First in Flight

Effects of License Plate Attributes on Automatic License Plate Recognition

NORTH CAROLINA

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Primary purpose of license plates is to identify vehicles

NC DMV standard issue plate is embossed with 3 letters and 4 numbers (red ink 2007-2009)

~100 specialized license plates
  - Full background
  - Standard issue background

Personalization also an option on standard plates and most specialized plates
Background

- **Automatic License Plate Recognition (ALPR)**
  - A tool to identify vehicles
  - Also known as:
    - Automatic number plate recognition
    - Automatic vehicle identification
    - Car plate recognition
    - License-plate recognition
  - Operates at up to 160 mph
  - 1,000’s of license plate checks per shift (50-100 manually)
Objective

- To determine the readability of North Carolina’s license plates with an ALPR system
- Focus on law enforcement applications using two ALPRs
  - City of Raleigh Police Department
  - Federal Signal / PIPS Research and Development
- Controlled environment
Experiment Design

• Collect plates (902 total)
• Catalog
  – Type
  – Plate number
  – Condition
  – Reflectivity
• Sort for field test
Experiment Design – 6 Plate Types

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LRV-7900
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WXF-7388
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0325KF
NORTH CAROLINA

S4486
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Blue Ridge Parkway Foundation

0409BP
NORTH CAROLINA

Friends of the Smokies

6C99SM
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Measures of Effectiveness

- **Capture Rate** represents the ability to locate and identify a license plate
  
  \[
  \text{Capture Rate} = \frac{\text{Number of License Plates Recognized As License Plates}}{\text{Total Number of License Plates Studied}}
  \]

- **Read Rate** represents accuracy of reading and processing characters
  
  \[
  \text{Read Rate} = \frac{\text{Number of License Plates Accurately Read}}{\text{Number of License Plates Recognized As License Plates}}
  \]
Read Rate and Capture Rate

- Three options for evaluating an ALPR:
  - No capture:
  - Capture only:
  - Capture and read:
# Overall Results

<table>
<thead>
<tr>
<th>Raleigh PD ALPR Match Type and Quantity</th>
<th>Capture and Read</th>
<th>Capture Only</th>
<th>No Capture</th>
<th>Raleigh PD ALPR Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raleigh PD ALPR</td>
<td>271</td>
<td>16</td>
<td>6</td>
<td>293</td>
</tr>
<tr>
<td>Capture Only</td>
<td>81</td>
<td>297</td>
<td>23</td>
<td>401</td>
</tr>
<tr>
<td>No Capture</td>
<td>15</td>
<td>70</td>
<td>123</td>
<td>208</td>
</tr>
</tbody>
</table>

**PIPS R&D ALPR Total**

<table>
<thead>
<tr>
<th>Capture and Read</th>
<th>Capture Only</th>
<th>No Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>367</td>
<td>383</td>
<td>152</td>
</tr>
</tbody>
</table>

902
## Results by Plate Type

<table>
<thead>
<tr>
<th>Plate Type</th>
<th>Syntax Type</th>
<th># Plates</th>
<th>Raleigh PD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Capture Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>% (Number)</td>
</tr>
<tr>
<td>Standard Issue - Blue Ink</td>
<td>Std</td>
<td>154</td>
<td>96% (148)</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>86</td>
<td>84% (72)</td>
</tr>
<tr>
<td>Standard Issue - Red Ink</td>
<td>Std</td>
<td>249</td>
<td>66% (164)</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>25</td>
<td>56% (14)</td>
</tr>
<tr>
<td>Specialty FIF - No Stacked Character</td>
<td>Std</td>
<td>43</td>
<td>86% (37)</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>4</td>
<td>50% (2)</td>
</tr>
<tr>
<td>Specialty FIF - Stacked Character</td>
<td>Std</td>
<td>83</td>
<td>80% (66)</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>12</td>
<td>33% (4)</td>
</tr>
<tr>
<td>Specialty Non-FIF - New Style</td>
<td>Std</td>
<td>213</td>
<td>80% (171)</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>27</td>
<td>52% (14)</td>
</tr>
<tr>
<td>Specialty Non-FIF - Old Style</td>
<td>Std</td>
<td>5</td>
<td>20% (1)</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>1</td>
<td>100% (1)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>902</td>
<td>77% (694)</td>
</tr>
</tbody>
</table>

Note: Std = Standard, Person = Personalized
Stacked Characters

- 341 stacked characters on the 902 plates
- Raleigh PD ALPR system was able to capture 75% and able to accurately read 60% of the captured plates
Calibration

• For repeatability testing, 5 stations did not change during testing
• Four of the calibration stations had consistent readings on all but 1 of the possible 288 readings
  – Correct & Consistent: All 36 runs for the 2 standard syntax blue character plates and specialized plate in the standard issue format resulted
  – Incorrect & Consistent: Personalized standard issue blue character license plate, the Raleigh PD ALPR system reported an “8” instead of a “B”
    • One inconsistency: PIPS R&D ALPR same error as the Raleigh PD ALPR system for 35 of the runs and a different error on one of the runs in which the number string “15” was reported as “IS”
• The specialty plate with the full-background design created more difficulty in terms of repeatability for the two systems
  – Approximately two-thirds of the readings were consistent
Modeling Readability

• A logistic regression model was developed to model the probability of capture and read for standard issue license plates based on the Raleigh PD ALPR system
• Each of the terms were statistically significant
• Equations are:
  – Capture Rate = 0.05 - 1.3 * Red Ink + 0.03 * Contrast - 0.8 * Personalized
  – Read Rate = 0.4 - 2.1 * Red Ink + 0.01 * Contrast - 3.1 * Personalized

Where:
  – Red Ink = Presence of Red Ink on License Plate (0 = Blue Ink, 1 = Red Ink)
  – Contrast = Contrast Ratio of License Plate Characters and Background
  – Personalized = Presence of Personalized Syntax (0 = Standard Syntax, 1 = Personalized Syntax)
Modeling Readability - Capture Rate

![Graph showing probability of capture vs license plate contrast]

- Blue Ink, Personalized Syntax
- Red Ink, Personalized Syntax
- Blue Ink, Standard Syntax
- Red Ink, Standard Syntax

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Modeling Readability - Read Rate

![Graph showing the relationship between license plate contrast and the probability of read, with different inks and syntaxes.](http://www.itre.ncsu.edu)
Summary

• Most readable: standard issue, blue ink license plate
• Personalization resulted in a read rate ½ of the read rate of the standard issue syntax
• Red ink performed significantly worse
• Specialty plates without the stacked character were more easily captured and read
• Specialty license plates with the full background were generally captured, but difficulty accurately reading the plates
Conclusions and Recommendations

- Many incorrect matching combinations are matches between letters and numbers, supporting a need for syntax to read plates consistently
- Found significant difficulty with accurate readings of various specialty and personalized license plates
- Readability should be a criteria for consideration when decisions are made regarding new license plate designs
  - Ink color, syntax type, and contrast have a significant impact
  - Stacked characters, background colors, and consistent location of symbols are important on specialty plates
Acknowledgements

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Questions?

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