**Intelligent Vehicle Drive Mode Which Predicts the Driver Behaviour Vector to augment
Engine Performance in Real-time**

**Srikanth Kolachalama\*, Hafiz Malik**

Electrical and Computer Engineering, University of Michigan, Dearborn 48128, USA
Corresponding author: skola@umich.edu; Co-author: hafiz@umich.edu

**Supplementary Material - Tables**

1. **Datasets retrieved - Cadillac test vehicles (General Motors Inc.)**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Data Set 1** | **Data Set 2** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Odometer (km) | 12723 | 7.000 | 0.00055 | 12750.470 | 7.321 | 0.0006 |
| Speed (MPH) | 70.092 | 1.184 | 0.0169 | 69.8071 | 2.529 | 0.0362 |
| Acceleration (m.$s^{-2}$) | 0.00782 | 0.239 | 30.6057 | 0.0846 | 0.316 | 3.7403 |
| Longitudinal acceleration (m.$s^{-2}$) | -0.0092 | 0.144 | -15.755 | 0.0433 | 0.253 | 5.8505 |
| Lateral acceleration (m.$s^{-2}$) | 0.0174 | 0.288 | 16.5578 | -0.0313 | 0.300 | -9.6047 |
| Yaw rate (deg.$s^{-1}$) | 0.217 | 0.831 | 3.81748 | 0.0001 | 0.763 | 6157.3535 |
| Cabin air temperature (℉) | 68.786 | 0.329 | 0.0048 | 68.899 | 0.149 | 0.0022 |
| External air temperature (℉) | 39.225 | 0.301 | 0.0077 | 40.819 | 0.653 | 0.0160 |
| Tire Pressure Left Front (kPa) | 241.263 | 2.444 | 0.01013 | 240.850 | 1.636 | 0.0068 |
| Tire Pressure Left Rear (kPa) | 235.894 | 0.642 | 0.00272 | 235.683 | 1.080 | 0.0046 |
| Tire Pressure Right Front (kPa) | 243.69 | 1.070 | 0.00439 | 243.440 | 1.387 | 0.0057 |
| Tire Pressure Right Rear (kPa) | 235.25 | 1.560 | 0.00664 | 234.195 | 1.990 | 0.0085 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 149.93 | 60.210 | 0.40159 | 158.333 | 87.714 | 0.554 |
| IES (rad.$s^{-1}$) | 183.151 | 7.129 | 0.03893 | 195.442 | 31.653 | 0.162 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 265.289 | 90.471 | 0.34103 | 311.094 | 177.058 | 0.569 |
| EST (°F) | 204.996 | 0.869 | 0.00424 | 204.797 | 0.701 | 0.003 |
| ACRFP (PSI) | 39.517 | 1.038 | 0.02627 | 41.442 | 1.042 | 0.025 |

**Table S1:** 2019 Cadillac XT6 — (**Date**: March 11, 2020)

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Data Set 1** | **Data Set 2** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Odometer (km) | 30343.016 | 0.426 | 0.000 | 30308.689 | 0.700 | 0.000 |
| Speed (MPH) | 74.541 | 6.427 | 0.086 | 72.194 | 2.719 | 0.038 |
| Acceleration (m.$s^{-2}$) | -0.006 | 0.210 | -37.434 | 0.045 | 0.178 | 3.944 |
| Longitudinal acceleration (m.$s^{-2}$) | 0.254 | 0.268 | 1.053 | -0.109 | 0.151 | -1.388 |
| Lateral acceleration (m.$s^{-2}$) | 0.049 | 0.245 | 4.960 | 0.109 | 0.215 | 1.968 |
| Yaw rate (deg.$s^{-1}$) | 0.121 | 0.573 | 4.749 | -0.247 | 0.398 | -1.615 |
| Cabin air temperature (℉) | 69.000 | 0.000 | 0.000 | 70.000 | 0.000 | 0.000 |
| External air temperature (℉) | 83.355 | 0.215 | 0.003 | 85.612 | 0.782 | 0.009 |
| Tire Pressure Left Front (kPa) | 227.310 | 0.000 | 0.000 | 227.310 | 0.000 | 0.000 |
| Tire Pressure Left Rear (kPa) | 248.000 | 0.000 | 0.000 | 248.000 | 0.000 | 0.000 |
| Tire Pressure Right Front (kPa) | 227.310 | 0.000 | 0.000 | 227.310 | 0.000 | 0.000 |
| Tire Pressure Right Rear (kPa) | 248.000 | 0.000 | 0.000 | 248.000 | 0.000 | 0.000 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 105.647 | 71.676 | 0.678 | 130.339 | 62.899 | 0.483 |
| IES (rad.$s^{-1}$) | 196.371 | 15.530 | 0.079 | 186.821 | 7.514 | 0.040 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 234.445 | 142.880 | 0.609 | 231.247 | 99.410 | 0.430 |
| EST (°F) | 200.499 | 1.979 | 0.010 | 198.760 | 3.202 | 0.016 |
| ACRFP (PSI) | 108.982 | 2.256 | 0.021 | 106.842 | 2.062 | 0.019 |

