Study of Highway Surface Monitoring Using Acceleration Sensor

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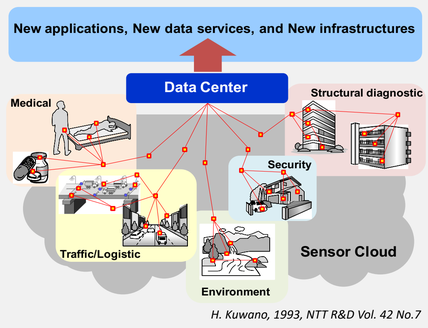
An alternative solution for a daily road inspection that doesn't require any special hardware or skills for data analysis.

1. Background and Motivation

- Integrating multiple sensors in different fields, connecting the sensing systems and collecting the data to create smart applications for remotely monitoring objects and processes.

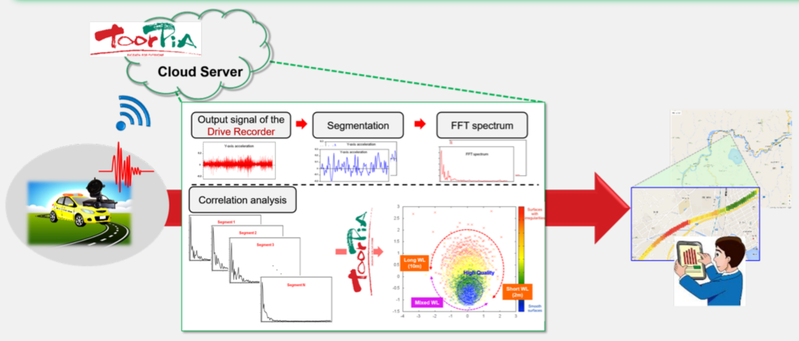
➡ IoT

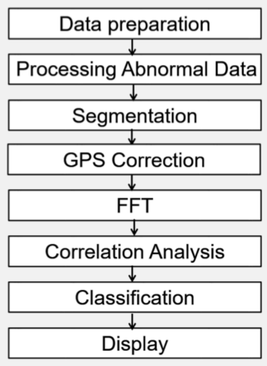


H. Kuwano, 1993, NTT R&D Vol. 42 No.7

- Traffic/Logistic field: Road Damage Diagnosis system
  - ✓ Lower cost
  - ✓ Less time consumption: daily inspection

2. Concept and Program Flow

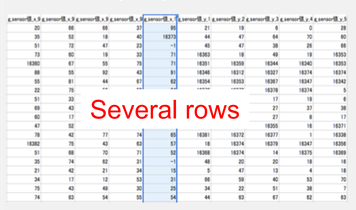




3. Study case: National Route 252

1. Generation of Road Reference Points (RRP) and Lane Reference Points (LRP)

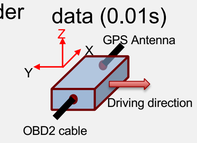
2. Data preparation: download the collected data from the server



Many attributes

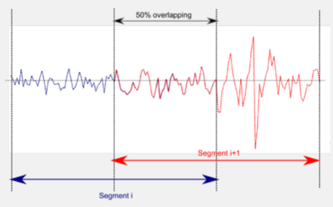
① GPS time
② Latitude
③ Longitude
④ Speed
⑤ Absolute throttle
⑥ GPRS signal strength
⑦ GPRS condition

1 row = 1 single transmission packet = 1s of data of a Drive Recorder = 100 X/Y/Z G-Sensor data (0.01s)



3. Processing Abnormal Data
   - ➢ Abnormal G-sensor value
   - ➢ Missing data packets due to severe geographical conditions or tunnels
4. Segmentation
   - ➢ Reducing the sampling rate to 20Hz
   - ➢ Dividing

