Zentrale Stelle
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im Sicherheitsbereich

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Driver identification using electronic vehicle data in the forensic context of a hit and run accident

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Aims

1) Develop a workflow for driver identification in digital forensics

2) Apply a simple but sound method for model validation with time series data and

3) Transfer the model results as answers to the forensic questions

   a) to which suspect does the evidence most likely belong to and

   b) how certain is the evidence claim.

What was done?

- Use freely available data to classify drivers by their natural driving behavior
- Apply ML methods to identify the driver in a forensic scenario of a hit and run accident with three known suspects
- Suggestions for an understandable and useful reporting of model results in the light of the needs in forensics

Hit and run accident with 3 known drivers

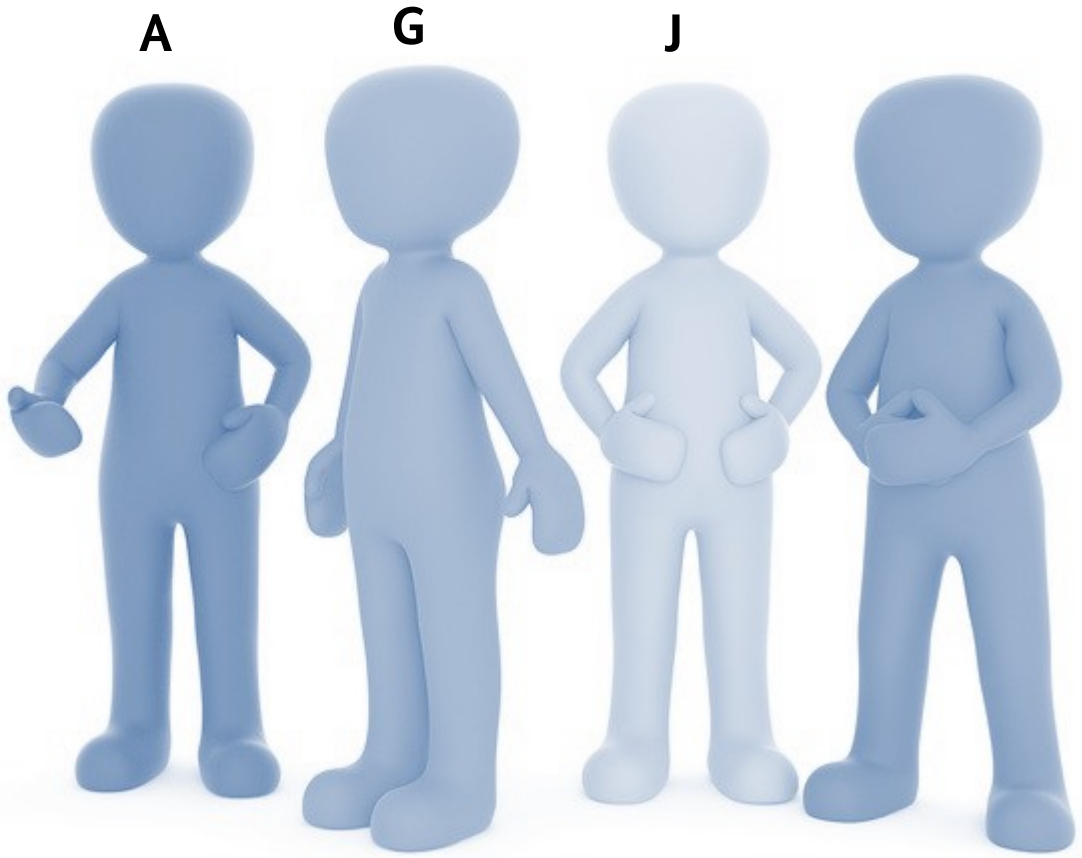

Bild von Peggy und Marco Lachmann-Anke auf Pixabay

Forensic workflow

- Extract the data (e.g. CAN-Bus data)
- Ask suspects for driving sample in the same vehicle
- Calculate the model
- Apply the model on the evidence data

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ML workflow

1) Data: CAN-Bus data
   - 10 individuals in the same vehicle
   - Defined pathway including various street types (parking, highway, city traffic)
   - Variables: driving wheel position, gas pedal position, vehicle speed…
   - Time interval: 1 s
2) Random Forest („supervised classification“) for all combinations of 3 drivers
3) Evaluation: Accuracy, FDR, RMP for training data, random test data and random block test data
4) Predictions: probabilities, RMP for the time the accident happened, time series