**Table S2:** 2021 Cadillac CT4 — (**Date**: August 07, 2020)

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Data Set 1 (AWD)** | **Data Set 2** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Odometer (km) | 34394.044 | 0.662 | 0.000 | 13001.923 | 0.889 | 0.000 |
| Speed (MPH) | 75.985 | 1.039 | 0.014 | 72.764 | 1.979 | 0.027 |
| Acceleration (m.$s^{-2}$) | -0.022 | 0.142 | -6.542 | -0.024 | 0.181 | -7.572 |
| Longitudinal acceleration (m.$s^{-2}$) | -0.001 | 0.102 | -69.281 | 0.080 | 0.256 | 3.206 |
| Lateral acceleration (m.$s^{-2}$) | -0.047 | 0.237 | -5.035 | 0.036 | 0.125 | 3.440 |
| Yaw rate (deg.$s^{-1}$) | -0.346 | 0.528 | -1.525 | -0.210 | 0.496 | -2.359 |
| Cabin air temperature (℉) | 71.000 | 0.000 | 0.000 | 70.000 | 0.000 | 0.000 |
| External air temperature (℉) | 76.993 | 0.564 | 0.007 | 90.921 | 0.768 | 0.008 |
| Pitch (rad) | -0.001 | 0.001 | -0.975 | 0.006 | 0.002 | 0.380 |
| Roll (rad) | 0.003 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 |
| Tire Pressure Left Front (kPa) | 248.000 | 0.000 | 0.000 | 248.000 | 0.000 | 0.000 |
| Tire Pressure Left Rear (kPa) | 248.000 | 0.000 | 0.000 | 248.000 | 0.000 | 0.000 |
| Tire Pressure Right Front (kPa) | 248.000 | 0.000 | 0.000 | 248.000 | 0.000 | 0.000 |
| Tire Pressure Right Rear (kPa) | 248.000 | 0.000 | 0.000 | 248.000 | 0.000 | 0.000 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 268.991 | 41.284 | 0.153 | 237.077 | 63.279 | 0.267 |
| IES (rad.$s^{-1}$) | 173.451 | 4.363 | 0.025 | 165.538 | 4.279 | 0.026 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 454.373 | 68.957 | 0.152 | 398.614 | 93.198 | 0.234 |
| EST (°F) | 200.444 | 2.289 | 0.011 | 204.594 | 4.690 | 0.023 |
| ACRFP (PSI) | 119.427 | 2.489 | 0.021 | 196.758 | 3.172 | 0.016 |

