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FUSION OF LIDAR AND PROFILE FOR PAVEMENT CONDITION ASSESSMENT

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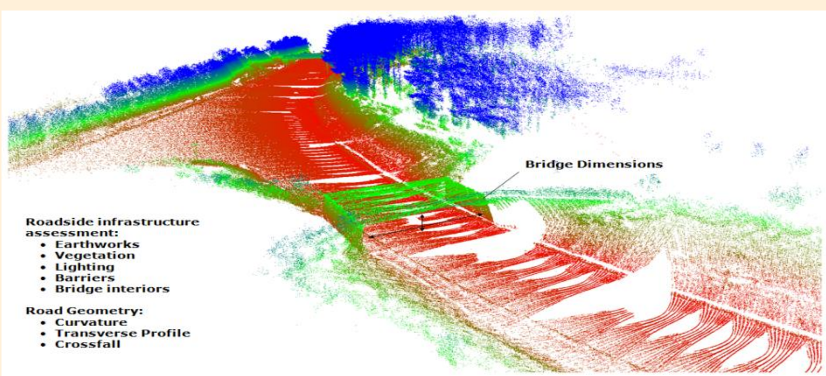
LIDAR



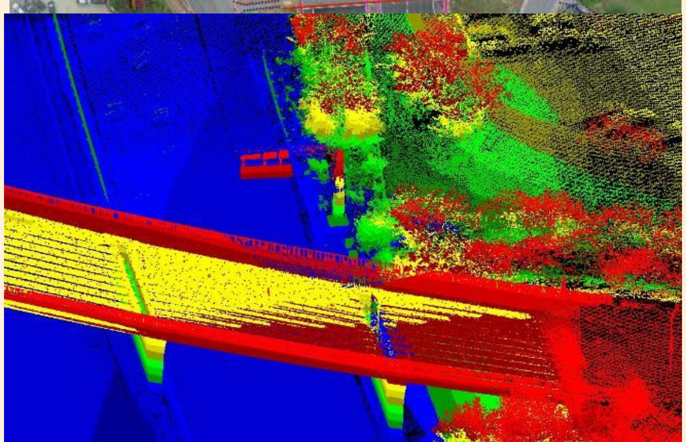
- **Light Detection and Ranging**
- **Laser technology capable of imaging a huge range of material types**
- **Precision range-finding using "time of flight" analysis**
- **Multi-directional scanning using spinning lasers**
- **To provide a 3D dataset of the surveyed asset**

- **This presentation: could we add LIDAR to our kit of asset and pavement assessment tools?**

Collecting LIDAR data

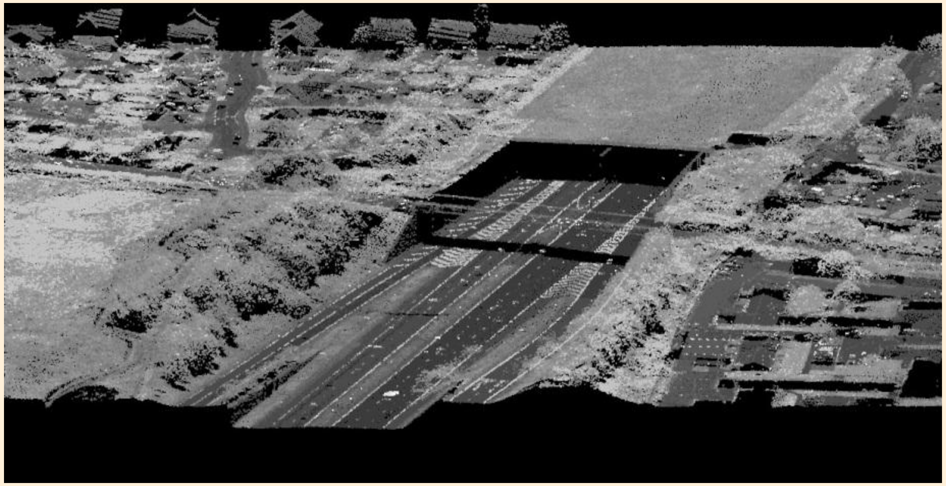
- **"Traditional" surveys are airborne e.g.**
  - **Helicoptor surveys @100-400m altitude**
  - **Surveying 60m "strips"**
  - **50km/day**
  - **Claiming @5cm accuracy**
- **LIDAR, inertial and GPS data are combined**
  - **May use a local GPS base station**
- **Terrestrial surveys also undertaken using specialist vehicles**