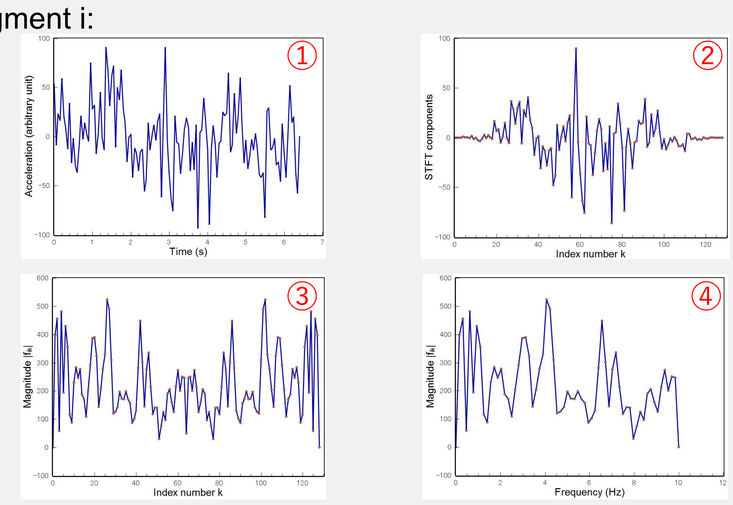
1 segment = 128 Z-axis acceleration measurements = 6.4s



5. Correction of the GPS data.
   - ➢ Assigning the RRP Index:
     1) GPS data is available
        - Accurate GPS data
        - Less than 10 consecutive data are inaccurate

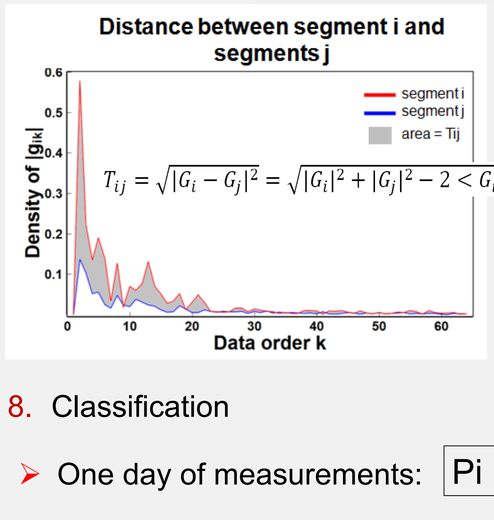
     } Assign the measurements to the closest RRP

     2) Missing GPS data: we calculate the GPS data using the last available GPS coordinates, the speed and the time laps then we assign the measurements to the closest RRP.
   - ➢ Assigning the LRP Index:
     i. We define the driving direction based on the order of the RRP Indexes of the segments.
     ii. We divide the segments into two lanes.
     iii. We assign to each segment the appropriate LRP.
6. Fast Fourier Transform (FFT)
   For each segment i:



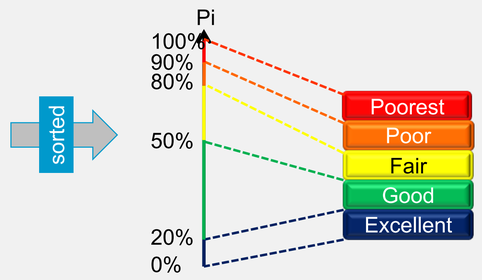
7. Correlation analysis

T_{ij} : Distance between segment i and segment j



- ➢ T_{ij} is small: segment i and segment j have similar surface profile and same quality
- ➢ T_{ij} is large: segment i and segment j have different surface profile and different quality

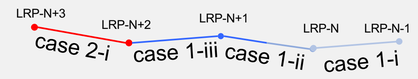
8. Classification
   - ➢ One day of measurements: $Pi = \Sigma_j |gij|^2$
   - ➢ Over a specific period of measurements: $Pi_{ave} = \Sigma_j |\, gij_{ave}\,|^2$



