25TH ITS WORLD CONGRESS
COPENHAGEN
17 – 21 SEPTEMBER 2018
Quality of life

PASSENGER TRANSPORTATION ANALYSIS USING SMARTPHONE SENSORS AND DIGITAL SURVEYS

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PUBLIC TRANSPORTATION IS CHANGING

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- Usage of electric vehicles is increasing rapidly – also in public transportation
- It is important to be able to recognize used vehicle and measure qualities of the ride automatically in Mobility as a Service (MaaS)
  - Measurement of travel conditions and passenger satisfaction
  - For automatic billing
- We study this from measurement point of view
- The work is a part of Living Lab Bus (LLB) project

LIVING LAB BUS

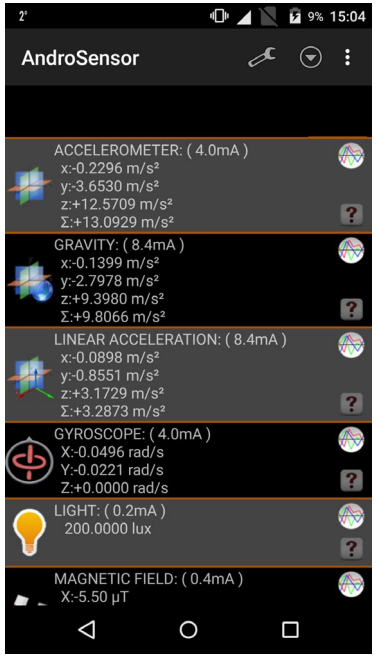
INITIAL GOALS

- To recognize whether the user onboard/offboard
- To recognize whether the user is in electric/diesel bus
- To automatically estimate the passenger satisfaction

DATA COLLECTION

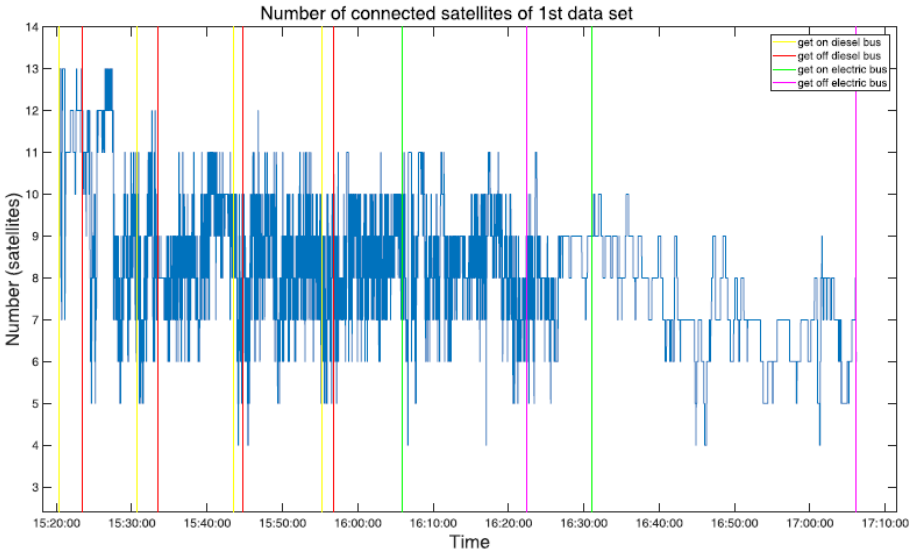
- The measurements were made using Android-based smartphone using AndroSensor-application in both – diesel and electric – buses
  - 2Hz sampling frequency was used
- Digital passenger survey was performed simultaneously with smartphone measurements

