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

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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

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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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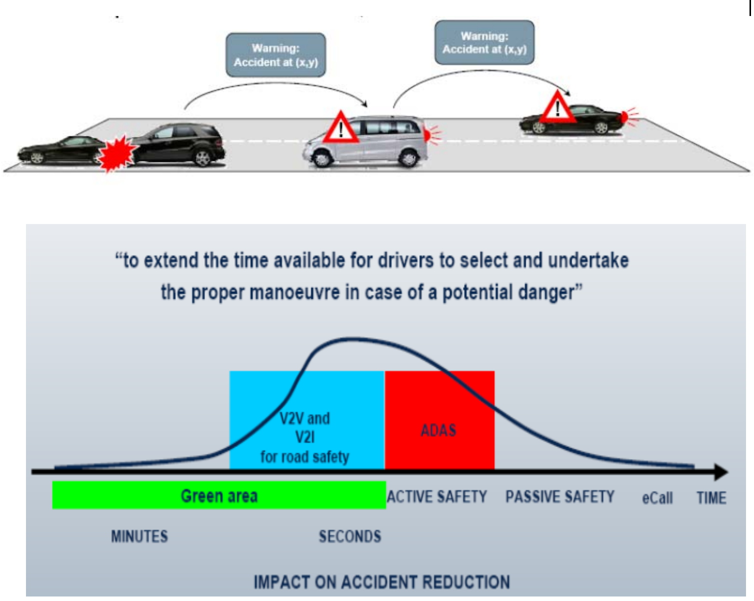
Initial Requirements for Selected Features (General Motor studies)

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

Requirement for positioning and map accuracy (US DoT reported: Enhanced Digital Mapping Project Final Report, 2004)

Application Types	Positioning Accuracy	Map Accuracy
Stop Sign Assistant - Warning	~1m	~0.5m
Curve Speed Assistant - Warning	~1m	~0.5m
Forward Collision Warning	0.3-1m	0.2-0.5m
Curve Speed Assistant- Control	0.3-1m	0.2-0.5m
Lane Departure Warning	<0.3m	<0.2m



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

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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

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Road surface detection (1)

- Road surface detection
  - Aim to successfully detect the road centrelines
  - Need to distinguish road surface from vegetations
  - Select C_b channel in YC_rC_b 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

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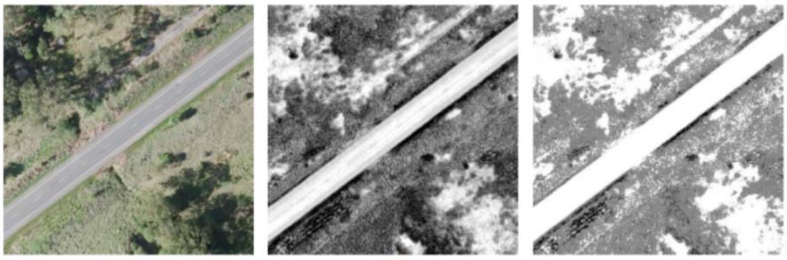

a b c

Figure 1. Image unsupervised segmentation, (a) original aerial image, (b) enhanced the C_b component image, and (c) image segmentation result

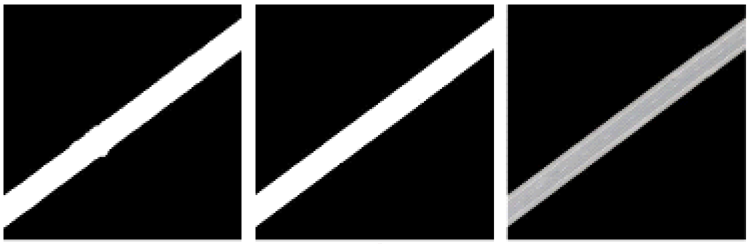

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Figure 2. Road surface extraction, (a) segmented road surface, (b) road side smoothed by the least square line approximation, and (c) is the final extracted road surface

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 *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