Kwak, Woo, Kim 2017: Know Your Master: Driver Profiling-based Anti-theft Method, arXiv:1704.05223

http://ocslab.hksecurity.net/Datasets/driving-dataset

CAN-Bus data

```
## 'data.frame':    94380 obs. of  54 variables:
##  $ Fuel_consumption                     : num  269 243 218 205 218 ...
##  $ Accelerator_Pedal_value              : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Throttle_position_signal             : num  5.2 6.1 5.2 4.7 5.7 5.7 5.7 6.6 7.1 7.1 ...
##  $ Short_Term_Fuel_Trim_Bank1           : num  0 0 0 0 0 0 0 0 0 0.8 ...
##  $ Intake_air_pressure                  : int  33 40 41 38 40 41 42 52 60 65 ...
##  $ Filtered_Accelerator_Pedal_value     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Absolute_throttle_position           : num  13.3 13.7 13.7 13.3 13.7 13.7 13.7 14.5
14.5 14.9
##  $ Engine_soacking_time                 : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ Inhibition_of_engine_fuel_cut_off    : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Engine_in_fuel_cut_off               : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Fuel_Pressure                        : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Long_Term_Fuel_Trim_Bank1            : num  -0.8 -0.8 -0.8 -0.8 -0.8 -0.8 -0.8 -0.8 -
0.8 -
##  $ Engine_speed                         : int  929 726 685 675 716 740 682 670 655 648 ...
##  $ Engine_torque_after_correction       : num  5.5 7 7 7 8.2 9 11.7 16.8 21.5 23.8 ...
##  $ Torque_of_friction                   : num  9 7.8 7.4 6.6 11.3 16 16.4 18 18.8 19.5 ...
##  $ Flywheel_torque_.after_torque_interventions.: num  -5.9 1.7 -3 -1.3 -15.6 -16.9 -10.8
1.3
##  $ Current_spark_timing                 : num  -8.6 -11.3 -12.8 -9.8 -7.9 -7.5 -1.9 -1.1 -0.4 -
1.1 ...
##  $ Engine_coolant_temperature           : int  95 95 95 95 95 95 94 94 94 94 ...
##  $ Engine_Idel_Target_Speed             : int  650 670 670 670 670 670 670 670 670
670 ...
##  $ Engine_torque                        : num  5.5 7 7 7 8.2 9 11.7 16.8 21.5 23.8 ...
##  $ Calculated_LOAD_value                : num  23.9 30.6 31.8 29 30.2 31.4 31.8 41.2 49
54.1 ...
##  $ Minimum_indicated_engine_torque      : num  2 2 2 2 2 2 2 2 2 2 ...
##  $ Maximum_indicated_engine_torque      : num  58.2 53.9 53.1 53.1 53.5 53.9 53.1
53.1
##  $ Flywheel_torque                      : num  -5.9 1.8 -2.8 -1.2 -15.9 -17 -10.5 1.9 9.1 12.1
##  $ Requested_spark_retard_angle_from_TCU: int  15 15 15 15 15 15 15 15 15 15 ...
##  $ TCU_requests_engine_torque_limit_.ETL.: int  508 508 508 508 508 508 508 508
508 508
##  $ TCU_requested_engine_RPM_increase    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Target_engine_speed_used_in_lock.up_module : int  3040 3040 3040 3040 3040 3040
3040
##  $ Glow_plug_control_request            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Activation_of_Air_compressor         : int  0 0 0 0 1 1 1 1 1 1 ...
##  $ Torque_converter_speed               : num  939 710 663 652 692 ...
##  $ Current_Gear                         : int  0 0 0 0 0 0 14 14 14 14 ...
##  $ Engine_coolant_temperature.1         : int  87 87 87 87 87 87 87 87 87 87 ...
##  $ Wheel_velocity_front_left.hand       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Wheel_velocity_rear_right.hand       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Wheel_velocity_front_right.hand      : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Wheel_velocity_rear_left.hand        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Torque_converter_turbine_speed_._Unfiltered : num  936 710 664 653 694 ...
##  $ Clutch_operation_acknowledge         : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Converter_clutch                     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Gear_Selection                       : int  0 0 0 0 0 0 7 7 7 7 ...
##  $ Vehicle_speed                        : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Acceleration_speed_._Longitudinal    : num  -8.5 0.1 0.1 0.1 0.1 0 0 0 0 -0.1 ...
##  $ Indication_of_brake_switch_ON.OFF    : int  1 1 1 1 1 2 2 2 2 2 ...
##  $ Master_cylinder_pressure             : num  325.5 0.9 0.9 0.9 0.9 ...
##  $ Calculated_road_gradient             : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Acceleration_speed_._Lateral         : num  -8.8 -0.2 -0.2 -0.2 -0.2 -0.2 -0.2 -0.2 -0.2 -
0.2
##  $ Steering_wheel_speed                 : int  0 0 0 0 0 0 0 0 8 0 ...
##  $ Steering_wheel_angle                 : num  -3.4 -3.6 -3.6 -3.6 -3.5 -3.4 -3.6 -1.6 7.9
7.7 ...
##  $ Time.s.                              : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ Class                                : Factor w/ 10 levels "A","B","C","D",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ PathOrder                            : int  1 1 1 1 1 1 1 1 1 1 ...
```