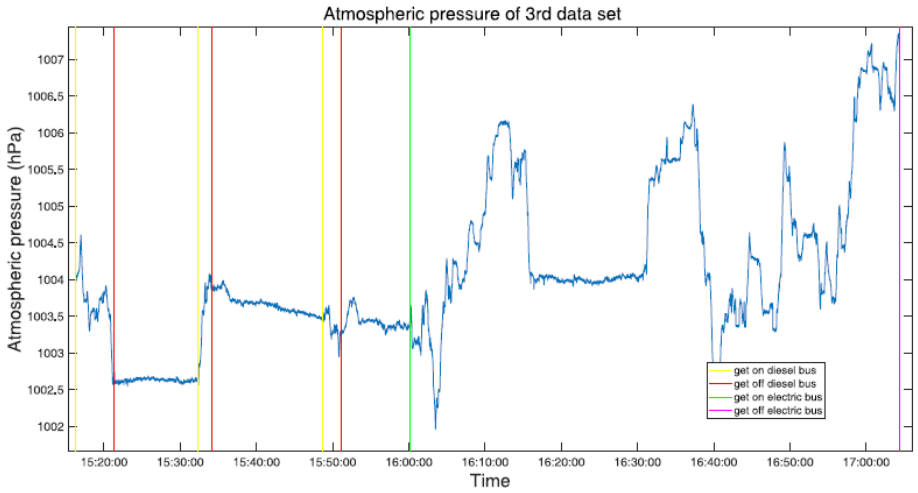
Sensor	Dimensions	Unit
Accelerometer	3	m/s^2
Gyroscope	3	rad/s
Light	1	lux
Magnetometer	3	µT
Barometer	1	hPa
Sound	1	dB
GNSS Latitude	1	deg
GNSS Longitude	1	deg
GNSS Altitude	1	m
GNSS Speed	1	km/h
GNSS Accuracy	1	m
GNSS Orientation	1	deg
GNSS Satellites (connected/visible)	1	number



DATA PROCESSING

- Machine learning (ML) algorithms in Matlab ML Toolbox were used for classification of sensor data
  - Essential features were used for context recognition
- Also weather data from Finnish Meteorological Institute (FMI) and Foreca were utilized
- Results from survey were joined with the results from sensor measurements





DATA SETS

- 4 data sets used for testing:
  - 1: May 9th 2017, 15:00 to 17:00
    4 diesel and 2 electric buses
  - 2: May 9th 2017, 18:15 to 20:45
    3 diesel and 3 electric buses
  - 3: May 10th 2017, 15:00 to 17:00
    3 diesel and 1 electric buses
  - 4: May 10th 2017, 18:15 to 20:45
    6 diesel and 1 electric buses

RESULTS: ONBOARD/OFFBOARD

- 50% of 3rd data set used as a training data
- Different sets of features tested

- Classifiers:
  - TEA: Tree Ensemble AdaBoost
  - KNN: K-Nearest Neighbors
  - NB: Naive Bayes

Training data	Test data	Type of Classifier	Accuracy of feature sets [%]					
			1st	2nd	3rd	4th	5th	Average
50% of 3rd data set	1st data set	TEA	92.71	95.45	91.33	92.46	95.94	93.58
		KNN	90.48	90.69	66.64	75.12	95.5	83.69
		NB	74.52	73.27	73.11	73.32	97.05	78.25
	2nd data set	TEA	78.14	80.12	80.02	79.23	75.27	78.56
		KNN	88.18	88.15	73.33	76.61	75.69	80.39
		NB	84.71	84.24	84	83.86	77.21	82.8
	50% left of 3rd data set	TEA	97.24	97.59	97.7	96.79	96	97.06
		KNN	99.18	99.25	99.46	99.61	98.24	99.15
		NB	94	93.94	94.97	94.23	96.3	94.69
		Average	88.8	89.19	84.51	85.69	89.69	

RESULTS: DIESEL/ELECTRIC

- 50% of 1st data set used as a training data
- Different sets of features tested