**Table S3:** 2021 Cadillac Escalade ESV — (**Date**: August 11, 2020)

|  |  |  |
| --- | --- | --- |
| **Parameters** | **ACC Speed [25 40] MPH** | **ACC Speed [40 55] MPH** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Absolute time (s) | 3807.133 | 1922.575 | 0.505 | 4182.933 | 1968.170 | 0.471 |
| Odometer (km) | 15230.660 | 44.699 | 0.003 | 15239.960 | 45.639 | 0.003 |
| Speed (MPH) | 34.433 | 4.231 | 0.123 | 47.734 | 4.659 | 0.098 |
| Acceleration (m.$s^{-2}$) | 0.579 | 0.613 | 1.058 | 0.437 | 0.459 | 1.051 |
| Longitudinal acceleration (m.$s^{-2}$) | 0.411 | 0.582 | 1.415 | 0.260 | 0.441 | 1.698 |
| Lateral acceleration (m.$s^{-2}$) | 0.352 | 0.303 | 0.861 | 0.348 | 0.353 | 1.016 |
| Yaw rate (deg.$s^{-1}$) | 0.009 | 0.024 | 2.646 | 0.008 | 0.021 | 2.495 |
| Cabin air temperature (℉) | 66.000 | 0.000 | 0.000 | 66.000 | 0.000 | 0.000 |
| External air temperature (℉) | 85.501 | 3.770 | 0.044 | 86.337 | 3.434 | 0.040 |
| Tire Pressure Left Front (kPa) | 270.424 | 2.822 | 0.010 | 269.869 | 3.170 | 0.012 |
| Tire Pressure Left Rear (kPa) | 270.886 | 2.307 | 0.009 | 270.885 | 2.570 | 0.009 |
| Tire Pressure Right Front (kPa) | 267.259 | 2.961 | 0.011 | 266.713 | 3.259 | 0.012 |
| Tire Pressure Right Rear (kPa) | 270.081 | 3.164 | 0.012 | 270.792 | 3.007 | 0.011 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 119.135 | 69.890 | 0.587 | 142.408 | 78.788 | 0.553 |
| IES (rad.$s^{-1}$) | 199.642 | 66.334 | 0.332 | 210.297 | 53.398 | 0.254 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 277.618 | 199.441 | 0.718 | 324.459 | 190.869 | 0.588 |
| EST (°F) | 199.262 | 2.478 | 0.012 | 199.546 | 2.112 | 0.011 |
| ACRFP (PSI) | 156.398 | 18.163 | 0.116 | 164.076 | 15.808 | 0.096 |

**Table S4:** Dataset 1—2020 Cadillac CT5 (**Date**: June 16, 2020) [Kolachalama and Malik, 2021]

|  |  |  |
| --- | --- | --- |
| **Parameters** | **ACC Speed [55 65] MPH** | **ACC Speed [65 75] MPH** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Absolute time (s) | 4773.918 | 2424.428 | 0.508 | 4620.057 | 2330.081 | 0.504 |
| Odometer (km) | 16042.450 | 33.226 | 0.002 | 16042.910 | 29.183 | 0.002 |
| Speed (MPH) | 60.451 | 2.774 | 0.046 | 68.834 | 2.536 | 0.037 |
| Acceleration (m.$s^{-2}$) | 0.268 | 0.339 | 1.265 | 0.199 | 0.283 | 1.419 |
| Longitudinal acceleration (m.$s^{-2}$) | 0.114 | 0.330 | 2.902 | 0.021 | 0.269 | 13.035 |
| Lateral acceleration (m.$s^{-2}$) | 0.388 | 0.414 | 1.065 | 0.387 | 0.442 | 1.143 |
| Yaw rate (deg.$s^{-1}$) | 0.015 | 0.021 | 1.353 | 0.014 | 0.019 | 1.355 |
| Cabin air temperature (℉) | 84.250 | 3.709 | 0.044 | 85.353 | 2.194 | 0.026 |
| External air temperature (℉) | 72.850 | 0.989 | 0.014 | 72.992 | 1.000 | 0.014 |
| Tire Pressure Left Front (kPa) | 264.708 | 6.304 | 0.024 | 264.692 | 5.024 | 0.019 |
| Tire Pressure Left Rear (kPa) | 264.608 | 3.973 | 0.015 | 264.662 | 3.418 | 0.013 |
| Tire Pressure Right Front (kPa) | 262.423 | 7.459 | 0.028 | 263.400 | 6.077 | 0.023 |
| Tire Pressure Right Rear (kPa) | 262.869 | 7.223 | 0.027 | 264.923 | 4.024 | 0.015 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 172.568 | 75.253 | 0.436 | 172.744 | 76.107 | 0.441 |
| IES (rad.$s^{-1}$) | 198.841 | 45.060 | 0.227 | 209.786 | 38.033 | 0.181 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 347.000 | 176.180 | 0.508 | 360.484 | 160.091 | 0.444 |
| EST (°F) | 200.148 | 3.164 | 0.016 | 200.331 | 2.599 | 0.013 |
| ACRFP (PSI) | 175.395 | 14.489 | 0.083 | 173.653 | 19.962 | 0.115  |