9. Display
   - Damage level of an LRP is shown as a colored line section along the lane.

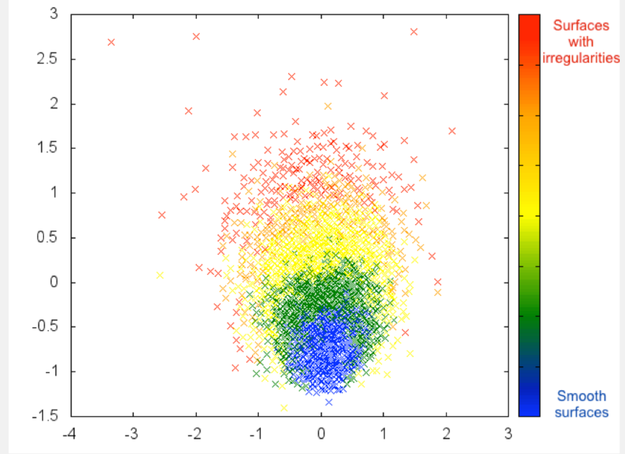
   1) If an LRP N has a damage level of color C_N
      i. If LRP N+1 has the same damage level of color C_N
      ii. If LRP N+1 has a damage level of color C_{N+1}
      iii. If LRP N+1 does not have a damage level

   1) If an LRP N does not have a damage level
      i. If LRP N+1 has a damage level of color C_{N+1}
      ii. If LRP N+1 does not have a damage level: No displaying

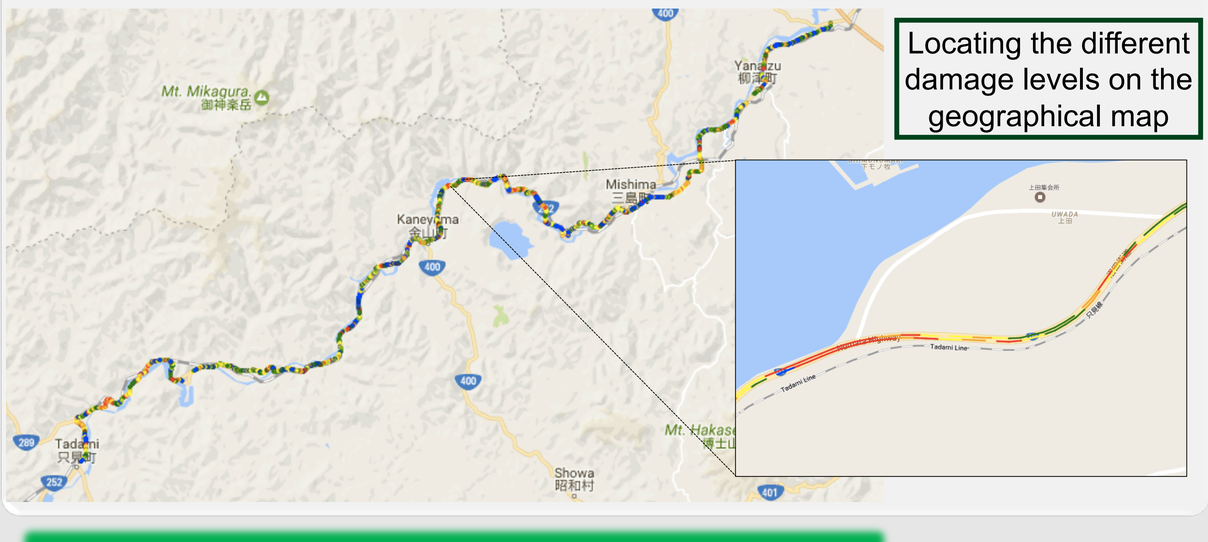


4. Results and discussion

Distinguished damage levels on the toorPIA map

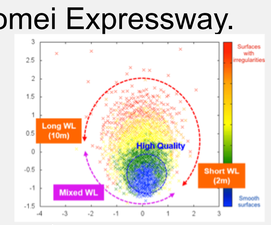


Locating the different damage levels on the geographical map



5. Conclusions

- The obtained results have been proved valid and matched with the real condition of analyzed road which has led to the decision of Fukushima Local Government for jointly a prototype system.
- The solution has been tested on different other roads such as Tomei Expressway.
- An algorithm is to be developed for the automatic classification of the damage modes:



- An algorithm is to be developed for the evaluation of the damage rate over an analysis period.
- The concept of the proposed solution decreases the cost of the Road Damage Diagnosis to the fourth per year and provides a daily inspection without any data specialists.
- The same concept, with different sensing data, can create new solutions for several applications such as driving conditions, structure diagnosis, health monitoring, information security.

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