VOTERS
Versatile Onboard Traffic Embedded Roaming Sensors

Overview
End of Year One NIST Site Visit

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Overview Outline

- VOTERS Vision
- Management
- Technical Highlights
- Outreach
- Summary
Vision

Reliable, safe, and cost effective highway maintenance system

A systems approach
Reasons for Infrastructure Vulnerability

- Poor or incomplete knowledge
- Lack of data prevents critical decision making
- Current condition in disrepair
- Lack of fund to repair
Benefits of VOTERS System

• Added value of VOTERS to existing and improved infrastructure management systems
• Goal to make maintenance decision easier through more useful information
  – Denser spatial and temporal coverage
  – Measurements providing useful information currently not used
• If some information (e.g. potholes, poor roadways) made public, it could make entities in charge of planning and management of maintenance more accountable
• Raise awareness of how cost effects road and bridge conditions
• Innovative Solutions for Infrastructure Management
• Use Vehicles of Opportunity as economic and safe fleet of sensor systems
• Collect reliable geo-referenced multi-sensor data sets with dense spatial and temporal coverage
• Provide added value information for pavement and bridge deck management
VOTERS - YEAR 1

• Theme: **Start R&D and Engineering on all individual VOTERS components** (except MAP)
  – Significant technical progress in many areas
  – Specifications for all subsystems are nearing completion

• Welcome Trilion Quality Systems to the VOTERS Joint Venture
  – In process added optical sensor system to VOTERS as important sensor subsystem
Management
Areas of Responsibility

Management & Administrative Support
Director: Ming L. Wang
Deputy Director: Sara Wadia-Fascetti
Program Manager: Jeff Doughty

Consultants:
• Infrasense
• G. McDaniel
• D. Busuioc

Supporting Organizations

Feb. 25th, 2010 | 9
Management and Evaluation Processes

- Regular team meetings joining JV partners and consultants

**VOTERS Meeting Schedule**

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td>9:00 Radar</td>
<td>10:00 VOTERS Staff</td>
<td>11:30 XY Stage</td>
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<td>11:30 Systems Integ.</td>
<td>2:00 Mgmt. Committee</td>
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<td>1:00 TestBed</td>
<td>2:00 Administrator</td>
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<td>1:00 Perform. Specs</td>
<td>3:00 TEASe</td>
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<td>3:00 Technical Staff</td>
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- Progress will also be monitored by GANTT charts
- Evaluation will be governed by decision points
Technical Highlights
VOTERS SYSTEM DIAGRAM

- GEARS
- RADAR Materials Characterization
- SLiMR
- TEASe
- Data Registration
- Onboard Processing
- BOSS
- Supporting Sensor Systems
- SOPRA

MAP

Feb. 25th, 2010 | 12
Sensing Technologies

TEASe: Tire Excited Acoustic Sensing
• Adaptation of SONAR concepts to road surface analysis. Assesses subsurface conditions.

GEARS: Gigahertz Electromagnetic Array Roaming Sensor
• Radar system built to operate under vehicles at driving speed for on-the-fly interpretation. Assesses subsurface conditions.

SLiMR: Surface Looking Millimeter Wave Radar
• Automatic quantitative pavement surface analysis, indicates pavement health (surface profile and crack density/porosity), ice, water, oil cover.

SOPRA: Surface Optical Profilometry Roadway Analysis
• Phase profilometry technology uses digital pictures illuminated by periodic shadows to profile road surfaces. Map roadway and bridge deck surface and observe active cracking.
## Design Goals Clarified

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<tr>
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<th>Defect Category</th>
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<th>Secondary</th>
<th>Tertiary</th>
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<td>Surface Contour</td>
<td>Surface Textures</td>
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<td>SLiMR</td>
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<td>GEARs</td>
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<td>Rebar and Corrosion</td>
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<td>TEASe</td>
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<td>Expansion Joint Condition</td>
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<td>Crack Activity</td>
<td>SOPRA</td>
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<td>-</td>
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<td></td>
<td>Density</td>
<td>-</td>
<td>TEASe</td>
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Measured Acoustic Wave from Road Vibrations

