Next Generation Laser Scanning: Technology Futures

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Outline

• Vehicle Safety Standards
  – Advancing Vehicle Capabilities
  – Working with industry

• Next Generation Ladar
  – Technology Need
  – NGL, BAA results
Standards for Industrial Vehicles
toward advancing ASME B56.5

• Used a SICK LMS as ground truth and a CSEM SR2 to detect British standard EN1525 sized objects

• Promoted non-contact sensors for AGV safety systems with MHIA and AGV vendors to ASME B56.5 committee

• Standard was changed in November 2004
• Several publications describing our tests written for 2005 conferences
Standard Experiment

Set-up

The test pieces:

Closest to BS EN1525 size obstacle
Standard Experiment

Collected Data from SR2

CSEM intensity

CSEM range
Beyond Standards …

- Further experiments with 3D Ladar:
  - Optimal placement on vehicle (low or high)
  - Multiple SR2s for wider FOV

- AGV vendor says “also view objects that are beside vehicle” – i.e., Ladars facing each other

- Healthcare Project: coupled Ladar with stereo sound for guiding blind person from room to room.
Industry CRADA
to advance current vehicle capabilities

*Visualization of Pallets*

- Vehicle taught *approximately* where pallets are located and pallet/load size
- Sense to verify:
  - exact size pallet on conveyer
  - if pallets are or can be stacked, rotated
  - if clear to carry stack (blocks one sensor --> safe?)
  - if truck is empty or not, truck skew
  - if truck has correct size opening to accept pallet stack
  - what opening sizes are left to fill
Industry CRADA

Set-up and Testing at NIST

SICK S3000, SPanner mounted on a Mock Fork Truck

- **SPanner**
  - SICK LMS on a Panning motor
  - Scan:
    - 0.25 deg resolution
  - Field of view:
    - 100 degrees horizontal
    - LADAR 401 pixels

- **S3000**
  - Safety and LMS sensor
  - Scan:
    - 0.25 deg resolution
  - Field of view:
    - 100 degrees horizontal
    - LADAR 401 pixels
Stacked pallets, tines out and at stacked pallet height

SPanner data

S3000 data
SICK S3000
Raised tines, Inside loading dock, Viewing into empty truck
Delivery To Truck, Safety

color data:

S3000 data:
Stack in truck

SPanner data

S3000 data

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Advanced LADAR for Unmanned Ground Vehicles

WHY NEEDED?

• In support of the ARL UGV program, NIST identified performance requirements of LADAR for on- and off-road driving
• Current UGV LADAR sensors have limitations in performance, are large in size, and are expensive
• UGVs must be able to detect, recognize and track objects and terrain features in very cluttered environments surrounding the vehicle in order to drive autonomously
• Most of current LADAR development is for ATR and tracking on flying platforms
Where does technology fall short?

• Vehicle is myopic
• Current LADAR is low resolution and short range
• Current LADAR does not penetrate obscurants
• Planning is not optimized for road following
Driving on Roads

- Car turning left (position, velocity)
- Oncoming cars (position, velocity)
- Traffic signals (stop)
- Truck on own road (position, velocity)
- Own road edges (Old Georgetown Road, heading North)
- Intersecting road edges (Democracy Boulevard, to West)
- Self in lane 2 (position, velocity) intent (go straight)
HMMWV in the Woods

Where is a clear path?
How far apart are the trees?
What is the height or depth of an obstacle?
Driving in Woods
LADAR Image Color Coded for $z$
Non-Contact, Range Sensors
NIST Publication

• Published comprehensive report on next-generation LADAR for manufacturing, construction, and mobility
• Contains section on NIST BAA: Next Generation LADAR for Driving Unmanned Ground Vehicles
• Includes concept designs from*:
  – Advanced Scientific Concepts Inc.
  – Coherent Technologies Inc.
  – Lockheed Martin Missile & Fire Control
  – Raytheon Missile Systems

* NIST does not endorse products or organizations.

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Technology Requirements of Next Generation Ladar for Unmanned Ground Vehicles

- Ladars are needed for autonomous ground vehicles
  - range out to better than 100 meters
  - frame rate of at least 10 Hz
  - range resolution of about 5 cm
- Need Wide Field of View (WFOV) Ladar of about 40 X 90 degrees with spatial resolution of .25 degrees or better per pixel
- Need Narrow Field of View (foveal) Ladar of about 1/10th of WFOV with spatial resolution of .05 degrees or better per pixel
- Must operate in full sunlight but also be eye-safe
- Shall be capable of penetrating dust, fog, smoke, grass and light foliage
- Small size, low cost and rugged designs are needed
- NIST BAA was issued - four contracts for design concepts were awarded.
  - 15 proposals received
  - Phase I LADAR designs were reviewed.
  - Did not proceed to Phase II because of lack of funding
BAA Awardees
Main LADAR Design Features

Advanced Scientific Concepts Inc.
• 360 X 360 Focal Plane Array Flash Ladar – No mechanical moving parts, pulsed laser direct time-of-flight ranging, multiple-sampling capability, leverages existing development

Coherent Technologies Inc.
• Uses novel coherent laser FMCW (frequency modulation continuous wave - sweeps the wavelength of the laser signal over a given range) approach for range imaging with traditional mechanical scanners, very high sensitivity-reduces needed laser power, multiple returns readily detected

Lockheed Martin Missile & Fire Control
• Uses existing off-the-shelf components: small mechanical scanners, pulsed laser source and linear array detector, based on existing sensor products

Raytheon Missile Systems
• 256 X 256 Focal Plane Array Flash Ladar – No mechanical moving parts pulsed laser direct time-of-flight ranging, threshold detection allows limited number of returns per pulse, leverages existing work

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Example of Real-Time Flash FPA Range Imaging Taken With Existing Ladar Prototypes

Advanced Scientific Concepts Inc.

- Flash Images Taken With ADVAR 3D 128 X 128 Focal Plane Array Ladar (1570 nm, 15 uJ – 45 mJ per pulse laser) detector – InGaAs PIN Array
Advanced Scientific Concepts

range overlaid with intensity clearly identifies vehicle type
Advanced Scientific Concepts: *Flight Test System*

Figure 2. Flight Test System in Static Vehicle Test Configuration. The goal of this system development project is a UAV-based topographical mapping system with the capability of 350 km²/hr, a volume less than 1 ft³ and a total weight including GPS and INS less than 50 lbs.
Example of Real-Time Flash FPA Range Imaging Taken With Existing Ladar Prototypes

MIT Lincoln Laboratory

- Chevy van at 60 m taken with original 4 X 4 Geiger Mode APD (Avalanche Photon Detector) imager, mechanically scanned over the selected FOV
Low Cost Custom CMOS/CCD Technology
Prototype Miniature 3D TOF Cameras

CSEM – SwissRanger 2
160 X 124 pixel FPA detector

PMDTec – Observer 1k
64 X 16 pixel FPA detector

Range at each pixel – measures phase delay of reflected AM light
Typical max. range used 7.5 m
Low cost, low power LED illumination

Frame rate: up to 40 Hz
IBEO Alasca Multi-Layer Laserscanner

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LADARs for Mobility

CONCLUSIONS

• Work is continuing at NIST in an attempt to identify the sensory requirements for on and off-road autonomous driving subtasks
• Still have not seen the announcement of any new LADAR products that can meet all of the stated requirements in the original NIST LADAR BAA
• Prototype advanced LADAR cameras are becoming available for experimentation. Have potential for compact, low cost and high performance imaging
• Calibration and performance evaluation facilities are envisioned for LADARs used in mobility