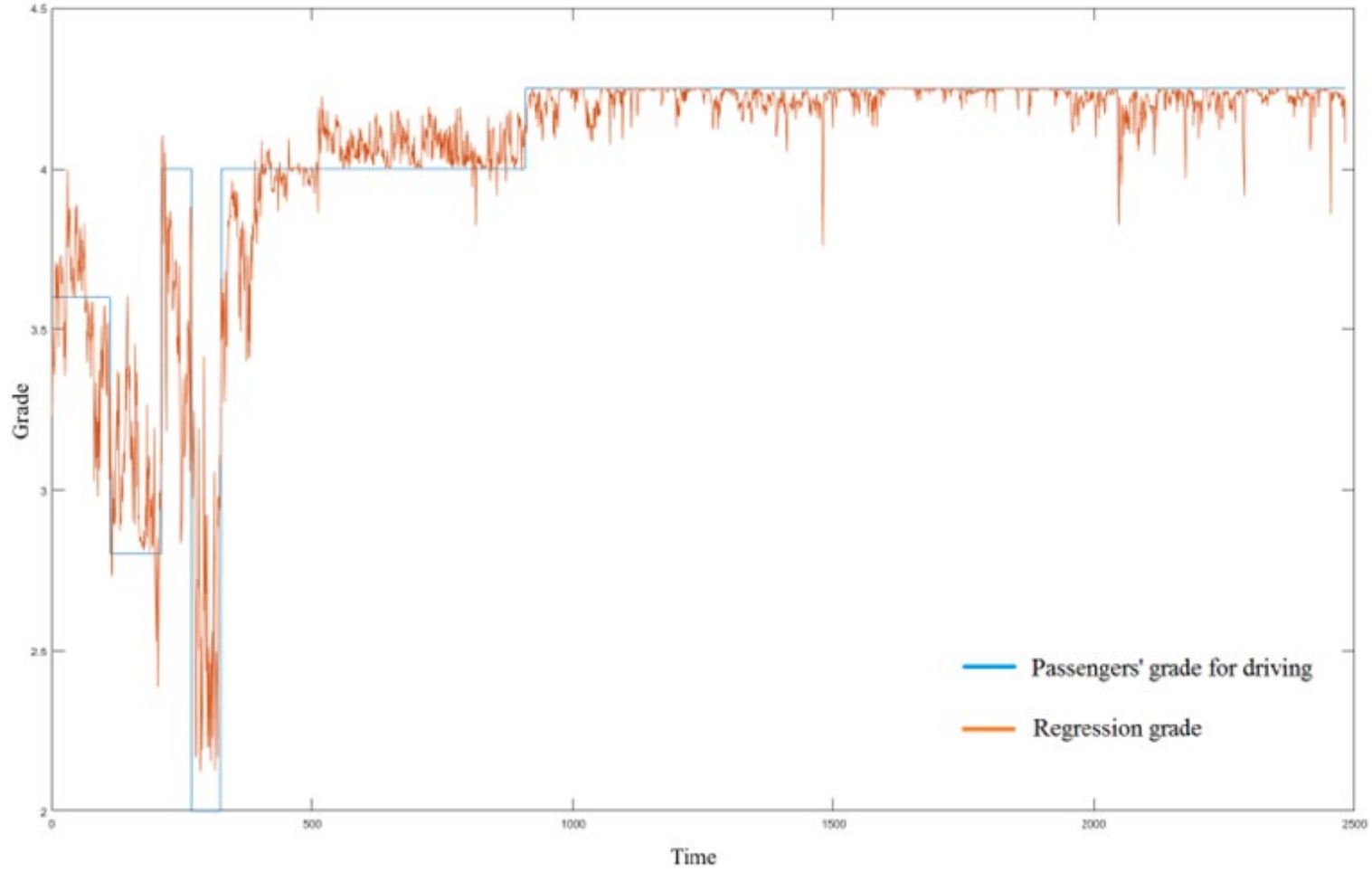
- Classifiers:
  - TEG: Tree Ensemble GentleBoost
  - KNN: K-Nearest Neighbors
  - DA: Discriminant Analysis

Training data	Test data	Type of Classifier	Accuracy of feature sets [%]						
			1st	2nd	3rd	4th	5th	6th	Average
50% of 1st data set	50% left of 1st data set	TEG	100	99.98	99.93	97.33	96.03	98.5	98.63
		KNN	99.87	99.54	99.64	99.52	94.78	98.52	98.65
		DA	97.3	93.47	94.89	94.65	89.59	92.93	93.81
	2nd data set	TEG	76.9	82.31	83.08	79.46	87.04	87.01	82.63
		KNN	77.47	78.49	78.35	78.44	81.69	89.2	80.60
		DA	73.8	85.77	83.99	78.69	88.87	88.17	83.22
	3rd data set	TEG	86.36	85.86	88.66	88.45	87.78	88.8	87.65
		KNN	81.3	81.55	80.68	81.47	79.89	87.25	82.02
		DA	89.37	95.3	93.8	91.43	88.82	94.86	92.26
	4th data set	TEG	61.51	63.81	70.84	62.24	78.3	78.22	69.15
		KNN	64.97	61.48	61.53	61.22	73.76	84.89	67.98
		DA	71.04	73.64	66.53	53.85	88.33	87.44	73.47
	Average		81.66	83.43	83.49	80.56	86.24	89.65	