Kwak, Woo, Kim 2017: Know Your Master: Driver Profiling-based Anti-theft Method, arXiv:1704.05223

http://ocslab.hksecurity.net/Datasets/driving-dataset

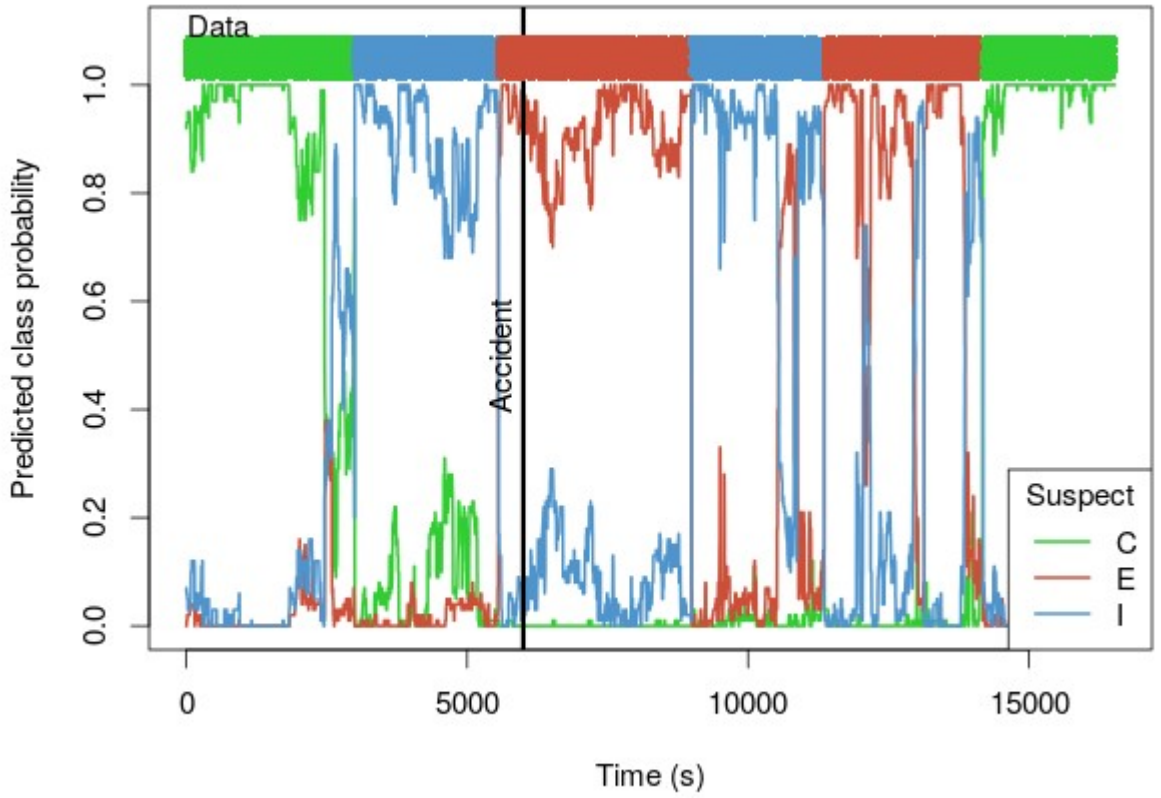
Selected features

Feature	Importance
Accelerator_Pedal_value_IRI	0.155
Vehicle_speed_IRI	0.152
Steering_wheel_speed_IRI	0.148
Vehicle_speed	0.112
Accelerator_Pedal_value	0.106
Master_cylinder_pressure	0.095
Fuel_consumption	0.073
Acceleration_speed_._Longitudinal	0.053
Steering_wheel_angle	0.049
Acceleration_speed_._Lateral	0.041
Steering_wheel_speed	0.017

