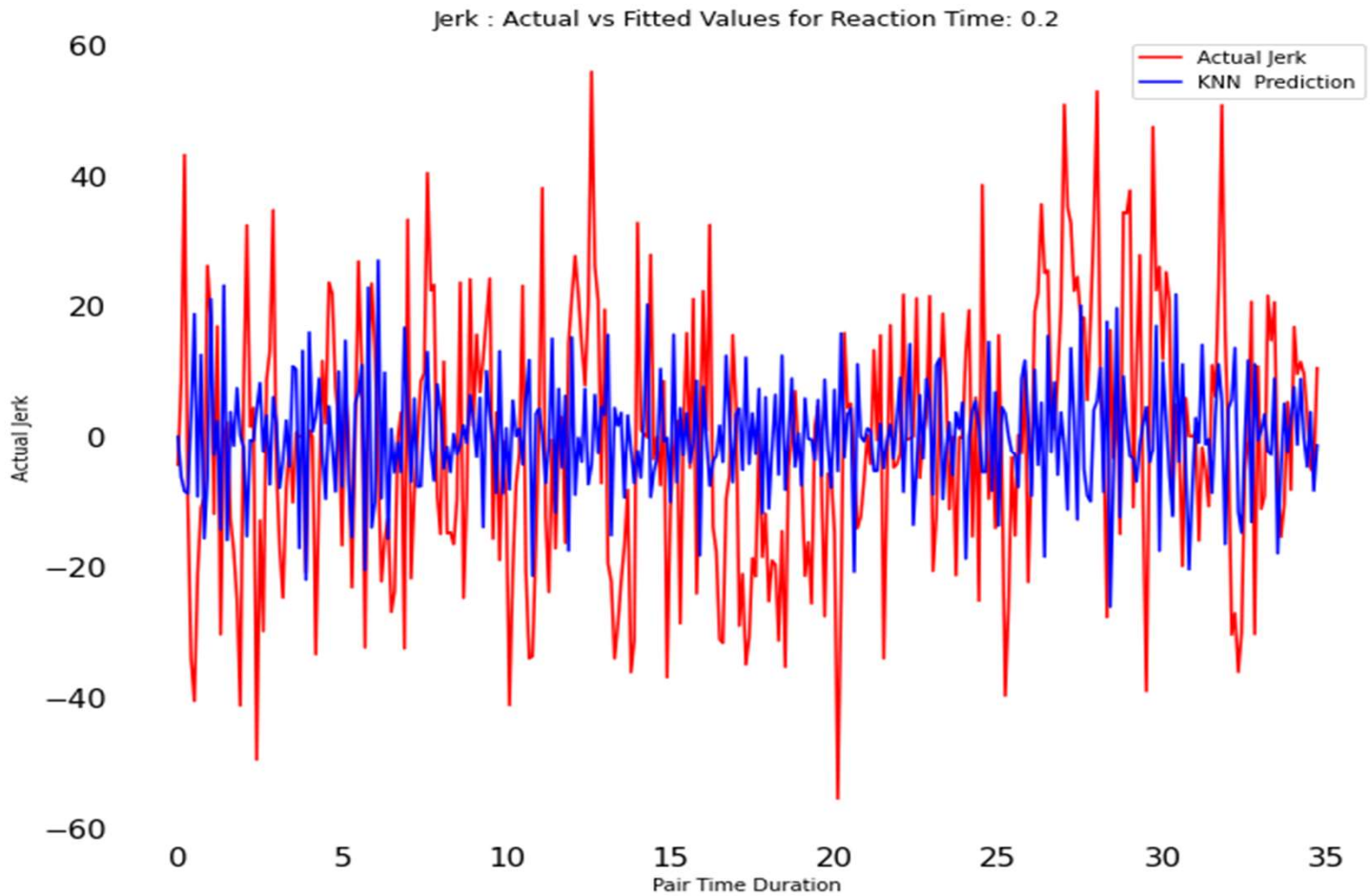
20
25
30
35
Pair Time Duration

Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.2
Actual Jerk
KNN Prediction
60
40
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Actual Jerk
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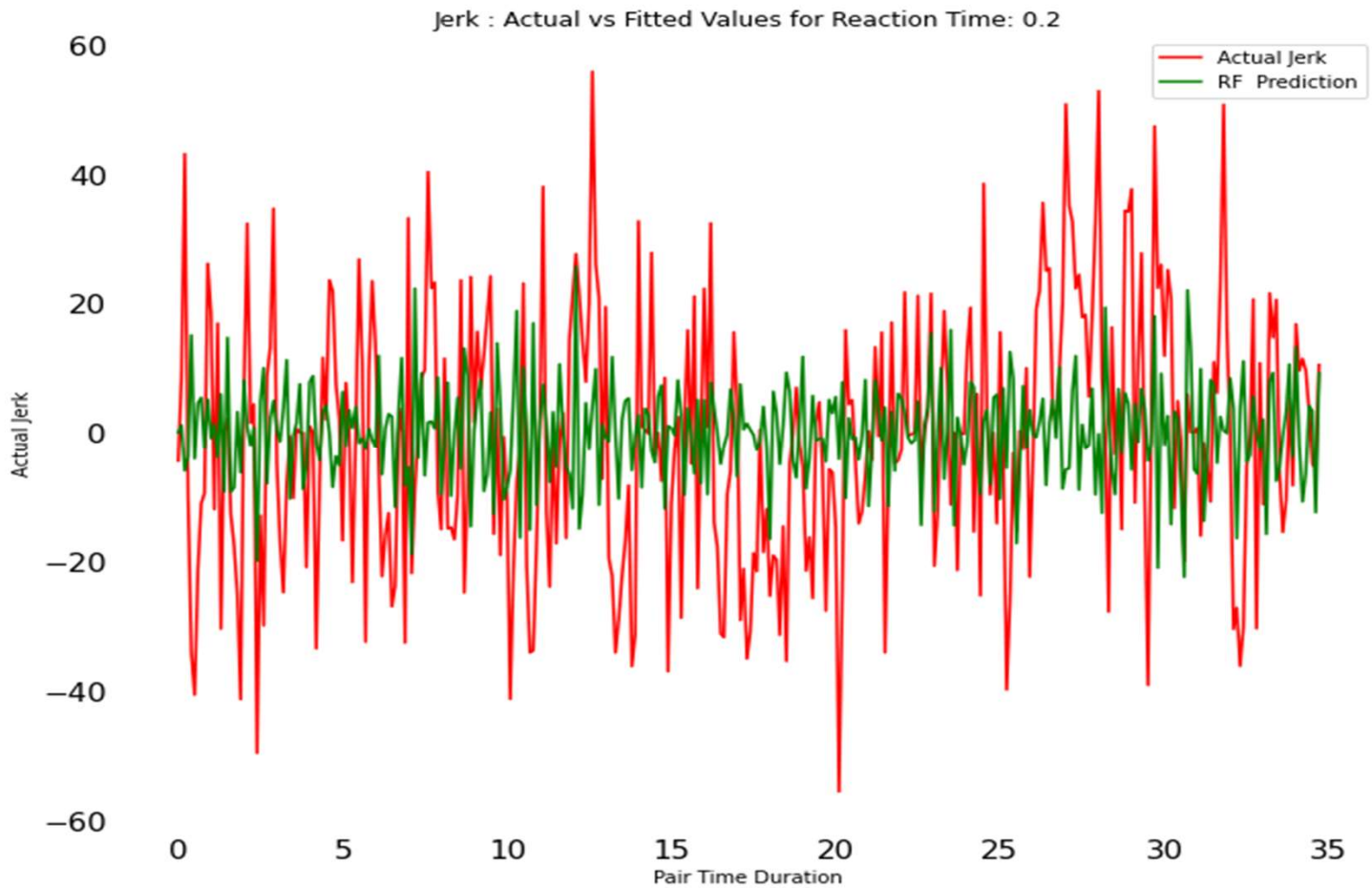
35
Pair Time Duration

Result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Actual Jerk
RF Prediction
60
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Actual Jerk
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Pair Time Duration