Common applications



- Pavement, roadside infrastructure, built and natural environments all mapped simultaneously
- For design and planning
  - Accurate 3D maps feed CAD design tools
- Assessing Earthworks
  - Slope instability
- Asset inventory

LIDAR surveys



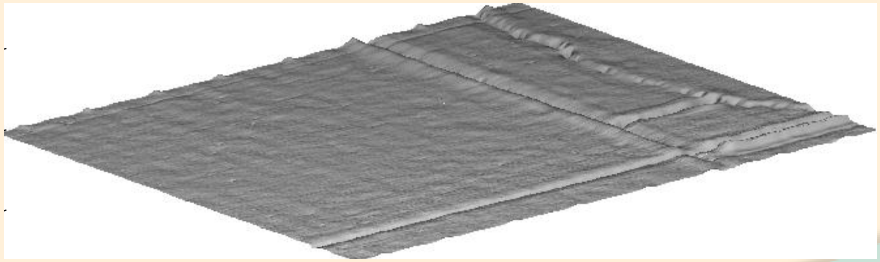
- Airborne surveys are very useful, but
  - Specialist / expensive
  - Complex
  - Coverage issues - can't measure underneath the assets
- In general
  - Focused on in-depth scheme/project level assessment (high value)
  - Accuracy may not be suitable for pavement surface/shape assessment, even for terrestrial surveys

Profile surveys

- Routine laser profile surveys measure
  - Transverse profile
    - Rutting
    - Water depth
  - Longitudinal profile
    - Ride quality (IRI)
  - Texture profile
    - High-speed skid resistance
  - Geometry
- Very accurate profile data
- Limited to a single lane per survey
- High efficiency (300km / day)
- Low cost



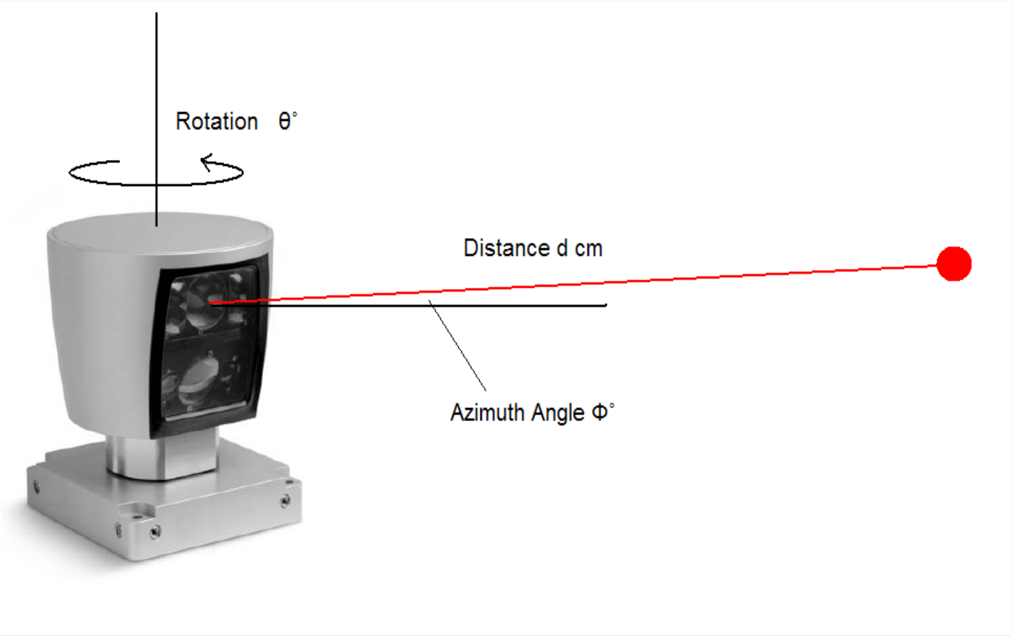




Terrestrial LIDAR (vehicle based)

