Towards an automatic road lane mark extraction based on ISODATA segmentation and shadow detection from large-scaled aerial images

Authored by Hang Jin and Yanming Feng
Presented by Yanming Feng
Email: y.feng@qut.edu.au
Queensland University of Technology

Presentation Overview

1. Introduction
   - Future generation vehicle navigation
   - Why lane marks extractions?
   - Existing data sources for lane feature extractions

2. Proposed approach for lane extractions
   - Road surface detection
   - Road lane marking extraction
   - Testing and evaluation

3. Summary
1. Introduction

- Current generation car navigation
  - Road level navigation and positioning
  - 2D or 2.5D road maps
  - Autonomous navigation with standalone GPS
  - Route guidance and location based services

- Next generation vehicle navigation
  - Lane level navigation and positioning
  - Enhanced 2D to real 3D road maps
  - Cooperative navigation with V2V and V2I communications
  - Lane guidance, road safety, intelligent mobility, energy efficiency

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### Initial Requirements for Selected Features (General Motor studies)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Position Req (m)</th>
<th>Comm Latency (s)</th>
<th>% Market</th>
<th>Max Range (m)</th>
<th>Transmit Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection Collision Warning</td>
<td>0.5 – 1.0</td>
<td>0.1</td>
<td>High</td>
<td>250</td>
<td>Periodic</td>
</tr>
<tr>
<td>Forward Collision Warning</td>
<td>0.5 – 1.0</td>
<td>0.1</td>
<td>High</td>
<td>250</td>
<td>Periodic</td>
</tr>
<tr>
<td>Lane Change Warning</td>
<td>0.5 – 1.0</td>
<td>0.1</td>
<td>High</td>
<td>250</td>
<td>Periodic</td>
</tr>
<tr>
<td>Blind Spot Warning</td>
<td>0.5 – 1.0</td>
<td>0.1</td>
<td>High</td>
<td>250</td>
<td>Periodic</td>
</tr>
<tr>
<td>Emergency Brake Warning</td>
<td>1.0 – 5.0</td>
<td>0.1</td>
<td>Medium</td>
<td>250</td>
<td>Event</td>
</tr>
<tr>
<td>Slow/Stopped Vehicle Advisory</td>
<td>1.0 – 5.0</td>
<td>1.0</td>
<td>Medium</td>
<td>1000</td>
<td>Event</td>
</tr>
<tr>
<td>Road Condition Advisory</td>
<td>1.0 – 5.0</td>
<td>1.0</td>
<td>Medium</td>
<td>1000</td>
<td>Event</td>
</tr>
<tr>
<td>Post Crash Advisory</td>
<td>1.0 – 5.0</td>
<td>1.0</td>
<td>Medium</td>
<td>1000</td>
<td>Event</td>
</tr>
<tr>
<td>Traffic Jam Ahead Advisory</td>
<td>1.0 – 5.0</td>
<td>1.0</td>
<td>Medium</td>
<td>1000</td>
<td>Event</td>
</tr>
<tr>
<td>In-Vehicle Dynamic Signage</td>
<td>&gt; 5.0</td>
<td>5.0</td>
<td>Low</td>
<td>1000</td>
<td>Periodic</td>
</tr>
<tr>
<td>Electronic Toll Payments</td>
<td>&gt; 5.0</td>
<td>10.0</td>
<td>Low</td>
<td>1000</td>
<td>Periodic</td>
</tr>
<tr>
<td>Traveler Information</td>
<td>&gt; 5.0</td>
<td>10.0</td>
<td>Low</td>
<td>1000</td>
<td>Periodic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application Types</th>
<th>Positioning Accuracy</th>
<th>Map Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop Sign Assistant - Warning</td>
<td>~1m</td>
<td>~0.5m</td>
</tr>
<tr>
<td>Curve Speed Assistant - Warning</td>
<td>~1m</td>
<td>~0.5m</td>
</tr>
<tr>
<td>Forward Collision Warning</td>
<td>0.3-1m</td>
<td>0.2-0.5m</td>
</tr>
<tr>
<td>Curve Speed Assistant - Control</td>
<td>0.3-1m</td>
<td>0.2-0.5m</td>
</tr>
<tr>
<td>Lane Departure Warning</td>
<td>&lt;0.3m</td>
<td>&lt;0.2m</td>
</tr>
</tbody>
</table>
Generation of enhanced digital maps

