Systematic Loop Fault Detection and Data Correction for Traffic Monitoring

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Outline

• Systematic Loop Fault Detection
• Macroscopic (PeMS/MTC) Faulty Data Analysis, Correction/Imputation:
• Mesoscopic (Corridor/BHL) Faulty Data Analysis, Correction/Imputation
• Microscopic (Control Cabinet Level) Loop Fault Detection
• Developing Reliable Communication System
• Concluding Remarks
Macroscopic (PeMS/MTC) Faulty Data Analysis, Correction/Imputation

- Data Source: aggregated data rely on communication
- Faulty Data Types
  - Communication Down
  - Insufficient Data
  - High/ Intermittent/ Constant
  - Feed Unstable
  - Systematic failures
  - Electrical failures
  - Synchronized failures
- Detection method: (a) statistic, (b) Entropy, (c) threshold checking, and (d) Comparing with neighbors
- Imputation: (a) omitting unreasonable data; (b) interpolation over time and/or space
- Identifying suspicious loops
PeMS
Mesoscopic (Corridor/BHL) Faulty Data Analysis, Correction/Imputation

• Data Source: aggregated data or real-time data rely on comm. syst.
• Faulty Types
  – Communication fault
  – Temporary data missing
  – No data or constant data
  – No data: card/cable broken
  – Improper card sensitivity
  – Identifying suspicious loops
  – Mismatch of ON/OFF time for dual loop stations
• Detection Approach: (a) analyzing sub-second data; (b) threshold check; (c) using dual loop station property; (c) vehicle re-identification;
• Data imputation: (a) interpolation over time/space, (c) vehicle re-identification;
The Berkeley Highway Laboratory

San Francisco Bay

Emeryville, CA
Powell St

I-80

Emeryville Tower (camera location)

Ashby Ave

Berkeley, CA

University Ave

Gillman St

-1400' 0' 1300' 2400' 4100' 5900' 7700' 8900' 9200' 10700' 13200'

primary video surveillance region

secondary video surveillance region

1-9: Loop Station ID

= paired loop detector station in each lane
Microscopic (Control Cabinet Level) Loop Fault Detection

• Loop faults looked at this level:
  – Mis-assignment
  – Temporary data missing
  – Crosstalk
  – Chattering, pulse broken
  – Improper card sensitivity
  – No data: broken card/cable; power off
  – mismatch of ON/OFF time instant between upstream and downstream loops for dual loop stations.
Microscopic (Control Cabinet Level) Loop Fault Detection

• Detection Approach:
  – Portable Loop Fault Detection Tool at control cabinet level based on ground-truth from an independent sensor
  – Lower level (sub-second) data analysis

• Data imputation: interpolation over time/space, …

• Data correction/cleansing: Adaptive sensitivity adjustment, …
Developing Reliable Communication System

- Communication Systems Used in Traffic Data Passing: Fiber optics, Cell phone line, Old telephone line, GPRS Modem, CDPD Modem, Other media
- Communication protocol: TCP (acknowledgment of receiving; may resending); UDP (no acknowledgment nor resending)
- Performance requirements for coordinated traffic management and control: Real-time; Accurate measurement; Continuous over time and space; Reliable with less attention and easy maintenance; Cost affordable; Data security in a long run
- Using fiber optics or GPRS modem if possible
- Using TCP with resending capability if possible
- Communication fault detection in all levels from sensor to PeMS/MTC
Developing Reliable Communication System

• Professional staff for regularly checking and reporting sensor and comm.. faults
• Regular and in-time system maintenance
• Future Traffic Management System divided into three levels:
  – TMC or PeMS Level: Central Computer and Database
  – Corridor Level: Hub-computer and Database
  – Freeway/Arterial Section Level: Control cabinet and sensors
• Communication system changing accordingly
  – Short/medium range communication:
    • Sensors, Control Cabinet ➔← Corridor Hub Computer and Database
  – Long Range:
    • Corridor ➔← TMC or PeMS
Portable Loop Fault Detection Tool at the Control Cabinet

- Overall System Structure
- Mobile Pole on Roadside for Video Camera Mounting
- Interface with Control Cabinet
- Synchronization of the Two Computers with Wireless Communication
- Real-Time Multi-lane Vehicle Tracking Algorithm
- Vehicle Tracking Over-Loop
- Comparison for Fault Diagnosis
Portable Loop Fault Detection Tool at the Control Cabinet
Mobile Pole on Roadside for Video Camera Mounting
Mobile Pole for Roadside Video Camera Mounting
Mobile Pole for Roadside Video Camera Mounting
Interface with Control Cabinet

332 Cabinet with 170 or 2070 Traffic Controller

170E or 2770 Controller

Loop Card

Smart Loop Card

R232 interface Controller

Interfacing with Smart Card for lower level signal

Laptop processor

802.11a/b

PTZ Video Camera

Vehicle tracking
Interface with Control Cabinet
Real-Time Multi-lane Vehicle Tracking
Real-Time Multi-lane Vehicle Tracking
Vehicle Tracking Over-Loop
Vehicle Tracking Over-Loop
Comparison for Fault Diagnosis

**Computer 1**

- **Video Processor:** Process the video and write the virtual loop packet to the data buffer

  ![Data Buffer](image1)

- **SndLoop:** Read from the data buffer and send the received virtual loop packet to computer 2 via network

**Computer 2**

- **Wrfile:** Read from data buffer, match the received physical loop package and virtual loop package with timestamp and compare results

  ![Visual display](image2)

- **RcvLoop:** Receive the virtual loop package from the network and write to the Data Buffer

  ![Data Buffer](image3)

- **Loop2DB:** Receive the loop inductance information from the Canoga card and write the physical loop package to the Data Buffer
$v = 5 \text{mph}$
\[
\mathbf{v} = 15\text{mph}
\]
$v = 25\text{mph}$
$v = 45 \text{mph}$
\( v = 50 \text{mph} \)
Reliable Detection

- **Tracking**
  - 10Hz
  - Continuous
  - Advance

- **Loop signal buffering**
  - 13 Hz for 3M Canoga C922 card
  - FIFO 256 slots

- **Selective comparison**
  - Signal with the closest time stamps
Concluding Remarks

- Systematic sensor fault detection is necessary;
- Reliable communication system is essential
- Only fault detection at control cabinet level is direct; all others are indirect
- Future work:
  - Loop fault detection
  - Fault detection
  - Data/fault correction
  - Missing data imputation
  - Adaptive sensitivity adjustment
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