Sensor Systems and Data Analytics to Measure Cognitive Ability while Driving

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Objective
- Continuous monitoring of instrumental activities of daily living as an alternative to repetitive cognitive testing.
- Driving is a high cognition activity.
- Hypothesis:
  - The repetitive nature of routine trips can be compared over time to identify changes.
  - Navigational ability and trip planning
  - Vehicle operation (turn signal use)

Background
- Increasing numbers of patients with dementia / Alzheimer's Disease.
- Clinical cognitive measurement challenges
  - Time consuming and costly
  - Variable: patient tiredness, focus, time of day
- Risk of driving with dementia vs. benefit of maintaining social engagement
  - Social engagement slows cognitive decline.
  - Driving enables social engagement
- Proposed driving variables vs. cognition:
  - reduced variety of destinations
  - reduced driving distance
  - avoiding distant destinations
  - reduced complexity of trips
  - variation in use of turn signals

Methodology
- 10 trips captured with 2 healthy drivers.
- Sensors: GPS, dashboard video
- Signal detection from dashboard video
- Trip Planning analysis:
  - Identification of the destinations/stops
  - Analysis to identify optimal order
- Route Planning analysis:
  - Measurement of the path travelled.
  - Comparison to gold standard routing.
- Turn signal usage
  - Indicator use from dashboard video analysis
- Turns: from GPS location trace and post drive GPS turn by turn instructions

Algorithm (Navigation)
- Remove noise/jitter when vehicle stopped
- Stop identification
- Destination = >2mins at location
- Segment (between stops) and overall trip calculations
- Google Maps analysis – as-driven and optimal distance and optimal time stop order
- Stop changes - extra, missing, total? - efficient order?
- Overall trip distance vs crow flight / Google references
- Segment level distances vs crow flight / Google references

Algorithm (Turns)
- Detection of turn signal lamps location changes on dash
- Correlate with ideal arrows including rotation
- Identify turns in GPS trace look for direction changes
- Remove high (>30km) directions changes
- For each stop to stop segment
  - Choose up to 8 intermediate "via" points equally spaced
- Submit locations to Google maps API and receive turn by turn direction file
- Identify all turns and merges within direction file and corresponding location

Correlate time sequences (GPS turns and video signals) with position sequence (GIS turns)

Measure signal use by comparing turn events with signal use

- Example of arrow detection algorithm image processing steps:
  a – Difference image for raw window containing potential signal arrow.
  b – Candidate image rotated to position with optimal correlation.
  c – Edge detection results for rotated candidate arrow.
  d – Cropped candidate arrow used for correlation.

Summary
- The proposed algorithms measure travel navigation, route planning and turn signal use by driver.
- Google Maps Reference: algorithm to automatically use Google Maps as a gold standard providing a comparison point for a drivers performance.
- GIS and GPS Reference: algorithm to automatically detect turn signal use and turns providing a measure for driver performance.

Results
- Performance of the stop detection algorithm for all stops within the validation data set.

Summary of the analysis results for the 7 validation trips as compared to the baseline trip formed from trips 1, 2 and 3.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Trip 1</th>
<th>Trip 2</th>
<th>Trip 3</th>
<th>Trip 4</th>
<th>Trip 5</th>
<th>Trip 6</th>
<th>Trip 7</th>
<th>Total</th>
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<td>78%</td>
<td>82%</td>
<td>82%</td>
<td>78%</td>
<td>78%</td>
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<td>79%</td>
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<td>76%</td>
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<tr>
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</tbody>
</table>

Summary of the result for the association of signaling events (lamp use) with identified turns.

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