Pressure peak predicted from plane wave acoustic model and acceleration peak

Accelerometer is 0.5 m from the impact

Long Rayleigh wavelength
Acoustic Sensor for Subsurface Damage

• Robust acoustic signature detected for subsurface road damage

• Wireless sensor design for dynamic tire pressure

Resonance Feature
~ 200 Hz

Pressure (dB re 20 microPa)

Frequency (Hz)
GEARS

• Technical challenges, initial specifications, and solution paths identified

• Pulse Generator – Strip line units developed, including controllable pulse shaping and high-frequency up conversion, signal amplified and launched through ultra-wideband antenna

• Demonstrate innovative, high performance, full-waveform signal sampling of launched signal
Novel Antenna Concepts for GPR Focusing

- Focusing Lens Rebar Detector
- Low profile Vivaldi feed element
- Compact offset parabolic mirror
Adjusted GEARS Plan

GEARS

GPR lens
- A dedicated rebar and corrosion detection system

Imaging GPR array

State-of-art hardware design
- Low-cost transmitter
- High-speed sampling
- Innovative antennae design

COTS Imaging GPR array
- Field Testing
- Baseline datasets
- Algorithm development
- Detect corrosion with Bozor filtering approach

Added feasibility study

Adjusted
SLiMR: Custom Built and COTS Radars

- Distinguishes water-infiltrated and Ice-coated roadway
- Alerts on change in pavement condition with changing position
- **Dielectric database**: 663 data points from 45 journal papers (until Feb. 21, 2010)
- **Experimental measurement facility**: Contact and non-contact methods for 0.1 GHz to 20 GHz
- **Theoretical investigation**: Dielectric mixture models for two-phase and three-phase mixtures
SOPRA
Surface Optical Profilometry Roadway Analysis

• Road surface shape in 3D
• Roadway damage detection
  - Pot hole
  - Cracking
  - Expansion Joints
• Optimized for 5mm resolution over 2m view
• Real-time distance to surface
• Vision registration data
• Continuous road surface image
BOSS and SYSTEM INTEGRATION
MAJOR ACCOMPLISHMENTS

• Put together experienced system integration team
• Determined overall high-level VOTERS system architecture
• Selected BOSS building blocks and assembled initial basic prototype
• Decided on following VOTERS strategies:
  – 3-Level Decision Making
  – GPS based Timing Synchronization
  – Data Collection Mode
• Working on Data Registration strategy
DGPS

Base: reference point
Rover: updates its accurate position

- Develop software from scratch.

- Improve the accuracy to half-meter using inexpensive receiver (<$100).

    Trimble Copernicus GPS chip ($80)

    Compact Magnetic-Mount Antenna ($10)

- Communicate via commercial wireless channel.
DGPS Results

Point B:
- East error: 0 to 2 m
- North error: 0 to 2 m
- Vertical error: 0 to 2 m

Point C:
- East error: 0 to 2 m
- North error: 0 to 2 m
- Vertical error: 0 to 2 m

Accuracy:
- Point B: East: 1 meters, North: 2 meters, Vertical 0.2 meters.
- Point C: East: 1 meters, North: 0.5 meters, Vertical 2 meters.
Outreach summary

• Patent disclosures: 4
• Papers: 5
• Conference submissions: 5
• Proprietary issue is hold back publications
• Public relation: magazines and newspapers
• Website: www.neu.edu/voters
• Industry interest : 20
Upcoming VOTERS Year 2

• Theme: Complete experimental prototypes of individual VOTERS components, start integration and field testing

• First sensor subsystem experimental prototypes will become available (e.g. SLiMR, Sept. 2010)

• Expect major advances in TEASe, GEARs, SOPRA, and DGPS
Expanding VOTERS

- Other roaming sensor ideas
- Other interest: Airports
- Build on industry interest
- Link MAP into existing roadway and bridge deck management systems and demonstrate added value
Summary

What do we like to achieve today?

• Team work
• Report to NIST of our progress and new opportunity
• Seek guidance from NIST-TIP program manager and the team