Result

Jerk : Actual vs Fitted Values for Reaction Time: 0.2
Actual Jerk
CNN Prediction
60
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−20
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−60
Actual Jerk
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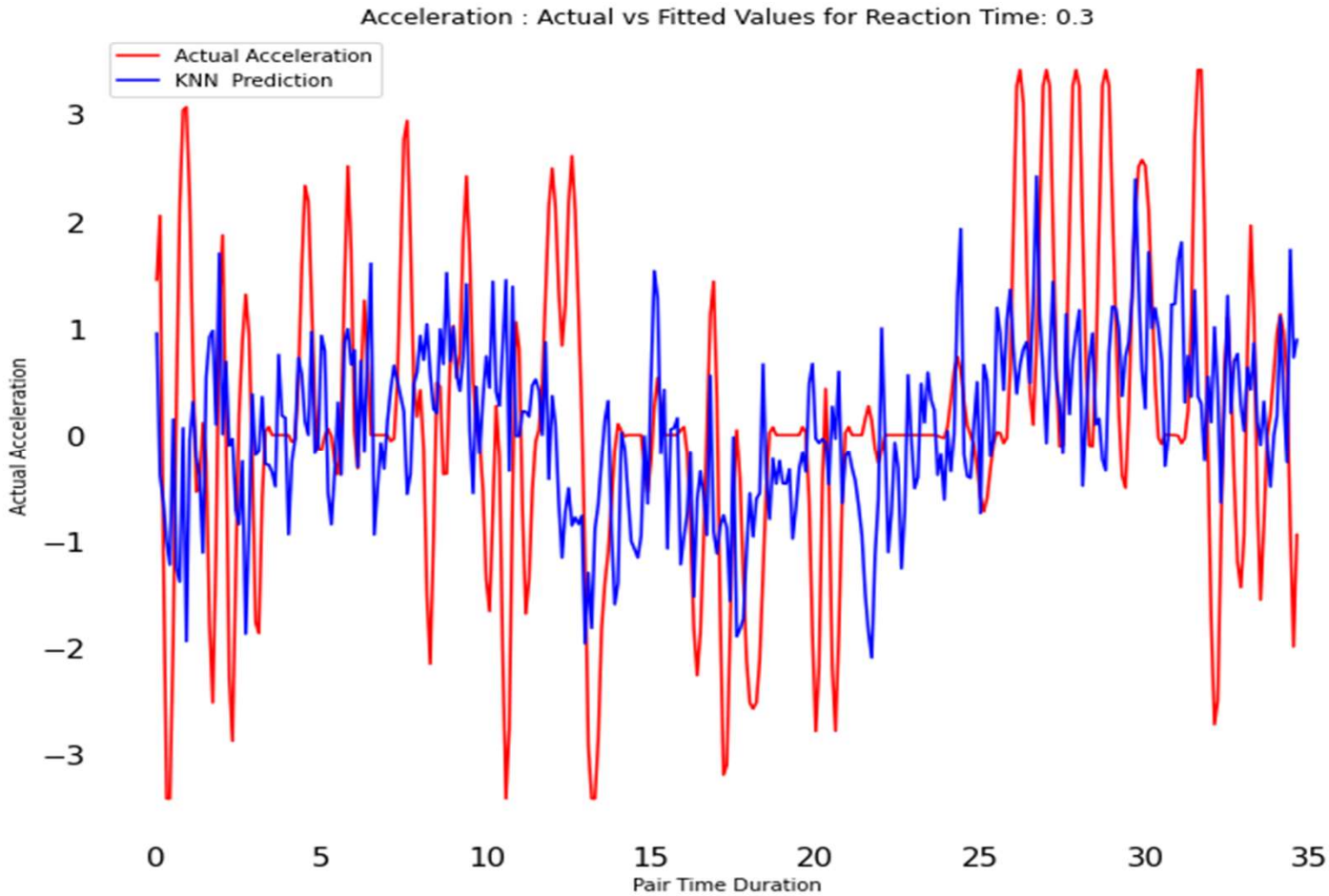
Pair Time Duration

Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.3
Actual Acceleration
KNN Prediction
Actual Acceleration
Pair Time Duration
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2
1
0
−1
−2
−3
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25
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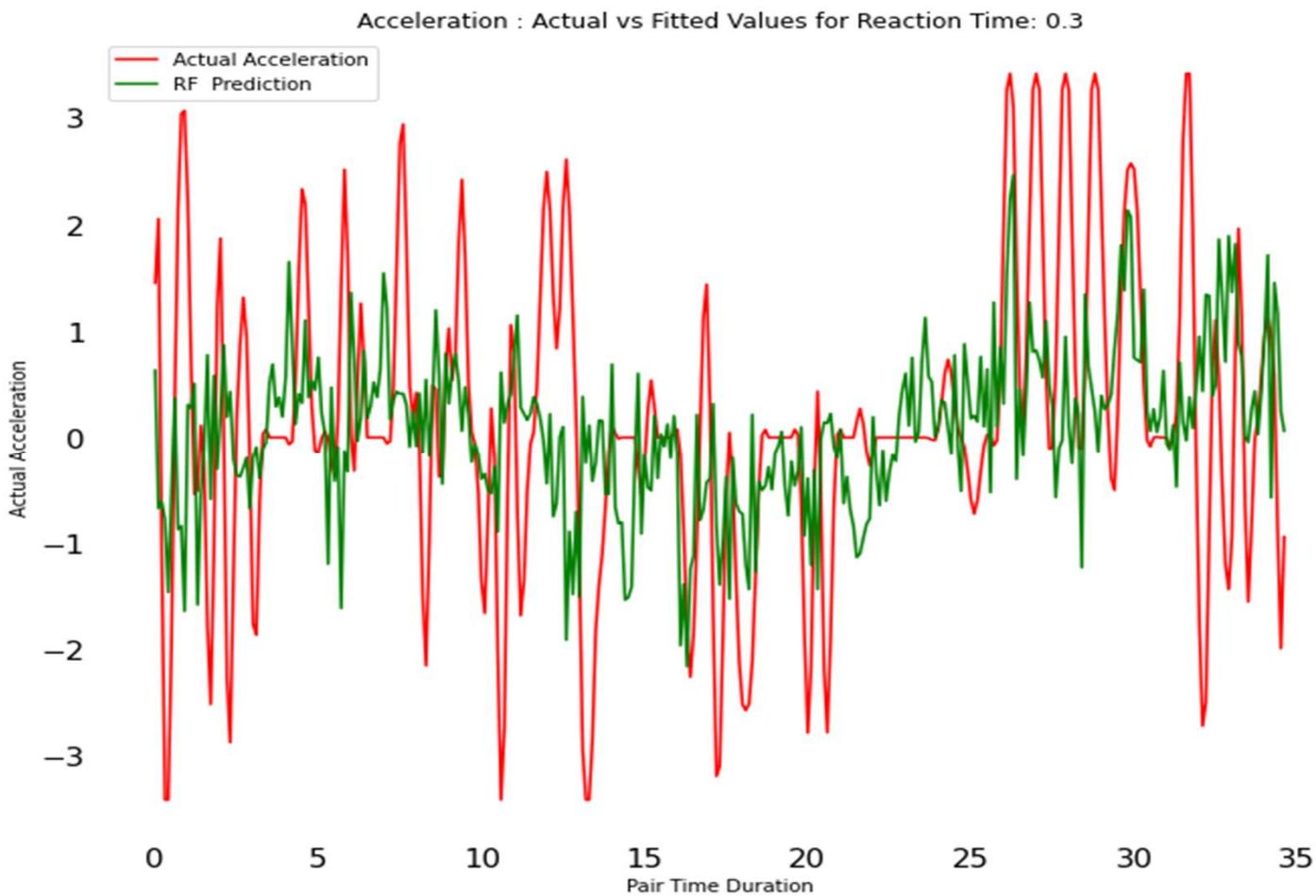
Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.3
Actual Acceleration
RF Prediction
3
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−1
−2
−3
Actual Acceleration
0
5
10
15
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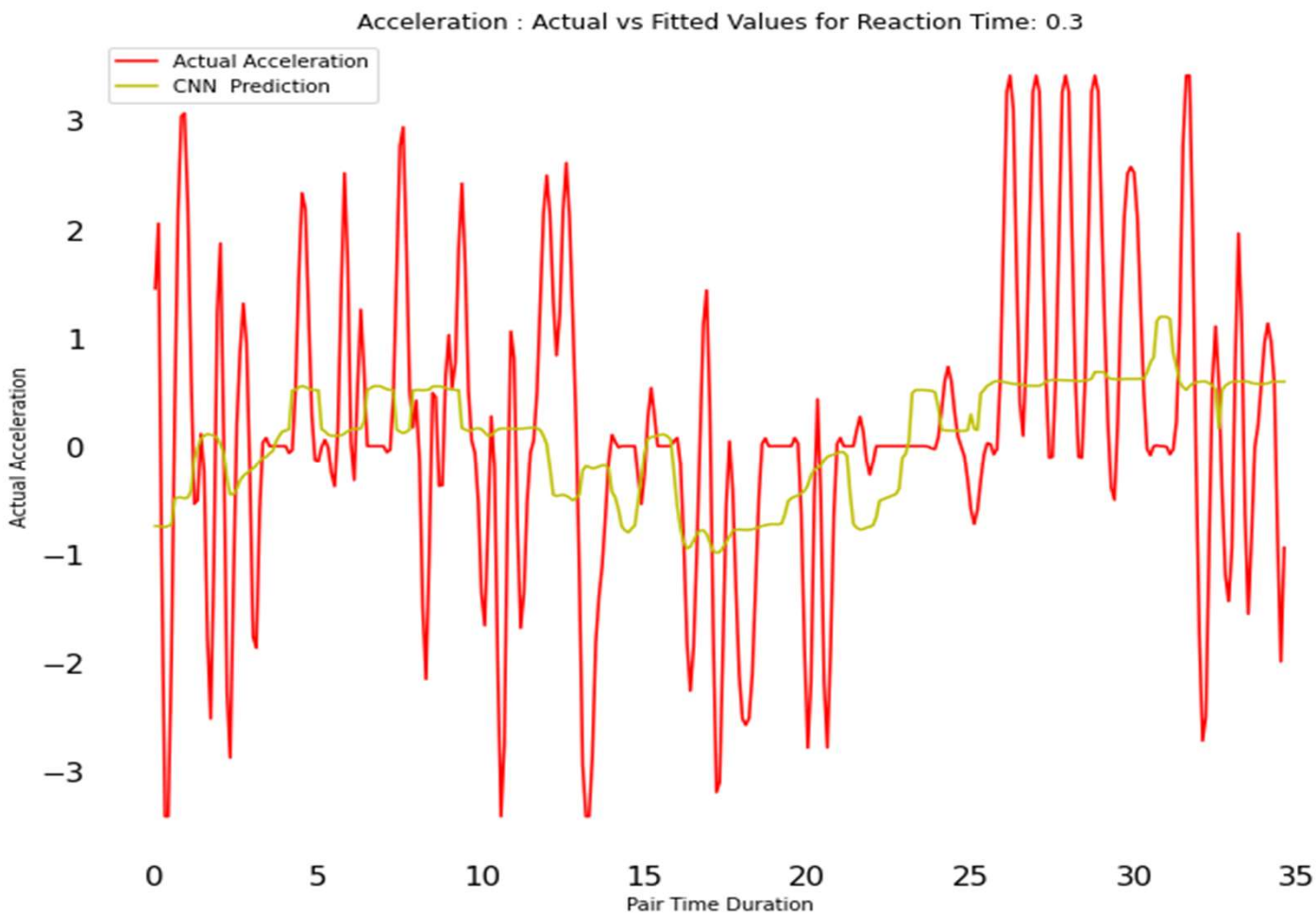
25
30
35
Pair Time Duration

Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.3
Actual Acceleration
CNN Prediction
Actual Acceleration
Pair Time Duration
3
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−2
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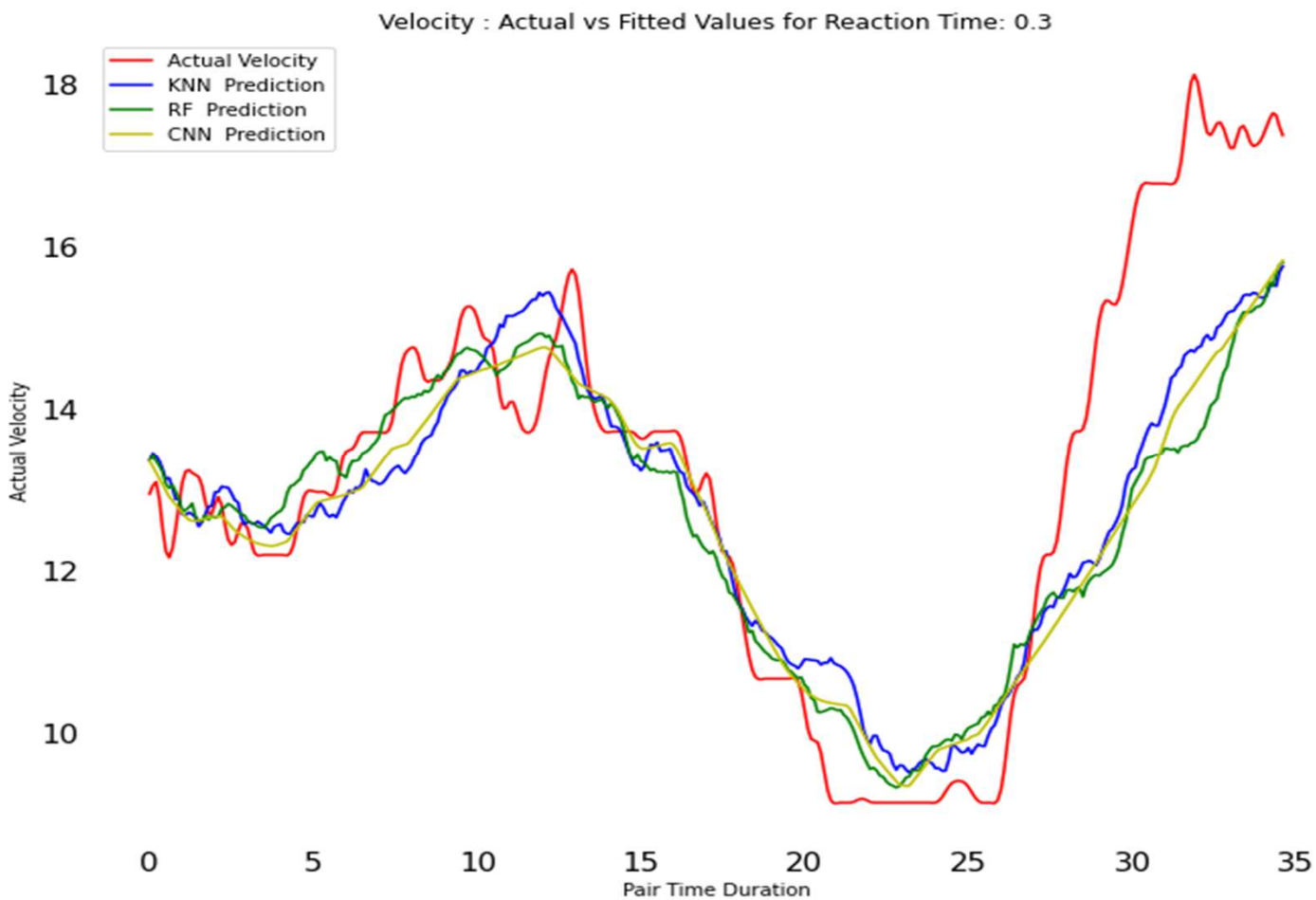
Result