**Table S5:** Dataset 2—2020 Cadillac CT5 (**Date**: June 16, 2020) [Kolachalama and Malik, 2021]

|  |  |  |
| --- | --- | --- |
| **Parameters** | **ACC Speed [25 40] MPH** | **ACC Speed [40 55] MPH** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Absolute time (s) | 1580.287 | 783.077 | 0.496 | 1588.548 | 206.355 | 0.130 |
| Odometer (km) | 24875.920 | 12.858 | 0.001 | 24875.520 | 2.893 | 0.000 |
| Speed (MPH) | 34.747 | 4.831 | 0.139 | 46.602 | 3.800 | 0.082 |
| Acceleration (m.$s^{-2}$) | 0.288 | 0.502 | 1.741 | 0.025 | 0.145 | 5.842 |
| Longitudinal acceleration (m.$s^{-2}$) | 0.111 | 0.487 | 4.388 | -0.129 | 0.160 | -1.239 |
| Lateral acceleration (m.$s^{-2}$) | 0.269 | 0.201 | 0.748 | 0.198 | 0.210 | 1.062 |
| Yaw rate (deg.$s^{-1}$) | 0.234 | 0.244 | 1.042 | 0.274 | 0.287 | 1.049  |
| Cabin air temperature (℉) | 74.746 | 4.628 | 0.062 | 74.375 | 7.544 | 0.101 |
| External air temperature (℉) | 39.664 | 1.039 | 0.026 | 39.954 | 1.225 | 0.031 |
| Tire Pressure Left Front (kPa) | 226.523 | 1.930 | 0.009 | 227.253 | 1.984 | 0.009 |
| Tire Pressure Left Rear (kPa) | 229.404 | 2.787 | 0.012 | 228.670 | 1.680 | 0.007 |
| Tire Pressure Right Front (kPa) | 248.317 | 3.511 | 0.014 | 250.345 | 2.399 | 0.010 |
| Tire Pressure Right Rear (kPa) | 227.405 | 2.628 | 0.012 | 227.787 | 1.980 | 0.009 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 79.217 | 51.955 | 0.656 | 85.042 | 35.108 | 0.413 |
| IES (rad.$s^{-1}$) | 185.691 | 60.608 | 0.326 | 144.195 | 7.987 | 0.055 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 174.504 | 150.452 | 0.862 | 125.877 | 49.408 | 0.393 |
| EST (°F) | 202.714 | 4.250 | 0.021 | 203.877 | 2.251 | 0.011 |
| ACRFP (PSI) | 49.462 | 4.939 | 0.100 | 47.960 | 1.814 | 0.038 |

**Table S6:** Dataset 3—2020 Cadillac CT5 (**Date**: February 25, 2021) [Kolachalama and Malik, 2021]

|  |  |  |
| --- | --- | --- |
| **Parameters** | **ACC Speed [55 65] MPH** | **ACC Speed [65 75] MPH** |
| **Inputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| Absolute time (s) | 3018.585 | 1042.301 | 0.345 | 2648.426 | 202.247 | 0.076 |
| Odometer (km) | 24822.230 | 26.519 | 0.001 | 24813.59 | 6.433 | 0.000 |
| Speed (MPH) | 60.789 | 3.287 | 0.054 | 69.476 | 2.617 | 0.038 |
| Acceleration (m.$s^{-2}$) | 0.023 | 0.175 | 7.518 | 0.004 | 0.085 | 21.540 |
| Longitudinal acceleration (m.$s^{-2}$) | -0.135 | 0.209 | -1.544 | -0.170 | 0.150 | -0.886 |
| Lateral acceleration (m.$s^{-2}$) | 0.413 | 0.333 | 0.807 | 0.307 | 0.156 | 0.510 |
| Yaw rate (deg.$s^{-1}$) | 1.049 | 1.112 | 1.060 | 0.779 | 0.312 | 0.400 |
| Cabin air temperature (℉) | 79.397 | 6.916 | 0.087 | 75.831 | 5.311 | 0.070 |
| External air temperature (℉) | 37.816 | 1.672 | 0.044 | 37.931 | 0.487 | 0.013 |
| Tire Pressure Left Front (kPa) | 248.338 | 3.060 | 0.012 | 247.232 | 1.939 | 0.008 |
| Tire Pressure Left Rear (kPa) | 226.759 | 3.717 | 0.016 | 226.654 | 3.352 | 0.015 |
| Tire Pressure Right Front (kPa) | 225.709 | 2.882 | 0.013 | 224.917 | 1.834 | 0.008 |
| Tire Pressure Right Rear (kPa) | 227.795 | 3.674 | 0.016 | 227.426 | 2.707 | 0.012 |
| **Outputs** | **Mean** | **Deviation** | **Variance** | **Mean** | **Deviation** | **Variance** |
| IET (Nm) | 121.307 | 49.420 | 0.407 | 128.956 | 43.276 | 0.336 |
| IES (rad.$s^{-1}$) | 158.194 | 27.338 | 0.173 | 172.430 | 6.571 | 0.038 |
| IFCR (1E-8 $m^{3}s^{-1}$) | 189.586 | 90.905 | 0.479 | 216.109 | 72.691 | 0.336 |
| EST (°F) | 200.331 | 3.881 | 0.019 | 198.797 | 4.055 | 0.020 |
| ACRFP (PSI) | 41.700 | 1.535 | 0.037 | 40.571 | 0.241 | 0.006  |

