Site-Based Video System Design and Development: Research Plans and Issues
Support SHRP2 program research questions:
- Establish crash surrogates
- Relationship of multiple factors to crash risk and candidate surrogates
- Driver, vehicle, roadway, environment

Develop a site-based video system to accurately capture multi-vehicle trajectories at intersections, along with observable & important factors.

Demonstration with small field trial, including analysis to address research question(s)

Give SHRP/community a reason and supporting evidence to seek further funding!
Site-based – Complementary to Instrumented Vehicles

- Better understanding of the role of site-specific factors in crashes (intersection design, interchanges, curves, crests, pavement conditions, …)
- Better at many intersection-related issues due to:
  - Number of vehicles
  - Detailed knowledge of site, e.g., enables predicting infrastructure countermeasure impacts
- Better at observing some interactions between vehicles, e.g., intersections, weaving zones, platoon braking
- Less information inside cabin, e.g., attention
- Less information about the driver, e.g., age, driving style
- Less accurate vehicle motion than the instrumented vehicle
Traffic Control Research - Interest in Accurate Trajectory Estimation

Source: Report on TRB Traffic Signal Systems Committee Workshop
San Jose, CA. Larry Head, Committee Chair, July 2007
Task 1: Literature Review
Task 2: Research Questions
Task 3: System Requirements
Task 4: Plan for System Build and Evaluation
Task 5: System Build
Task 6: Field Trial
Task 5: System Build (revised)
Task 7: Study Design
Task 8: Carry out Pilot Study
Task 9: Describe system capability
Task 10: Final Report

Design Phase
Develop & Test
Demonstrate

Development Phase

Demonstration and Evaluation Phase

Workshop 1: Link to S05 and S01 projects
Workshop 2: Link to S05 and S01 projects
Task 10: Final Report

The Science of Driving
Intersection Crash Kinematics

From: Najm, Smith, and Smith, 2001
Surrogates for Intersection Collisions
## Surrogates for Intersection Collisions

<table>
<thead>
<tr>
<th>Surrogate Conflict Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap Time (GT)</td>
<td>Time lapse between completion of encroachment by turning vehicle and the arrival time of crossing vehicle if they continue with same speed and path.</td>
</tr>
<tr>
<td>Encroachment Time (ET)</td>
<td>Time duration during which the turning vehicle infringes upon the right-of-way of through vehicle.</td>
</tr>
<tr>
<td>Deceleration Rate (DR)</td>
<td>Rate at which crossing vehicle must decelerate to avoid collision.</td>
</tr>
<tr>
<td>Proportion of Stopping Distance (PSD)</td>
<td>Ratio of distance available to maneuver to the distance remaining to the projected location of collision.</td>
</tr>
<tr>
<td>Post-Encroachment Time (PET)</td>
<td>Time lapse between end of encroachment of turning vehicle and the time that the through vehicle actually arrives at the potential point of collision.</td>
</tr>
<tr>
<td>Initially Attempted Post-Encroachment Time (IAPT)</td>
<td>Time lapse between commencement of encroachment by turning vehicle plus the expected time for the through vehicle to reach the point of collision and the completion time of encroachment by turning vehicle.</td>
</tr>
<tr>
<td>Time to Collision (TTC)</td>
<td>Expected time for two vehicles to collide if they remain at their present speed and on the same path.</td>
</tr>
</tbody>
</table>

*From: Surrogate Safety Measures From Traffic Simulation Models, FHWA-RD-03-050.*
Commercial Systems

- Traffic control and tolling systems, e.g. with automated license plate recognition and reading
- Occupancy detection in virtual loops for signal control
  - Autoscope … e.g. Oakland County, Michigan, has more than 275 Autoscope processors installed, and with more than 1,000 Autoscope cameras
  - TrafiCam, from Traficon is a similar system
  - Both use image processing to determine vehicle occupancy in small segments of roadway
  - Replace loop detectors and other functions - traffic volume and speed estimation, incident detection
- No such system is designed for trajectory capture and cannot yield engineering quality data for vehicle kinematics
Systems from Research Organizations

- California PATH: NGSIM (current), IDS & other (vision and sometimes radar)
- Virginia Tech: Vision + radar / CICAS
- U-Minnesota: Vision, radar, both
- TNO/NL: Vision
- Others

- Semi-automated, semi-robust, semi-portable
SAVME Project

Sponsor: NHTSA, contributions from ERIM International, Nonlinear Dynamics Inc.