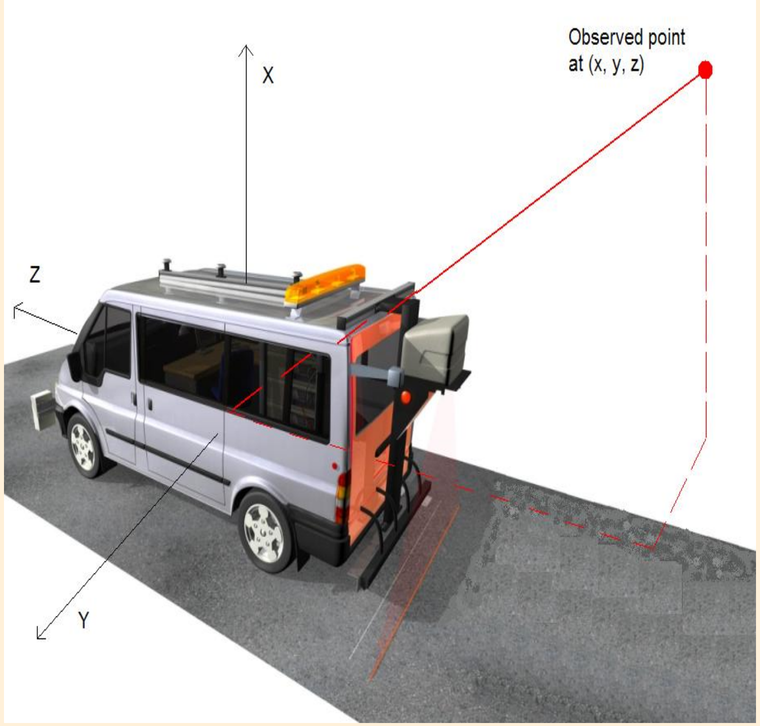
- Collection by installing Velodyne LIDAR head on a Profile survey vehicle (HARRIS2)
- LIDAR system gives distance from the laser only
- Onboard GPS and IMU needed to relate LiDAR data to the surrounding environment
  - Conversion from the LIDAR space to the Survey space

