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Proposal of Remote Anomaly Detection Method for Fitting Failure of Retrofitted Devices

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In addition to vehicle sales (product sales), car manufacturers are expanding their business area to mobility services (service sales), where vehicle data and other information are analyzed to provide various services. The development of automobile-based services requires collecting information about vehicle's condition and user operation history etc. via communication devices. Collecting information remotely by this way is under active research and development.

To develope a proper service, it is essential that the information collecting devices function properly and data can be collected without omission. So, it is important to correctly get the operational status of the vehicle. However, when vehicle information is collected remotely, it is more difficult to detect anomalies in data collection than on-site operations. For example, when a sensor is retrofitted to an existing vehicle system to collect information and provide services, the connector of the sensor to the vehicle system may become disconnected or have fitting failure. When data cannot be partially collected from a vehicle due to fitting failure, it is difficult to determine whether the fitting status is normal or abnormal with the collected data, because some data can be collected. One possible way to solve this problem is to remotely collect logs from the vehicle system. However, in the case of fitting failure, it is difficult to constantly monitor anomalies because data can sometimes be collected.

In this paper, we propose a method to detect anomalies when data collection is not possible due to fitting failures and report a case study of actual anomaly detection in a demonstration experiment of data collection via retrofitted communication device. The proposed method is to acquire data from multiple systems in a vehicle using a gateway. This method is based on a comparison between the vehicle uptime rate and the actual data collection at each hour. If a certain amount of data is not collected in relation to estimated vehicle uptime rate, a flag is set to indicate that an abnormality may have occurred, and if the observation flag continues for a certain period of time, the system determines that an abnormality has occurred. More specifically, if the start time of judgment is Ts, the time of judgment is t, the estimated vehicle uptime rate is Pt, the collection results are Rt, the threshold is Th, and the number of consecutive judgment times is N, then the proposed method judges an abnormality when $Ts<=t<=Ts+N$ and $Rt\text{-}Pt < Th$ for t are both satisfied.

In the demonstration experiment, approximately 60 vehicles were operated and data was collected. The proposed method was applied for one week, with the start time of vehicle operation set to a.m.0, the threshold set to -10% and the number of consecutive judgment times to determine an abnormality to be 2 hours. The information in Table 1 shows data collection results and abnormality detection results for fitting failure. We have three data sources and the rows 1 to 3 show number of times data is sent to cloud system. Signal data should sent 720 times per hour, and each camera image data should sent 60 times per hour. Rows 4 to 6 are indicated rate of each data sent per hour. Then maximum rate is defiend as vehicle uptime. Rows 8 to 10 show difference between the percentage of data collection result of each data soruces and "Estimated vehicle uptime rate ". Finally, rest of rows ,"Decision flag for signal data", "Decision flag for front camera" , and "Decision flag for inside camera" are set to NG during the time period when observation flag is set for continuously two hours. It can be seen that the uploading of the data for the inside camera of the vehicle has been stopped since midnight, and that the number of uploads for the front camera has been unstable since 7:00 a.m..

Based on the detection results, we checked the wiring conditions of the USB cables connected to each camera is loose, so we plugged them again at 11:00 a.m. The problem was resolved and data was sent normally from 12:00 p.m.. The proposed method was confirmed to be useful in identifying and dealing with communication devices that may have fitting failure from among multiple target devices.

Table1 Data collection results and abnormality detection results for fitting failure

Item	0a.m.	1a.m.	2a.m.	3a.m.	4a.m.	5a.m.	6a.m.	7a.m.	8a.m.	9a.m.	10a.m.	11a.m.	12p.m.	1p.m.	2p.m.	3p.m.	4p.m.	5p.m.	6p.m.	7p.m.	8p.m.	9p.m.	10p.m.	11p.m.
Num. of times signal data is sent	716	717	364	716	325	602	528	540	497	456	125	0	240	249	644	650	719	597	656	571	508	710	712	714
Num. of times the data from the front camera is sent	60	60	28	60	22	51	40	0	34	0	9	0	18	22	53	54	60	49	54	47	44	60	60	60
Num. of times the data from the inside camera is sent	0	0	0	0	0	0	0	0	0	0	0	0	15	22	52	52	60	49	52	46	44	60	60	60
Transmission rate of signal data (%)	99.4	99.6	50.6	99.4	45.1	83.6	73.3	75	69	63.3	17.4	0	33.3	34.6	89.4	90.3	99.9	82.9	91.1	79.3	70.6	98.6	98.9	99.2
Transmission rate of front camera data (%)	100	100	46.7	100	36.7	85	66.7	0	56.7	0	15	0	30	36.7	88.3	90	100	81.7	90	78.3	73.3	100	100	100
Transmission rate of inside camera data (%)	0	0	0	0	0	0	0	0	0	0	0	0	25	36.7	86.7	86.7	100	81.7	86.7	76.7	73.3	100	100	100
Estimated vehicle uptime rate (%)	100	100	50.6	100	45.1	85	73.3	75	69	63.3	17.4	0	33.3	36.7	89.4	90.3	100	82.9	91.1	79.3	73.3	100	100	100
Difference between the transmission rate of signal data and estimated rate of operating time (%)	-0.6	-0.4	0	-0.6	0	-1.4	0	0	0	0	0	0	0	-2.1	0	0	-0.1	0	0	0	-2.8	-1.4	-1.1	-0.8
Difference between the transmission rate of front camera data and estimated rate of operating time (%)	0	0	-3.9	0	-8.5	0	-6.7	-75	-12.4	-63.3	-2.4	0	-3.3	0	-1.1	-0.3	0	-1.3	-1.1	-1	0	0	0	0
Difference between the transmission rate of inside camera data and estimated rate of operating time (%)	-100	-100	-50.6	-100	-45.1	-85	-73.3	-75	-69	-63.3	-17.4	0	-8.3	0	-2.8	-3.6	0	-1.3	-4.4	-2.6	0	0	0	0
Decision flag for signal data	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Decision flag for front camera	OK	OK	OK	OK	OK	OK	OK	OK	NG	NG	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Decision flag for inside camera	OK	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK