Fuzzy Logic in Traffic Control

State Traffic Department Baden Württemberg
realized by INFORM Software Corporation

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Fuzzy Logic in Components of Traffic Control Systems

- Weather Station
- Visual Range Meter
- Traffic Sign Gantry
- Road Sensor
- Section Station
- Traffic Control Computer
- Supervise Field Equipment
- Analyse Weather Condition
- Intelligent Control
- Incident Detection Traffic Flow Analysis
- Signal Analysis at Induction Sensors
- Traffic Detection

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Vehicle Classification at Traffic Detection Sensors

Required Information: Vehicle Speed and Type

Evaluate Speed: \[ v_{Fahrzeug} = \frac{\text{Sensorabstand}}{t_v} \]
Evaluate Length: \[ L_{Fahrzeug} = \frac{v_{Fahrzeug}}{t_L} \]

to Classify Vehicles in Cars and Trucks
Vehicle Classification at Traffic Detection Sensors

Misleading: Talegating Cars are Detected as Trucks

Solution: Use Car Speed as Additional Criteria

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>Speed (km/h)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>120</td>
<td>Car</td>
</tr>
<tr>
<td>14</td>
<td>100</td>
<td>Truck</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>Truck</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
<td>2 Cars</td>
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Implementation: Defining Borders is not always Plausible

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→ Use of Multiple Criteria results in Black Box System
Vehicle Classification at Traffic Detection Sensors

Fuzzy Logic
Describe Criteria as

**Linguistic Variable**

Example Car Length:
- “typical Car”;
- “Long Truck”;
- “2 Cars”;
- “Short Truck”

Example Car Speed:
- “fast”;
- “regular”;
- “slow”

Describe Experience as

**Fuzzy Rules**

“A detected signal showing a speed of 80 km/h represents usually a truck.”
“A detected signal showing a vehicle length of 10 meter at low speed is assumed to be a truck, at high speed is assumed to be 2 cars.”
Road Map and Traffic Detection

Uses existing Detection Systems

Traffic: $q_{\text{Car}}$, $q_{\text{HGV}}$, $v_{\text{Car}}$, $v_{\text{HGV}}$ (per time for every lane)

Road Map: Distance between adjacent cross sections (= section), location of ascents, descents, entrances, exits

→ Reduces required data volume
Substitute missing Data by Time-Distance Traffic Forecast

- use previous cross section to forecast traffic on main and exit lanes
- use following cross section to forecast traffic on entrance lanes
- use historical data when neighbor cross section not available

Time Distance Forecast

1. Detect arriving vehicles at cross section,
2. Trace vehicles during the sector by using detected vehicle speed,
3. Calculate number of cars, that arrive at subsequent cross section for observed time interval.
Data Consistency

Traffic Detection

Compare Data of Neighbor Sections to Localize Incorrect Equipment

Compare Neighbor Cross Sections to Check Detection

for all Sections

<table>
<thead>
<tr>
<th>Data Consistency</th>
<th></th>
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<tr>
<td>History</td>
<td>Substitute Values</td>
</tr>
<tr>
<td>Road Map</td>
<td>Data Acquisition</td>
</tr>
</tbody>
</table>
Analyze Environmental Data

Plausibility of Environmental Data
- Road Surface and Precipitation
- Precipitation Type
- Road and Freezing Temperature
- Visual Range

Condition
- Road Carpet
- Visual Range

Supervise Data Sequence

Wether Station

Visual Range Meter

Road Sensor

Traffic Control

Data Consistency
- History
- Substitute Values
- Road Map
- Data Acquisition
Data Consistency

Road Condition

Biological Hazard in Precipitation Intensity Sensor

During heavy rainfall, the road surface must be wet.
Comparing road sensor with precipitation intensity sensor detects failure.

→ Automatic detection of road condition
→ Avoid wrong display
→ Initiate maintenance of local equipment

Heavy Rain
No water on Road Surface
Wrong Fog Warning caused by icing Visual Range Meter

Fog occurs slightly, a quick descent of visual range can be compared with other environmental data as air temperature and humidity.

- **Automatical detection of environmental condition**
- **Avoid wrong display**
- **Initiate maintenance of local equipment**

Temperature under Freezing Point

Visual Range goes down **quickly**
Environmental Condition

Indicate **Hail**

Indicate Precipitation Type

- compare environmental data from different sensors
- **Automatical detection of precipitation type**
- **Initiate display of traffic sign**

Air Temp. higher to **20°C**

Heavy Wind

Heavy Precipitation

Temperature on Road Surface **higher** than Air Temperature

Road Surface **wet**

Road Temperature **goed down quickly** under **15 °C**
If vehicle drivers reduce speed, a reason must be assumed.

Vehicles detected at a cross section **must** occur at the following cross section after the time they need to pass the section. Otherwise there is an incident.

- Incidents (e.g. accidents) can be detected when vehicles, that have passed the previous cross section, do not occur at the following.
- Detection by observing the traffic behind the incident.
- Applicable to section with distance >4 km between observation.
Analyze Traffic Situation
Accident on State Highway B27

Accident Report

Accident Time: 19:40 in Police Record, 17.2.96
Location: B27 Direction Stuttgart between Cross Sections 6 and 7 of Control System
Reason: Vehicle driving in wrong Direction
Supervised Sector: 621 m
Low Traffic Volume

Traffic Volume at Cross Section 7
Analyze Traffic Situation
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Location: B27
Direction Stuttgart
between Cross
Sections 6 and 7 of
Control System

Reason: Vehicle
driving in wrong
Direction

Supervised Sector:
621 m

Low Traffic Volume

Traffic Volume at Cross Section 7
Average Speed at Cross Section 6
Analyze Traffic Situation
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Traffic Volume at Cross Section 7
Average Speed at Cross Section 6
Traffic Density between Cross Sections
Analyze Traffic Situation
Accident on State Highway B27

Incident Detection

- Conventional Approach: Congestion Warning requires 18 Minutes

- Average Speed at Cross Section 6
- Traffic Condition of Conventional System
Analyze Traffic Situation
Accident on State Highway B27

Incident Detection requires 3 Minutes

Fuzzy Logic Congestion Warning

Average Speed at Cross Section 6
Traffic Condition computed by Fuzzy Logic
Analyze Traffic Situation
Accident on State Highway B27

Accident Report

Accident 17.2.96, 19:40
Location B 27 Direction Stuttgart in Supervised Area of Control System between Cross Sections 6 and 7
Sector Length: 621 m
Low Traffic Volume

→ Required Time
Fuzzy: 3 Minutes
Conventional: 18 Minutes

→ Fuzzy Logic enables More Reliable and Faster Detection

Traffic Volume at Cross Section 7
Average Speed at Cross Section 6
Conventional computed Traffic Condition
Traffic Condition computed by Fuzzy Logic
Analyze Traffic Situation
Accident on State Highway B27

Large Sector Length
Accident 17.2.96, 19:40
Location: Analyze
Cross Section 5 and 7
Direction Stuttgart
Sector Length: 1640 m
Low Traffic Volume

⇒ Required Time for Detection:
Fuzzy Logic: 3 Minutes
Conventional: No Detection
Usually the traffic flow is regular.

Within regular traffic flow, the results evaluated at local observation points can be used to describe the traffic situation for the complete section.

- Use regular traffic flow to estimate the number of cars that are currently between two crossing sections (real traffic density estimation).
- Use a subsequent calculation of arriving and departing vehicles to estimate the real traffic density in unstable traffic situations.
Map Traffic Condition to
Traffic Sign Gantry
Control by Variable Traffic Signs

Select Traffic Sign for Display at all Traffic Sign Gantry

Fuzzy Logic Control evaluates Traffic, Road, and Visual Range Condition. Existing assignments to the available traffic signs can be used.

Bounds on subsequent displays, (e.g. decreasing speed limits before detected congestion) and individual operator control of existing systems can be used.

- **Fuzzy Traffic Control allows for more flexible and transparent control systems, that decrease maintenance and operational effort**

- **Fuzzy Traffic Control can be used on existing systems**

- **Fuzzy Traffic Control was initiated by a State Traffic Department, responsible to operate and maintain existing traffic control systems.**
Traffic Control by Fuzzy Logic
(using variable traffic signs)
State Traffic Department Baden-Württemberg

- Select Traffic Sign for Display
- Dynamical Mapping of Traffic Situation to Traffic Sign Gantry
  - Incident-detection
  - Traffic Situation
  - Road Condition
  - Fog Condition

- Traffic Analysis
- Environmental Analysis

- Check Data Plausibility
- Historical Data
- Substitute Values (Traffic and Environmental Data)
- Road Map
- Data Acquisition (Traffic and Environmental Data)