Velocity : Actual vs Fitted Values for Reaction Time: 0.3
Actual Velocity
KNN Prediction
RF Prediction
CNN Prediction
18
16
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12
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Actual Velocity
0
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10
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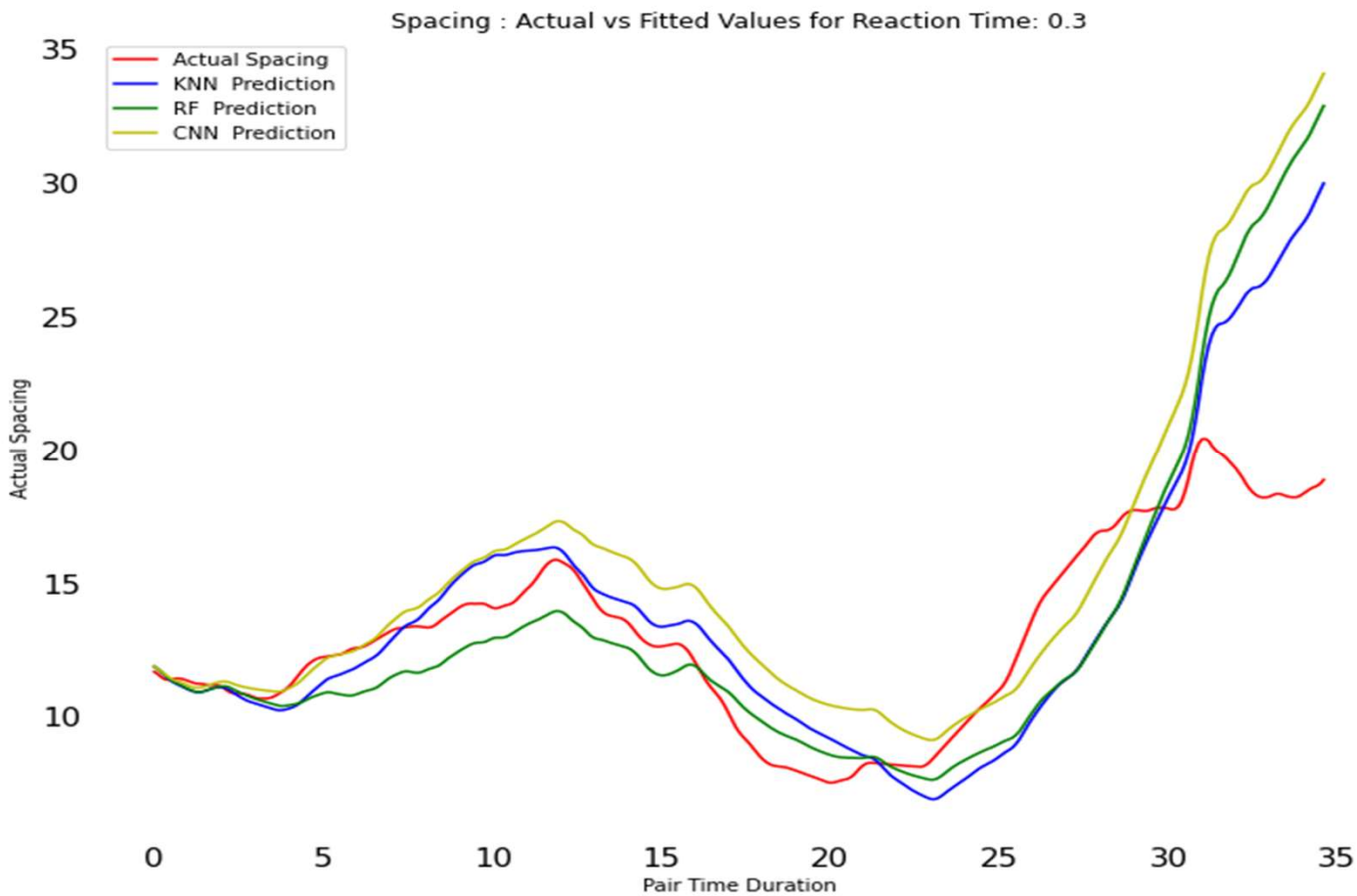
25
30
35
Pair Time Duration

Result


Spacing : Actual vs Fitted Values for Reaction Time: 0.3
Actual Spacing
KNN Prediction
RF Prediction
CNN Prediction
35
30
25
20
15
10
Actual Spacing
0
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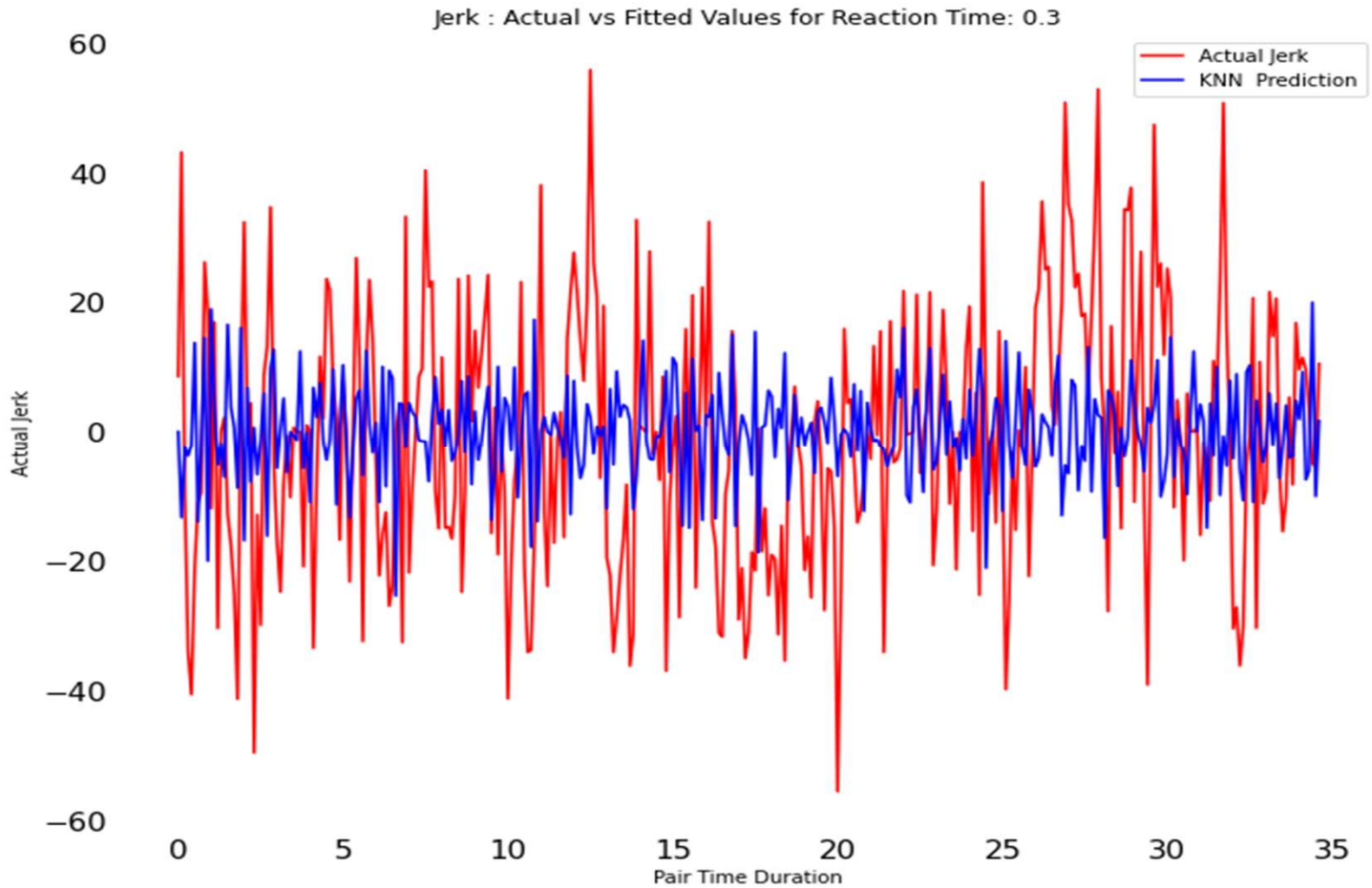
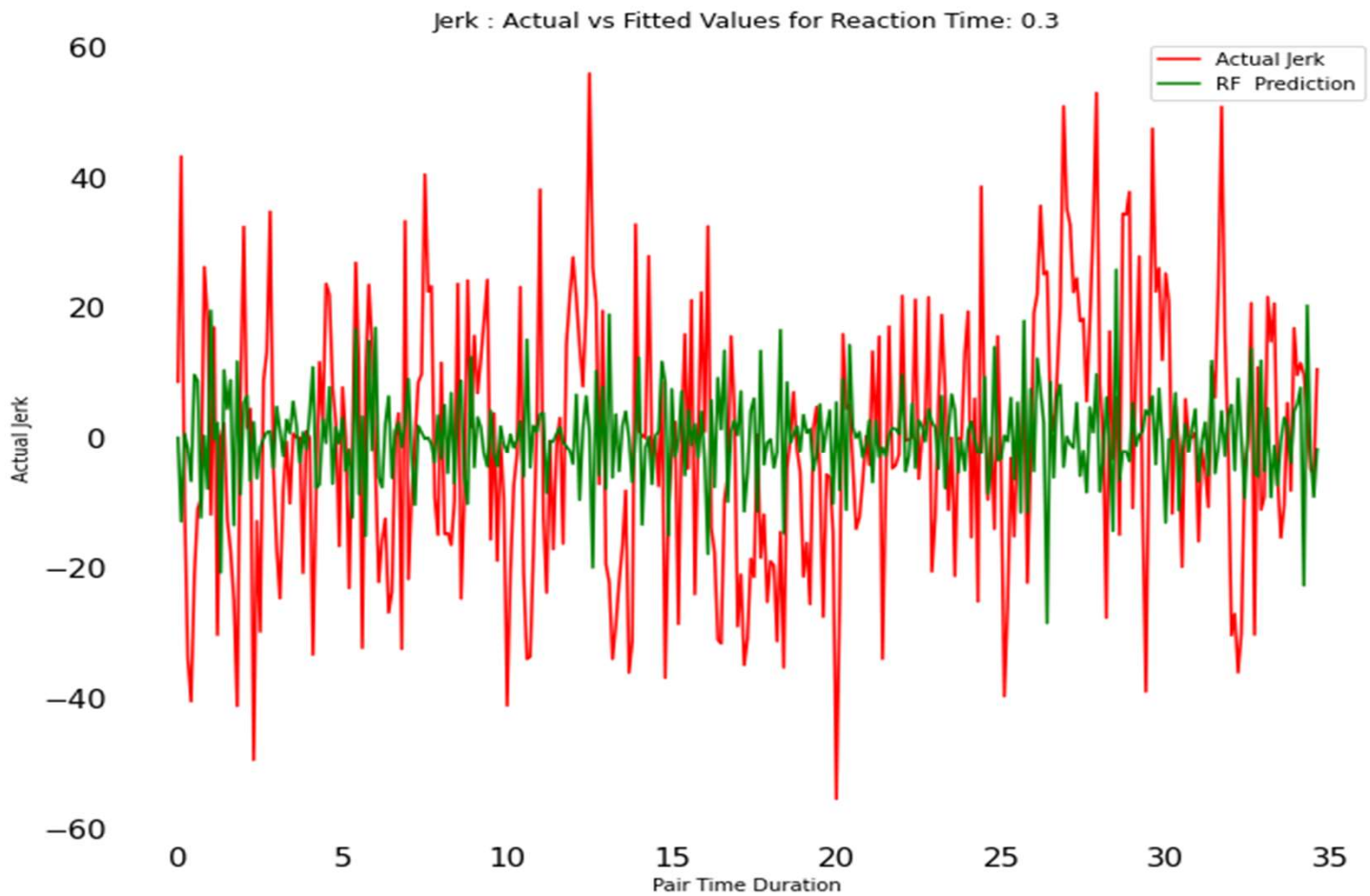
10
15
20
25
30
35
Pair Time Duration

Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.3
Actual Jerk
KNN Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

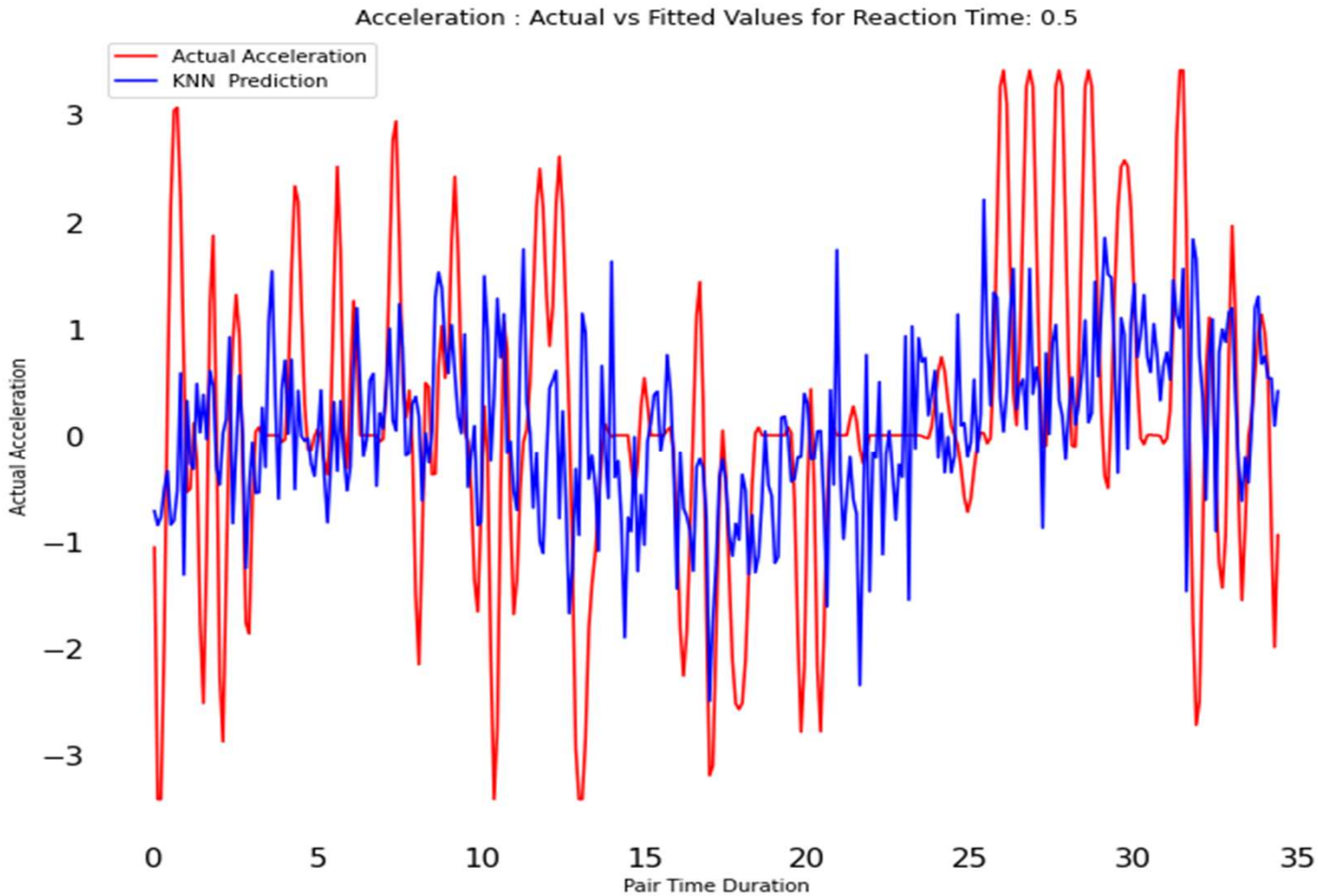
Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.3
Actual Jerk
RF Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

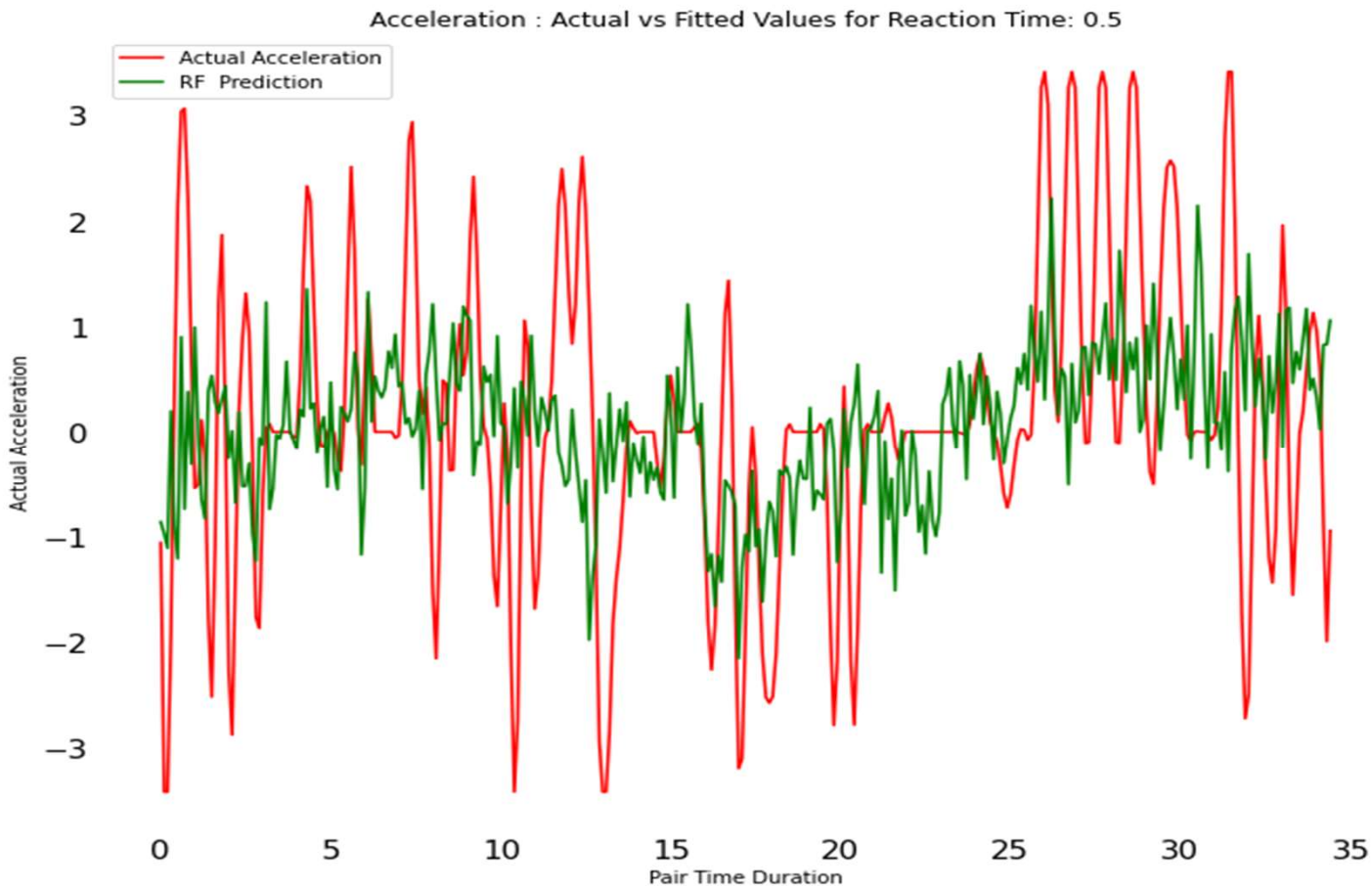
Result

Jerk : Actual vs Fitted Values for Reaction Time: 0.3
Actual Jerk
CNN Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