**Table S7:** Dataset 4—2020 Cadillac CT5 (**Date**: February 25, 2021)[Kolachalama and Malik, 2021]

1. **Vehicle Engine Performance** — **Criteria**

|  |  |  |
| --- | --- | --- |
| **Roads types** | **Speed Limits - MPH** | **Properties** |
| Parking lot, critical points | [0 15] | No significant effect on EOP  |
| Arterial local segments | [15 25] |  No significant effect on EOP |
| Low curvatures | [15 25]  | RRC = [ 8.34 42.57] m |
| Arterial connecting segments | [25 45] | Ideal zone: Higher IET |
| State ways | [45 65] | Green zone: Lower IFCR |
| Freeways | [65 85]  | High-speed zone: Higher IES |

 **Table S8**: Categorization of road segments. [Kolachalama and Malik, 2021]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Body module** | **Driver Behaviour** | **Environmental factors** | **EOP** | **CATOP** |
| Odometer | Speed and set CAT | EAT, ATP, HUM | IET | EST |
| Tire pressure and Load | LOT and LAT | Gradient | IES | ACRFP |
| Vehicle type | YAR | RRC | IFCR | CAT |

 **Table S9**: Controller Area Network data retrieved— Cadillac vehicle segment. [Kolachalama and Malik, 2021]

|  |  |  |  |
| --- | --- | --- | --- |
| **EAT (℉)** | **Higher limit (PSI)** | **EAT (℉)** | **Higher limit (PSI)** |
| 65 | 135 | 90 | 250 |
| 70 | 140 | 95 | 275 |
| 75 | 150 | 100 | 300 |
| 80 | 175 | 105 | 325 |
| 85 | 220 | 110 | 335 |

 **Table S10**: HVAC R134a refrigerant—ACRFP referral range [Kolachalama and Malik, 2021].

|  |  |  |
| --- | --- | --- |
|  **Generic** | **Engine specific** | **Smoothness Measure - spline fit** |
| **Parameter** | **Condition** | **Parameter** | **Condition** | **Parameter** | **Condition** |
| IET | Higher  | ED | Lower | $R^{2}$/Adj $R^{2}$ | Higher |
| IES | Higher  | ESC | Higher  | SSE | Lower |
| IFCR | Lower  | ETC | Higher  | RMSE | Lower |

**Table S11:** Vehicle Engine Performance - Criteria. [Kolachalama et al., 2021]

1. **Deep Learning Models - Prediction of [EOP, CATOP]**

|  |  |
| --- | --- |
| **NARX** | **LSTM** |
| **Model Parameter** | **Value** | **Model Parameter** | **Value** |
| Training Function | Levenberg-Marquardt backpropagation | Training Function | Stochastic Gradient Descent with Momentum Optimizer |
| Input Delays | 1:2 | Output Layer | Fully Connected and Regression |
| Feedback Delays | 1:2 | Network Layer | LSTM |
| Hidden Layer Size | 10 | Input Layer | Sequence Input |
| Network | Open | Gradient Threshold | 1 |
| Dataset analysis | [70 % training, 30 % testing] | Dataset analysis | [70 % training, 30 % testing] |
| Performance | RMSE | Hidden Units | 200 |

