High Occupancy Vehicle (HOV) and High Occupancy Tolling (HOT) Vehicle Occupancy Enforcement

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Xerox Innovation Commitment

- Jointly with Fuji-Xerox we invest $1.5B R&D/year
- Broadest portfolio of document systems, software and services
- > 100 new products & 500 awards in last 3 yrs
- 55,000 global patents, 10 US patents/week

"Innovation keeps us leading the industry, Xerox brings this capability to the Xerox Services (Formerly ACS) partnership"
Congestion Countermeasure: “Managed” Lanes

Traffic congestion sets US back by $87 billion/year in wasted fuel and time (2010)

Managed Lanes:
- High Occupancy Vehicle lanes (HOV)
- High Occupancy Tolling lanes (HOT)

Enforcement has Proven Difficult:
- HOV lane violation rate: up to 65%
- Manual HOV enforcement rate: <10%

“Current enforcement practices limit potential support for more HOV/HOT projects.” –McCormick Rankin Corp

HOT Lanes:
- HOV Lanes which Single Occupant Vehicles may use if they pay a toll.
- Toll is assessed with an RFID transponder.
- Use RFID transponders with Self-declaration switches
- Voluntary Compliance

### HOV / HOT Enforcement Goals

#### HOV Enforcement Goals

- Improve current manual enforcement accuracy
  
  *Increase from 10% → 60% to 70%*

- Improves Safety for Law Enforcement

- Provide automated process for enforcement and notification

- Provide mobile enforcement capabilities

#### HOT Enforcement Goals

- Need higher accuracy for toll violation enforcement – >90% desired

- Automated Process of both Toll Violation and HOV Violation

- Provide automated process for enforcement and notification

- Provide mobile enforcement capabilities
Video-Based Detection Challenges

1. Lack of proper illumination
2. Tinted glass
3. Occlusion of Occupants
4. Pose Variation of Occupants
5. Vehicle speed, size, shape
6. Imaging Geometry varies
7. Window Composition
8. Weather condition (snow, fog, atmospheric distortion etc)
9. Use of dummies
Xerox Occupancy Detection Strategy

- Can detect front and rear seat occupancy
- Dummy Detection Possible
- Robust to blurring due to motion
- More robust to weather related noises
- High cost/potential high accuracy

Capability/Performance Advances

- Geometric approach
  - Low cost/Acceptable accuracy
  - Rear seat occupancy imageable and automatically detectable
  - No distinction in Dummy and Human detection

- Biometric approach
  - Can detect front and rear seat occupancy
  - Dummy Detection Possible
  - Robust to blurring due to motion
  - More robust to weather related noises
  - High cost/potential high accuracy

Sample Images & Face Detection Algorithm

- Passenger Face Detected: Not a Candidate Violator
- Passenger Face Not Detected And Seat Detected: Candidate Violator
Leveraging Existing Tolling Infrastructure
Active Roadway Pilot Results: Vehicle Occupancy Testing
Baltimore, MD
November 2012
Front Seat Detection Processing Steps

• Raw Captured Infrared Image
• Xerox Automatic Windshield Detection

• Front Passenger Side Crop
• Xerox Automatic Passenger Detection
• Xerox Automatic Image Enhancement
• Cropped Windshield Sub-Image
Sample Side View Image
Pilot Side View Detection Performance

Statistics:

• Detection Accuracy: 94.3%
Summary: Vehicle Occupancy Detection
Public Roadway Testing

Baltimore, MD
City Road Intersection
November 12-27, 2012

2 Camera System: (1) Front Seat viewing Camera, (2) Rear Seat viewing Camera

**Front Seat:**
39,000 Images Captured, 24hrs/day
Image Quality for Human Review on >99% of Images
**Automatic Front Seat Passenger Detection Accuracy:** 97.6%

**Rear Seat:**
>3900 Image Captured, daytime only
Acceptable Image Quality for Human Review on >90% of Images
**Automatic Rear Seat Passenger Detection Accuracy:** 94.3% for >1300 Images