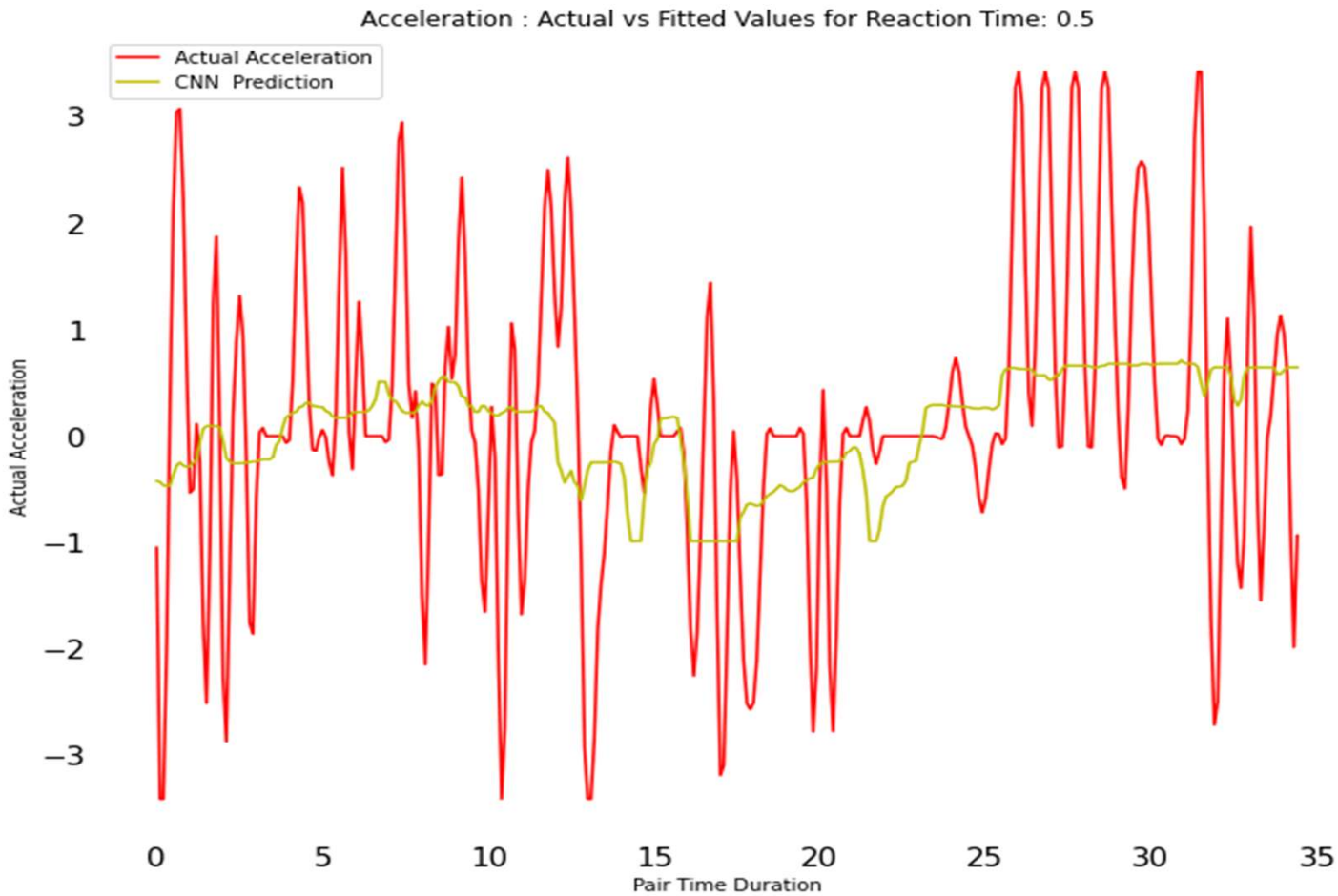
Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.5
Actual Acceleration
KNN Prediction
Actual Acceleration
Pair Time Duration
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
30
35

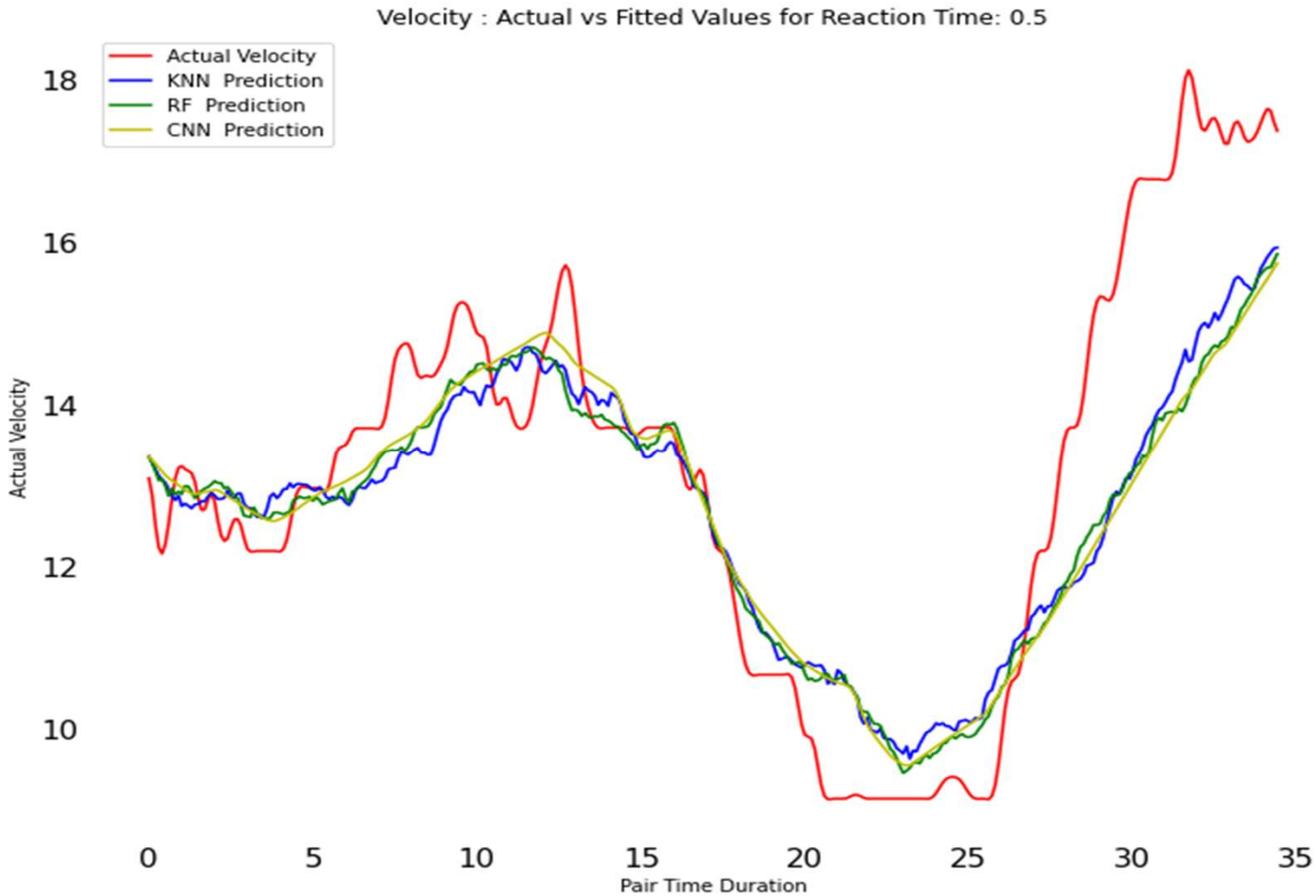
Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.5
Actual Acceleration
RF Prediction
Actual Acceleration
Pair Time Duration
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
30
35