**Table S12**: NARX and LSTM — Model Parameters (MATLAB) [Kolachalama et al., 2021]

|  |  |
| --- | --- |
|  | **NARX—Deep Learning Model Validation**  |
| **EOP** | **IET** | **IES** | **IFCR** |
| Data | RMSE | FOD | SNR | RMSE | FOD | SNR | RMSE | FOD | SNR |
| XT6 - Set 1 | 1.504 | 0.515 | 20.644 | 0.337 | 0.158 | 1.893 | 4.354 | 3.045 | 11.628 |
| XT6 - Set 2 | 1.84  | 0.802  |  9.807 | 0.248 | 0.177 | 41.559 | 6.503  | 4.561  | 78.539 |
| CT4 - Set 1 | 2.465 | 1.744  | 49.421 |  1.607  | 1.129 |  31.356 | 21.577 | 21.098 | 27.328 |
| CT4 - Set 2 | 0.967 | 0.666 | 160.83 |  0.122 | 0.072  | 27.012 | 8.175  | 6.539 | 27.012 |
| ESV - Set 1 | 2.415  | 1.723 | 53.748 | 0.26  | 0.179 | 39.937 | 15.072 | 13.034  | 26.963 |
| ESV - Set 2 | 1.791 |  1.235  | 30.921 | 0.063  | 0.036  | 10.636 | 14.259 | 10.049  | 16.201 |
|  | **LSTM—Deep Learning Model Validation** |
| **EOP** | **IET** | **IES** | **IFCR** |
| Data | RMSE | FOD | SNR | RMSE | FOD | SNR | RMSE | FOD | SNR |
| XT6 - Set 1 | 24.059  | 10.096 | 47.943 | 1.301  | 0.225  | 36.399 | 31.402  | 13.458 | 40.790 |
| XT6 - Set 2 | 18.515 | 6.0731 | 24.716 |  1.913  | 0.694  | 19.515 | 33.491  | 10.103 | 186.338 |
| CT4 - Set 1 |  53.504  | 4.399 | 128.137 | 7.738  | 1.420 | 32.036 |  122.147  | 12.143 | 209.046 |
| CT4 - Set 2 | 21.945  | 9.555  | 112.411 | 1.392  | 0.092 | 72.916 | 31.232  | 13.254  | 78.809 |
| ESV - Set 1 | 49.151  | 9.599 | 415.063 |  6.240  | 0.825 | 69.872 |  69.086  | 20.667  | 72.669 |
| ESV - Set 2 | 46.721  | 21.417 | 59.115 |  2.803  | 0.359 | 51.746 | 62.047  | 31.235  | 66.147 |

**Table S13:** Cadillac: Prediction of EOP—NARX and LSTM Model Performance. [Kolachalama et al., 2021]

|  |
| --- |
| **NARX—Deep Learning Model Validation**  |
| **CATOP** | **EST** | **ACRFP** |
| Data | ACCSSP | CAT (℉) | EAT (℉) | RMSE | FOD | SNR | RMSE | FOD | SNR |
| XT6 - Set 1 | 71 | 67 | 39.2 | 0.001 | 0.001 | 126.79 | 0.262 | 0.184 | 45.765 |
| XT6 - Set 2 | 74 | 68 | 40.96 | 0.000 | 0.000 | 0.239 |  0.09 | 0.063 | 71.956 |
| CT4 - Set 1 | 76 | 69 | 83.3 | 0.117 | 0.082 | 27.151 | 0.361 | 0.255  | 59.722 |
| CT4 - Set 2 | 70 | 70 | 86 | 0.098 | 0.069  | 70.436 | 0.1  | 0.063  | 2.139 |
| ESV - Set 1 | 75 | 71 | 77 |  0.058  | 0.041  | 13.827 |  0.22  |  0.155  | 37.714 |
| ESV - Set 2 | 73 | 70 | 90.5 |  0.057 | 0.04 |  19.125 | 0.156  | 0.109  | 15.93 |
| **LSTM—Deep Learning Model Validation** |
| **CATOP** | **EST** | **ACRFP** |
| Data | ACCSSP | CAT (℉) | EAT (℉) | RMSE | FOD | SNR | RMSE | FOD | SNR |
| XT6 - Set 1 | 71 | 67 | 39.2 |  0.000  | 0.000 | 0.000 | 1.266  | 0.235  | 639.558 |
| XT6 - Set 2 | 74 | 68 | 40.96 |  0.000  | 0.000 | 0.000 | 0.313  | 0.080  | 50.129 |
| CT4 - Set 1 | 76 | 69 | 83.3 |  0.690  | 0.096  | 162.252 | 3.030  | 0.329 | 831.615 |
| CT4 - Set 2 | 70 | 70 | 86 | 0.587  | 0.075  | 102.061 |  0.216  | 0.070 | 217.073 |
| ESV - Set 1 | 75 | 71 | 77 |  0.837  | 0.084  | 445.166 |  1.297  | 0.212 | 228.327 |
| ESV - Set 2 | 73 | 70 | 90.5 |  0.557  | 0.106 | 162.946 | 0.422  | 0.113 | 78.275 |