• Video data collection from dedicated 100 ft towers
• Delivered a database of 30,500 vehicle trajectories
• Validated tracking accuracy
• Sample scenario analyses
• Source data for later computational modeling
SAVME Data:

• Two video streams from high vantage points
  • Simplify transformations / perspective issues
  • Reduce occlusions
• Post-processing from video archive with operator interface to resolve image processing errors
• Basic optical tracking directly from video images
• Motion time histories for individual vehicles
SAVME Data:

- Kalman filtering greatly improved accuracy
- Inferred braking onset, beginning of lateral motions
- Database queries provide analyses of defined scenarios: case counts, histograms, measure distributions
Database query: TTC Metric on Flying Passes

The diagram shows the probability distribution of the time to collision (TTC) for flying passes in a maneuver. The x-axis represents the time to collision in seconds, ranging from 0 to 7 seconds. The y-axis represents the probability density function $P(x)$, ranging from 0 to 0.16. The bars indicate the frequency of collisions at different time intervals, with the highest probability occurring around 3 seconds to collision.
SAVME accuracy

Scenario: lead vehicle braking

Vehicle Speeds & Range-Rate (ft/sec)

Range-Rate

Time (sec)
California PATH – Video tracking of cars and other road users

- Developed as part of the NGSIM (Next Generation Traffic Simulation) project
- Combines
  - Background subtraction
  - Feature tracking
  - Trajectory estimation
Subtraction – remove background and focus on moving objects

Problems dealing with stationary traffic and background motions (e.g. shadows)
Example: California PATH
Example system concept

• Multiple camera installation giving multiple synched views of intersection region
• Local feature/shape tracking at each camera & existing (fused) estimates of vehicle motions/types
• Master processor with 3D shape models to create fused estimates for intersection
• Buffering if necessary to manage busy periods
• Incident detection & occasional image sequence buffering for validation
• Automatic
3D Methods enhanced by 3D site geometry
[Laser scanned site survey - MidWestern Consulting]
Data Acquisition System (DAS)

Successful Collection of 95.7% of FOT data
(325,000 mi – light vehicle)
(700,000 mi – heavy truck)

Sources of data loss

2.0% - boot-up time
2.1% - system failure
0.2% - DAS logic error
Learning about the Highway

- Detailed kinematics for crash, pre-crash and conflict

- Vehicle and site-based analysis can be joined via GIS to better understand highway factors

- To avoid bias, research should focus on “typical” as well as “problem” intersections
While site based data collection cannot directly monitor drivers’ activities within the vehicle,..  

- Major aspects of driver behavior can be inferred from vehicle motions – decisions and timing, delayed reactions, risk taking, control accuracy, ...  

- Multi-vehicle interactions resulting from those actions can be extracted, visualized and understood  

- Site based acquisition provides an ideal data resource for modeling the driver-vehicle system interacting with other vehicles and the highway
Accuracy Demands Via Simulation

- Simple kinematic simulations have been carried out.
- Demonstrates method and simple interim conclusion: ±1m accuracy in vehicle boundary tracking gives poor estimates for conflict metrics.
- *Matlab demo* of straight-crossing path and left turn across path conflicts.
Animation of left turn
Example showing sensitivity of conflict metric to uncertainty in vehicle motion
Initial Targets for Accuracy Requirements for Intersection Kinematics

- **vehicle boundary position:**
  - ±0.2m lateral and longitudinal within the intersection [0.6m in SAVME]
  - ±1m longitudinal, ±0.4m lateral at the periphery of the observational area.

- **vehicle longitudinal velocity:**
  - ±0.25 m/sec within the intersection [0.6 m/sec in SAVME]
  - ±1 m/s peripheral

- **vehicle longitudinal acceleration**
  - ±0.3 m/s/s within the intersection
  - ±1.0 m/s/s peripheral
Other System Requirements

- Expandable and deployable
- Low maintenance
- Robust to weather and traffic occlusions
- Fully automated track capture – searchable data
- Low intrusion (visually, passive / low emission sensors, …) – video is still the best option
- Compact data – limited or no video file storage (single stream of uncompressed monochrome video requires ~ 30Gb/hr)

...while maintaining kinematic accuracy and capacity for large volume data capture
Further Requirements

- Full automation of image processing
- Integrated motion analysis
- Feature registration in world coordinates
- 70+% availability
Next steps

Design phase:
- Complete review of existing systems
- Deeper analysis of research questions
- Complete system requirements definition
- Prepare system development plan

Development phase:
- Early tests to validate potential performance limits