RESULTS: PASSENGER SATISFACTION

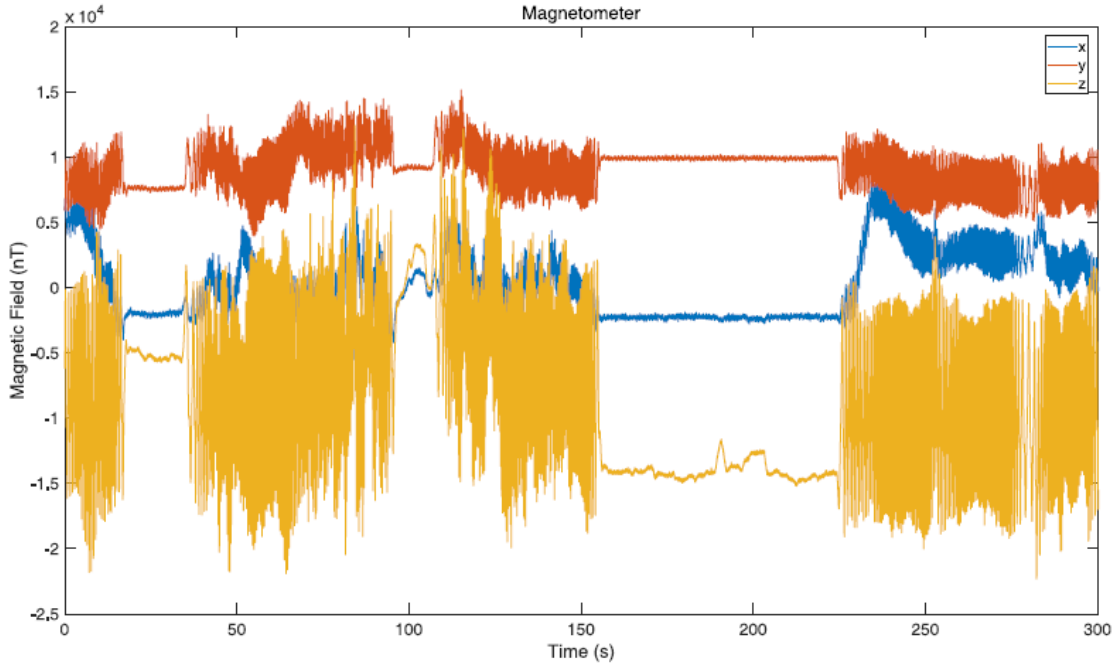
- The passengers evaluated their satisfaction for the bus ride on scale 1 to 5, i.e., very uneven - very smooth driving
- The average grade was 3.80 for all passengers, 3.77 for passengers traveling in diesel buses and 3.85 for electric buses
- The focus was on analysing the dependence between the satisfaction for the bus ride and the sensor measurements

RESULTS: PASSENGER SATISFACTION



CONCLUSIONS

- Due to slow sampling frequency (2Hz), important properties of the ride were not visible in the sensor data
- However, the context was recognized relatively well
  - Gives good basis for deeper analysation of the ride properties
- There are still features that needs further research



FUTURE WORK

- Measurements using higher sampling frequency (100Hz)
- Utilizing carrier to noise values of GNSS
  - Have showed promising results in our earlier studies
- Utilizing sensors integrated to buses
- Research on suitable ML methods to this research field

LIVING LAB BUS

SIGN UP FOR A DEMO!

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VTT

FORECA

eee DRIVE SMARTER

Linkker Intelligent eMobility

VAISALA

Passenger Engagement Tools

Environment Perception for Automated Driving

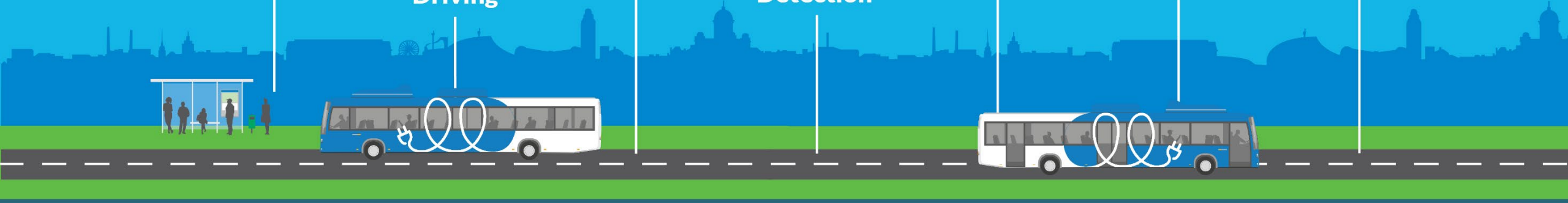
Enhanced Weather Predictions

Road Slipperiness Detection

Driving Optimization
Via CAN bus data

Intelligent eMobility
Emission free buses

Road Data Collection



PASSENGER EXPERIENCE

ENERGY EFFICIENCY

SMART SERVICES