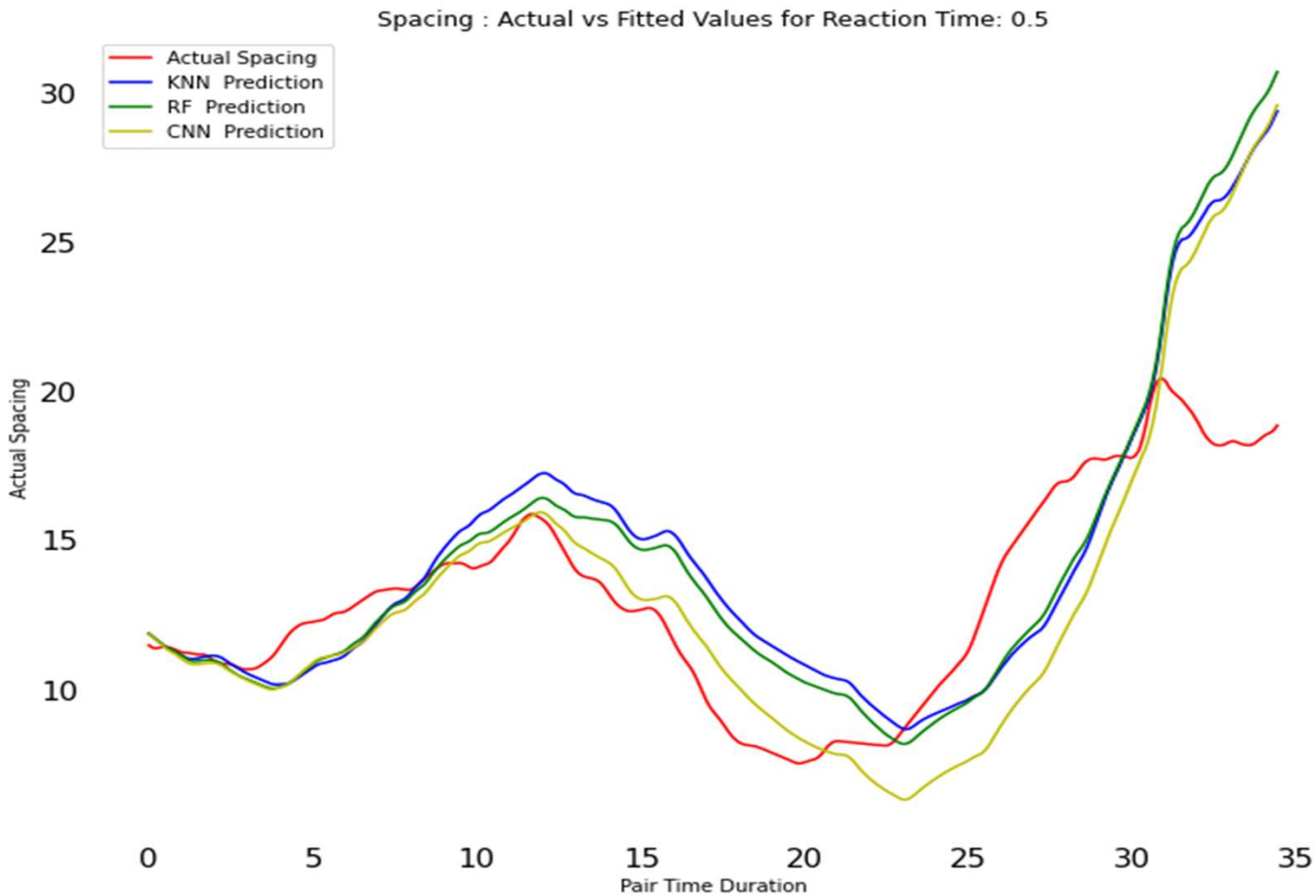
Result


Acceleration : Actual vs Fitted Values for Reaction Time: 0.5
Actual Acceleration
CNN Prediction
Actual Acceleration
Pair Time Duration
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
30
35

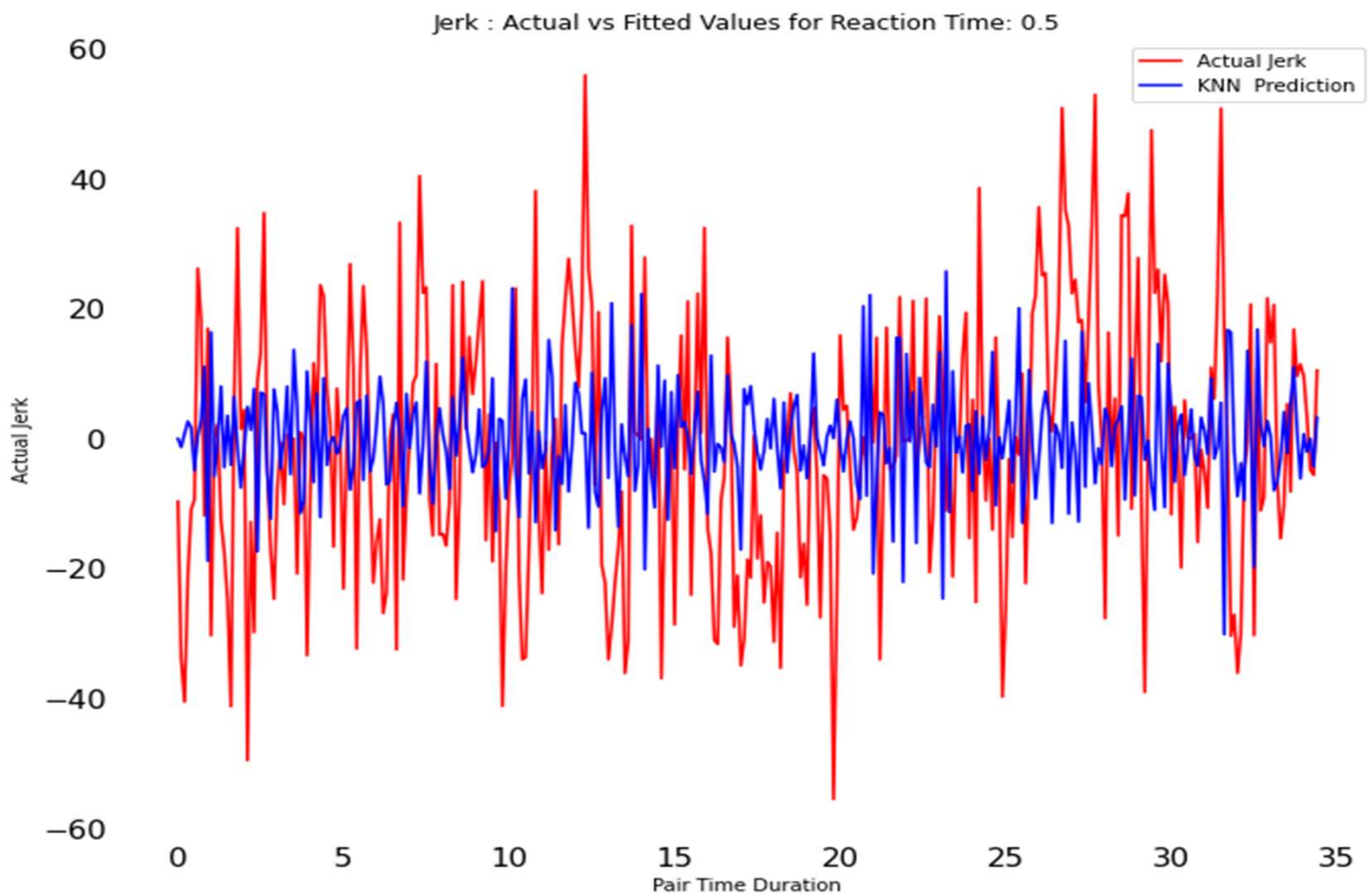
Result


Velocity : Actual vs Fitted Values for Reaction Time: 0.5
Actual Velocity
KNN Prediction
RF Prediction
CNN Prediction
18
16
14
12
10
Actual Velocity
0
5
10
15
20
25
30
35
Pair Time Duration