**Table S14:** Cadillac: Prediction of CATOP—NARX and LSTM Model Performance. [Kolachalama et al., 2021]

1. **NARX Deep Learning Models - Prediction of [EOP, CATOP]**

|  |
| --- |
| **NARX—DL Model** |
| **EOP** |  | **ACCSSP (MPH)** | **CATOP- Set 1** | **CATOP- Set 2** |
| **ACCSSP (MPH)** | **Training**  | **Training**  | **Training**  |
| 30  | 1–11082 | 35 | 1–1578 | 1–4842 |
| 40  | 1–24439 | 45 | 1–1913 | 1–4842 |
| 50  | 1–39191 | 55 | 1–5097 | 1–4842 |
| 60  | 1–54200 | 65 | 1–5563 | 1–4382 |
| 70 | 1–145925 | 75  | 1–2242 | 1–4382 |

**Table S15:** 2020 Cadillac CT5: Prediction of [EOP, CATOP] — Training sets [Kolachalama et al., 2021]

|  |  |
| --- | --- |
| Data | **NARX—Deep Learning Model Validation**  |
| EOP | **IET** | **IES** | **IFCR** |
| ACCSSP (MPH) | RMSE | FOD | SNR | RMSE | FOD | SNR | RMSE | FOD | SNR |
| 30  | 1.654 | 1.080 | 39.247 | 0.485 | 0.269 | 2.984 | 11.881 | 9.122 | 164.660 |
| 40  | 1.100 | 0.734 | 33.074 | 0.116 | 0.053 | 119.413 | 8.645 | 6.361 | 44.122 |
| 50  | 0.993 | 0.708 | 5.980 | 0.044 | 0.017 | 2.714 | 10.426 | 7.472 | 193.144 |
| 60  | 1.337 | 0.883 | 8.191 | 0.136 | 0.038 | 0.957 | 9.130 | 6.444 | 985.731 |
| 70  | 0.948 | 0.660 | 90.595 | 0.033 | 0.016 | 15.063 | 5.341 | 4.122 | 6.365 |

**Table S16:** 2020 Cadillac CT5: Prediction of EOP—NARX Model Performance. [Kolachalama et al., 2021]

|  |  |
| --- | --- |
| **EAT** $\geq $ **65 ℉** | **Data Set 1: NARX—Deep Learning Model Validation**  |
| **EST** | **ACRFP** |
| ACCSSP (MPH) | CAT (℉) | EAT (℉) | RMSE | FOD | SNR | RMSE | FOD | SNR |
| 35  | 67 | 83.30 | 2.206 | 1.587 | 5.107 | 14.002 | 10.561 | 16.135 |
| 45  | 65 | 80.375 | 1.817 | 1.429 | 7.118 | 10.815 | 7.439 | 12.112 |
| 55  | 66 | 70.205 | 1.131 | 0.835 | 11.140 | 4.668 | 2.931 | 4.442 |
| 65  | 68 | 80.942 | 1.082 | 0.7507  | 6.152  | 3.900 | 2.764 | 8.754 |
| 75  | 69 | 84.623 | 1.278 | 0.788 | 37.280 | 8.419 | 5.000 | 2.286  |
| **EAT < 45 ℉** | **Data Set 2: NARX—Deep Learning Model Validation**  |
| **EST** | **ACRFP** |
| ACCSSP (MPH) | CAT (℉) | EAT (℉) | RMSE | FOD | SNR | RMSE | FOD | SNR |
| 35  | 76 | 36.37 | 0.872 | 0.622 | 19.872 | 0.423 | 0.281 | 3.210 |
| 45  | 71 | 39.05 | 0.570 | 0.408 | 26.249 | 0.039 | 0.015 | 2.032 |
| 55  | 85 | 34.7 | 0.194 | 0.131 | 22.742 | 0.034 | 0.017 | 1.277 |
| 65  | 80 |  38.89 | 0.444 | 0.312 | 32.048 | 0.006 | 0.004 | 2.501 |
| 75  | 75 | 37.4 | 0.314 | 0.265 | 3.284 | 0.000 | 0.000 | 1.717  |

**Table S17:** 2020 Cadillac CT5: Prediction of CATOP—NARX Model Performance. [Kolachalama et al., 2021]