- Mobile Mapping Systems
  - Mature technologies, collect all the road information
  - High resolution, medium to high costs
- Mobile Laser Mapping
  - A novel 3D mapping system to scan roads, buildings and trees from a moving vehicle
- LiDAR image processing
  - High resolution, high costs
  - Automatic lane extraction from aerial images
    - High resolution possible, low to medium costs
    - Suitable for lane extraction over regional and remote areas
2. Proposed method for lane feature extractions

- Image preprocessing
  - Geometrical correction
  - Contrast stretching
- Road surface detection
  - Image segmentation
  - Shadow process
    - Shadow detection
    - Shadow compensation
- Road lane marks detection
- Tests and evaluation
Image preprocessing

- Problems of raw aerial image
  1. Geometric distortions
     - Variations of the sensor platform
     - Relief displacement
  2. Low image quality
     - Contrast deficiency

- Solutions
  1. Image geometric correction
     - Commercial photogrammetry software, e.g. ERDAS, LPS
  2. Image contrast stretching
     - Histogram equalization

Road surface detection (1)

- Road surface detection
  - Aim to successfully detect the road centrelines
  - Need to distinguish road surface from vegetations
  - Select $C_r$ channel in YCrCb color space to distinguish road surface from vegetations
    - Thanks to relative low value of blue component in RGB
  - Use ISODATA method to segment the image
    - To classify road surface from other ground objects
  - Use linear regression to smooth the road sides
Road surface detection (2)

- **Shadow detection**
  - Road surface affected by shadows casted by trees or vehicles on the road
  - Cause information and features loss

- **Spectral ratio technique:**
  - based on \( \frac{Cr+1}{(Y+1)} \) ratio image, shadow regions have relatively large digital numbers (DN)

- **Image segmentation**
  - based on homogeneity histogram, taking into account not only the color information but also the spatial relations
  - Employ Gaussian filter to smooth the histogram
Road surface detection (3)

- Shadow compensation
  - Recover the shadow areas using the mean and standard deviation of both shadow and non-shadow regions

\[ I' = m_c + \frac{I - m_s}{\sigma_s} \sigma_c \]

where \( I \) is the DN before shadow compensation, \( I' \) is the de-shadowed DN, \( m_s \) and \( \sigma_s \) are the mean and standard deviation of the shadow region, \( m_c \) and \( \sigma_c \) are the mean and standard deviation of the non-shadow areas, respectively.
Road lane markings detection (1)

- Road lane marking characteristics:
  - Shape and size are constricted to standards
  - Constitute high contrasted objects (generally asphalt, white lane marking)

Geometric specifications of the pavement markings in a rural arterial road environment (Queensland Department of Main Roads, 2001).
Road lane markings detection (2)

- **Marking extraction process**
  - 1st PCA is selected to reduce calculation
  - Using co-occurrence contrast to enhance the lane markings

\[
 f = \sum_{n=0}^{N} n^2 \left( \sum_{i=1}^{N} \sum_{j=1}^{N} p(i,j) \right)
\]

where \( p(i,j) \) is \( i \)th entry in a normalized gray-tone spatial-dependence matrix, \( N \) is the number of distinct gray levels in the quantized image, and \( |i-j| = n \).

- Image binarized by histogram thresholding
- Thinning and vectorization

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**Experiment: Lane marking detection**

- **upper**: non-shadow region
- **bottom**: shadow region
- **left**: co-occurrence contrast image
- **middle**: extracted road lane marks
- **right**: final road model
Evaluation of Results

Data set:
Aerial image set with spatial resolution of 0.1m, with RGB colour bands, located in Gympie, Queensland

Testing
6 testing areas are selected covering 2 km², and quantitative evaluation is conducted in terms of completeness, correctness, and quality.

The overall completeness rate is 83.7%, correctness is 91.5%, and quality 76.6%

Summary

- High accuracy road maps are important for road safety applications:
  - Moving from road level to lane level navigation
  - Automatic driver assisted systems
  - Tendency to cooperative navigation and positioning
- One of the effective road map generation techniques is to extract the lane level information from the high resolution aerial images
Summary (2)

- The proposed method combined detection of road surface and lane marking
- We presented a shadow detection and compensation method
- Experimental results from a test area in Gympie showing:
  - Completeness: 83.7%
  - Correctness: 91.5%
  - Quality: 76.6%
  - Reasonably effective, but further work required
- Requirements:
  - High spatial resolution is required
  - Distinct contrast between road marking and pavement

Thank you for your attention! Questions?