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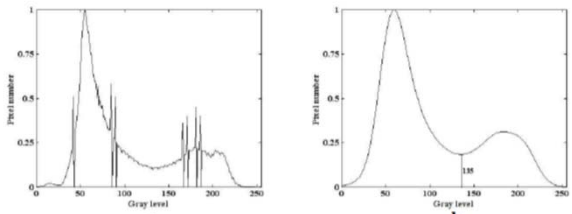
Figure 4. Shadow detection, (a) the original aerial image (512×512 pixels), (b) $(C_r + 1)/(Y + 1)$ ratio image of (a), and (c) extracted shadow regions



a b

Figure 3. Homogram, (a) the original homogram of the ratio image, (b) Gaussian smoothed homogram using Lin's method

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 σ_s are th mean and standard deviation of the shadow region, m_c and σ_c are the mean and standar deviation of the non-shadow areas, respectively.

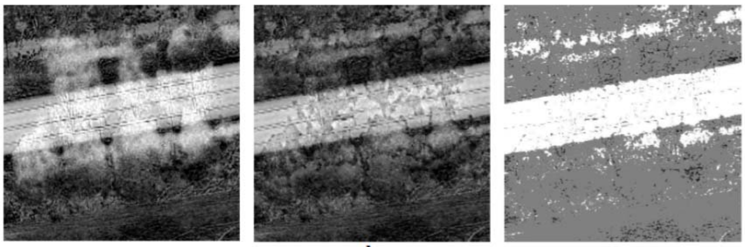
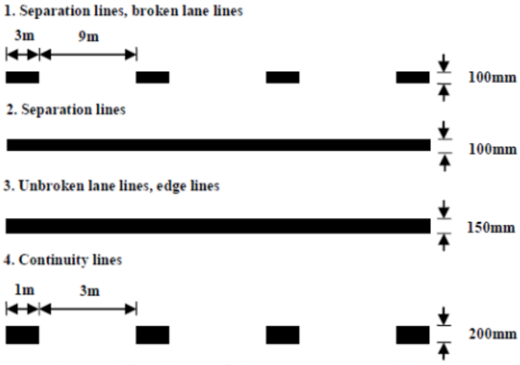


Figure 5. Shadow compensation, (a) contrast stretched C_b component image, (b) shadow recovered C_b component image, and (c) detected road surface from the shadow compensated C_b image

Figure 6. Road surface extraction, (a) classified road surface, (b) road surface smoothed with least square approximation, and (c) final extracted road surface

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).

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Road lane markings detection (2)

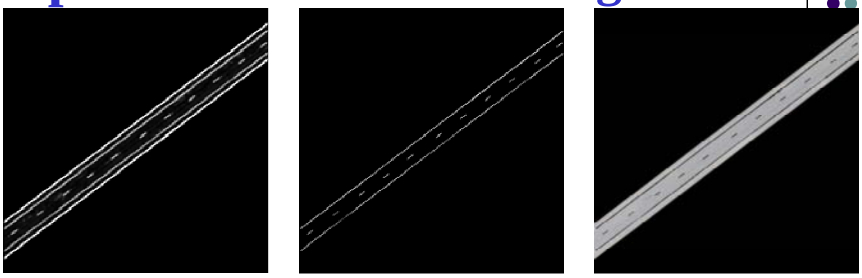
- **Marking extraction process**
  - 1st PCA is selected to reduce calculation
  - Using co-occurrence contrast to enhance the lane markings

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

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

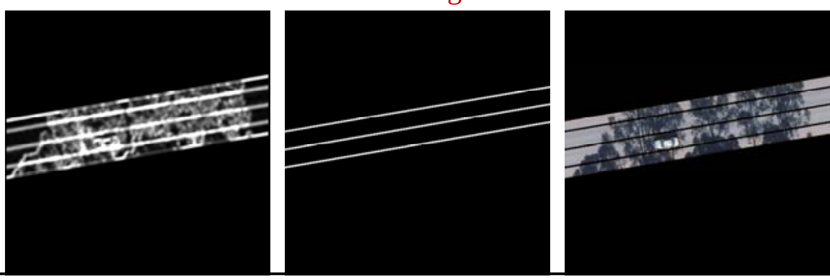
  - Image binarized by histogram thresholding
  - Thinning and vectorization

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



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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 km^2, 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%

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Summary

- High accuracy road maps are important for road safety applications:
  - Moving form 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

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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?