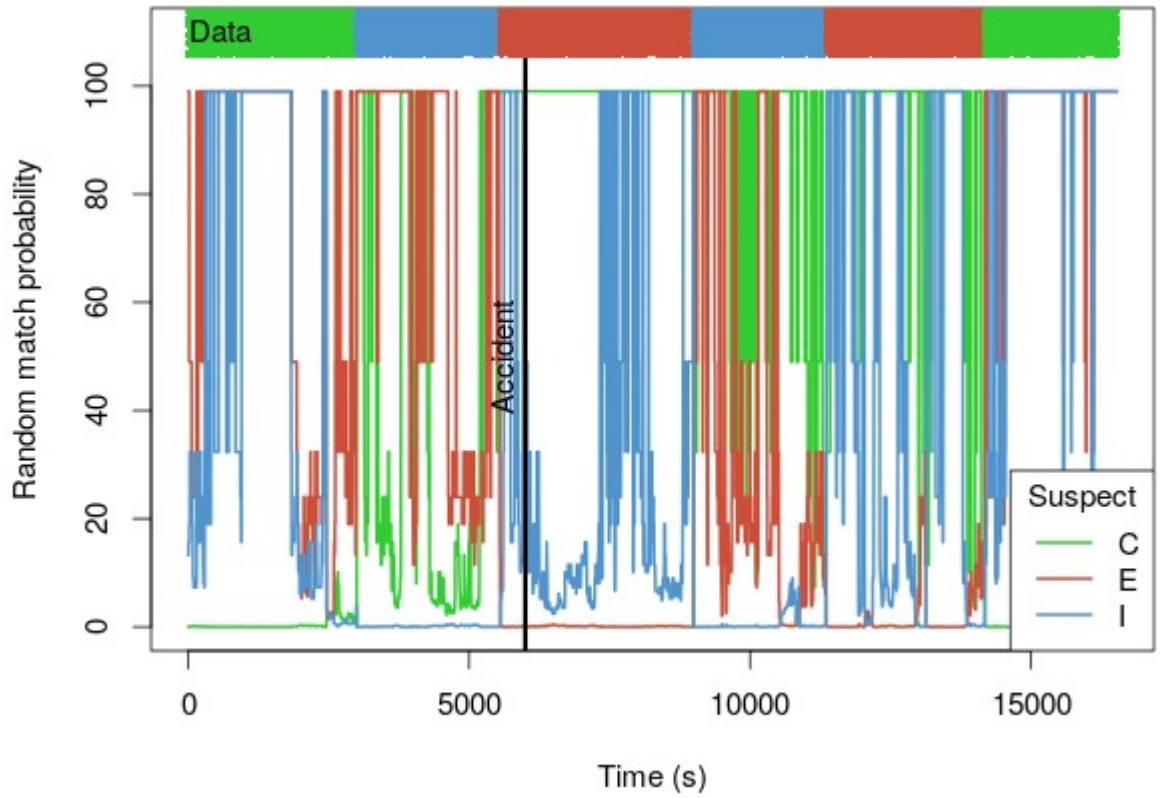
Model validation

dt for rolling mean (in s)	Accuracy train	Accuracy random split	**Accuracy random blocks**	FDR train	FDR random split	**FDR random blocks**
1	1	0.99	**0.78**	0	0.22	**0.01**
2	1	0.98	**0.8**	0	0.2	**0.02**
3	1	0.98	**0.785**	0	0.215	**0.02**
4	1	0.98	**0.785**	0	0.215	**0.02**
5	0.995	0.97	**0.8**	0.005	0.2	**0.03**
8	0.93	0.88	**0.78**	0.07	0.22	**0.12**
10	0.99	0.96	**0.8**	0.01	0.2	**0.04**
30	0.96	0.92	**0.8**	0.04	0.2	**0.08**

Prediction on evidence data



Prediction on evidence data



Highlights

- Drivers could be identified with high reliability using a combination of figures for **predicted class probabilities** together with the **random match probability (RMP)** across the time series

- For classification models used in the forensic context instead of model accuracy the **false detection rate (FDR)** pointing to the false conviction rate (= % of innocent persons being convicted for a crime) need to be used

- Validation considering the temporal auto-correlation in the time series data needs to be done especially when the model quality measures are used to decide on the future life of real persons. We suggest **random block splitting** as an easy to use method.

Please do not hesitate to contact me for any questions: **klara.dolos@zitis.bund.de**