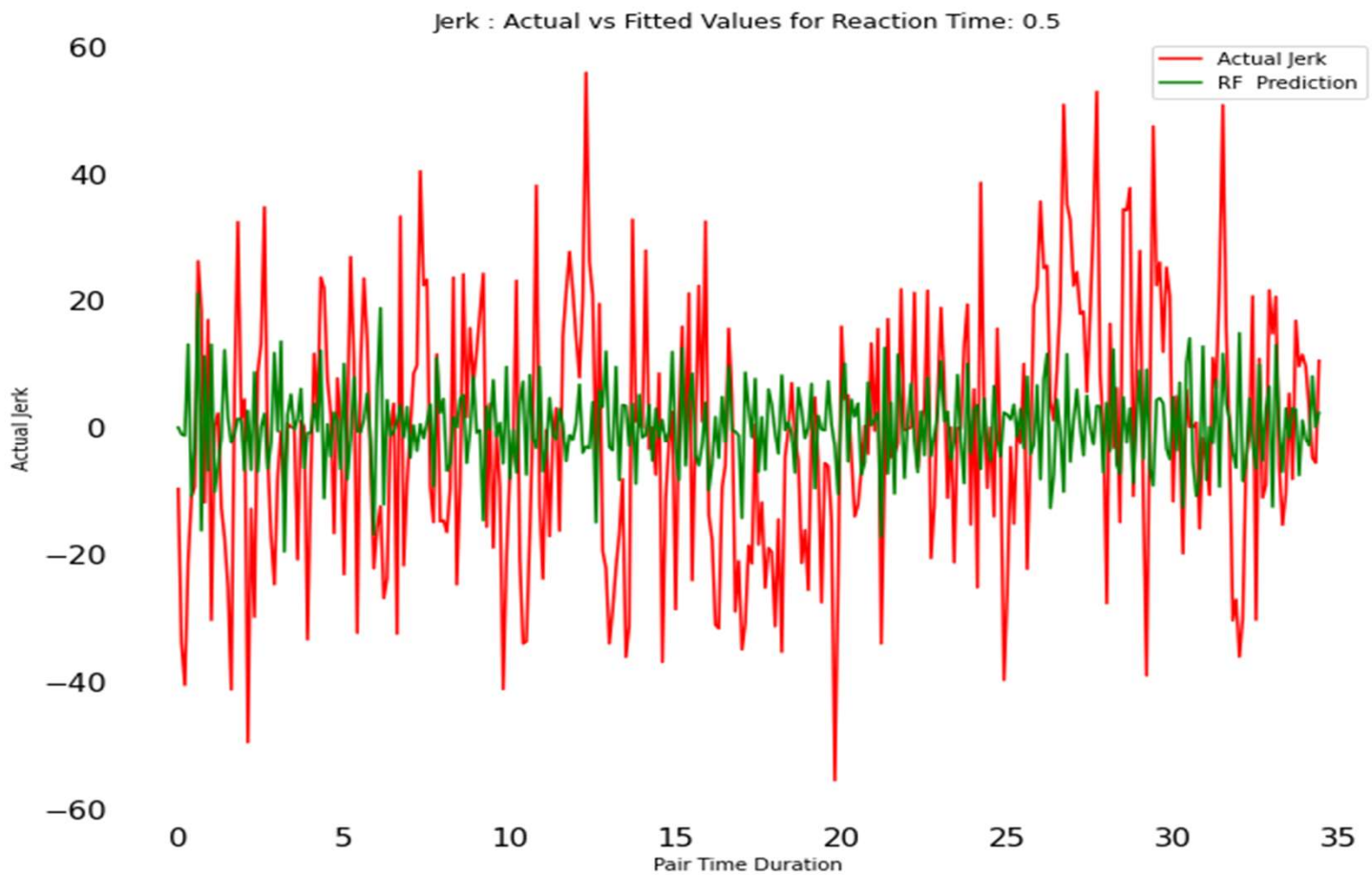
Result


Spacing : Actual vs Fitted Values for Reaction Time: 0.5
Actual Spacing
KNN Prediction
RF Prediction
CNN Prediction
Actual Spacing
30
25
20
15
10
0
5
10
15
20
25
30
35
Pair Time Duration

Result


Jerk : Actual vs Fitted Values for Reaction Time: 0.5
Actual Jerk
KNN Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

Result

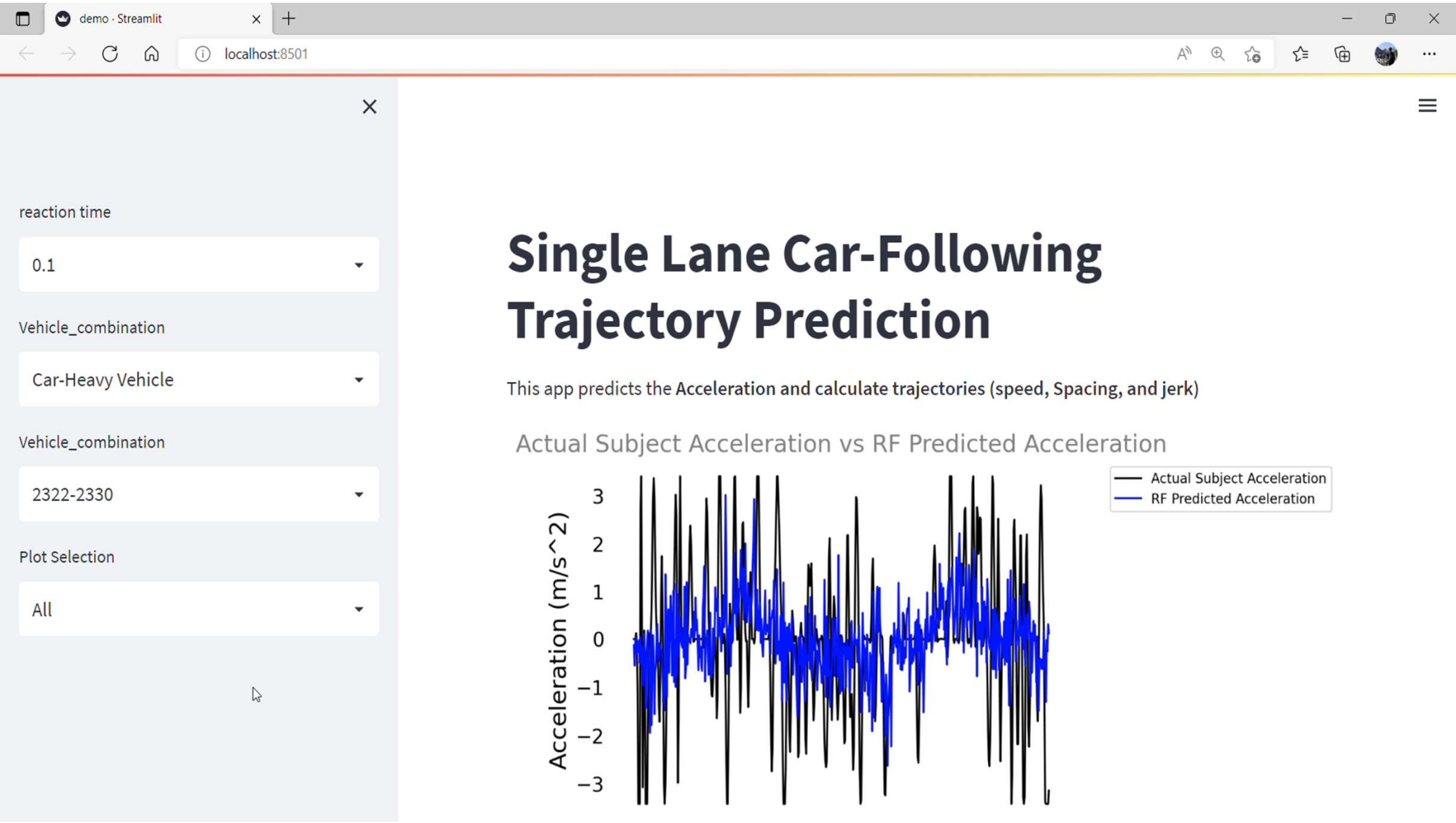

Jerk : Actual vs Fitted Values for Reaction Time: 0.5
Actual Jerk
RF Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

Result

Jerk : Actual vs Fitted Values for Reaction Time: 0.5
Actual Jerk
CNN Prediction
60
40
20
0
−20
−40
−60
Actual Jerk
0
5
10
15
20
25
30
35
Pair Time Duration

Future Scope:

- Create Prod App which predicts based on excel input.
- Use Server and Docker to move past storage and CPU limitation.
- Once on Docker update Random Forest from 30 to 150 Regressors.
- Re-Train models on entire NGSIM data including Lankershim and Peach tree.
- Use Dynamic Time Warping to verify Accuracy.


demo · Streamlit
localhost:8501
reaction time
0.1
Vehicle_combination
Car-Heavy Vehicle
Vehicle_combination
2322-2330
Plot Selection
All
Single Lane Car-Following Trajectory Prediction
This app predicts the Acceleration and calculate trajectories (speed, Spacing, and jerk)
Actual Subject Acceleration vs RF Predicted Acceleration
Actual Subject Acceleration
RF Predicted Acceleration
Acceleration (m/s^2)
3
2
1
0
−1
−2
−3

Queries