LIDAR Space



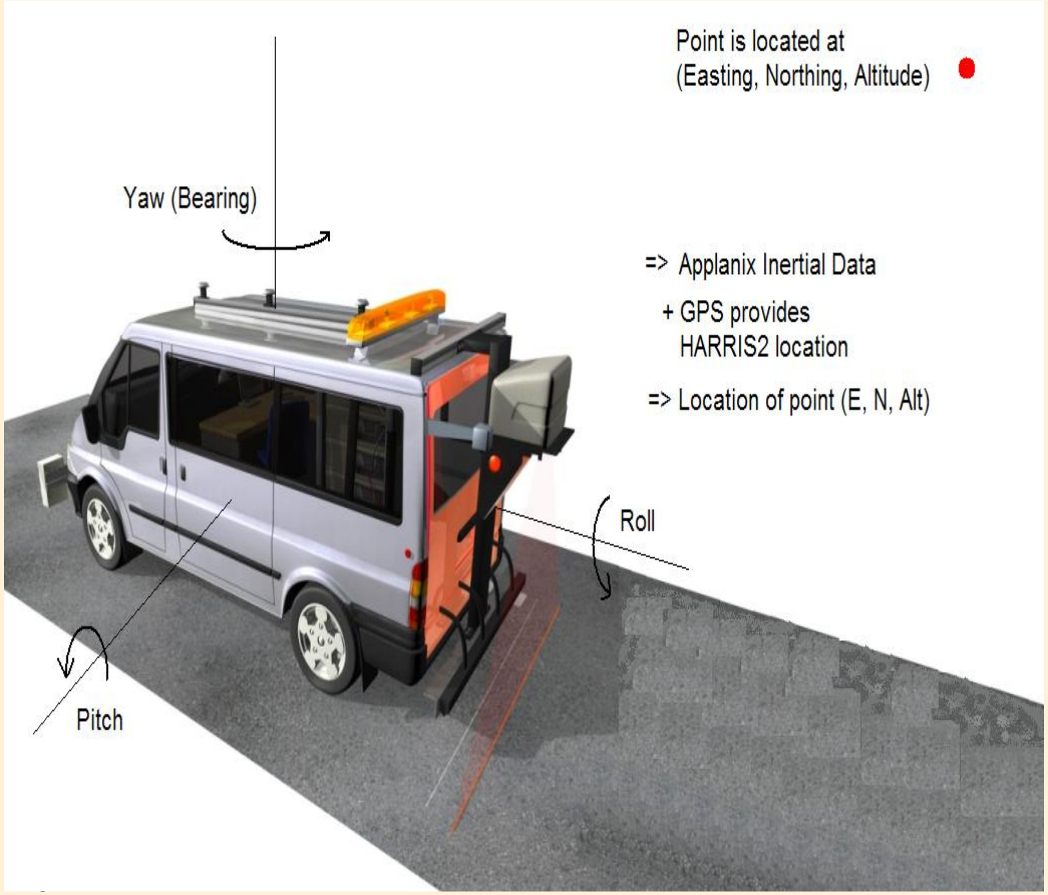
- The Velodyne LIDAR provides a head rotation angle and 32 distances (one per laser in each bank)
- Azimuthal and rotational angles of the individual lasers are provided in a separate file
- The location of each observed point is determined w.r.t the base of the LIDAR unit

Vehicle space



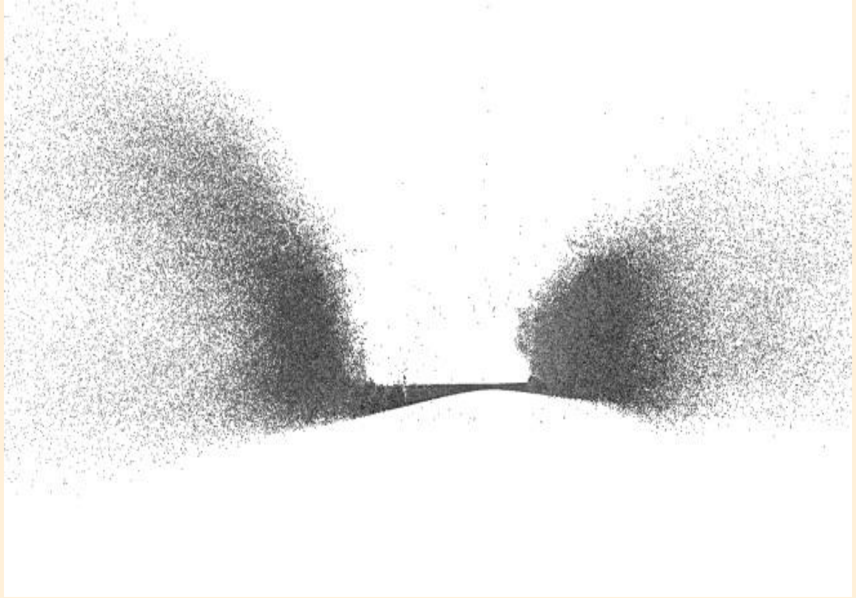
- **LIDAR head is mounted at a 23 degree angle**
- **Position and orientation of LIDAR head used to rotate the LIDAR space position into Vehicle space**
- **The (0, 0, 0) point is at the location of the inertial measurement unit**
- **Vehicle space is 'at rest' w.r.t vehicle**
- **Pitch, Roll and Yaw are not considered yet**

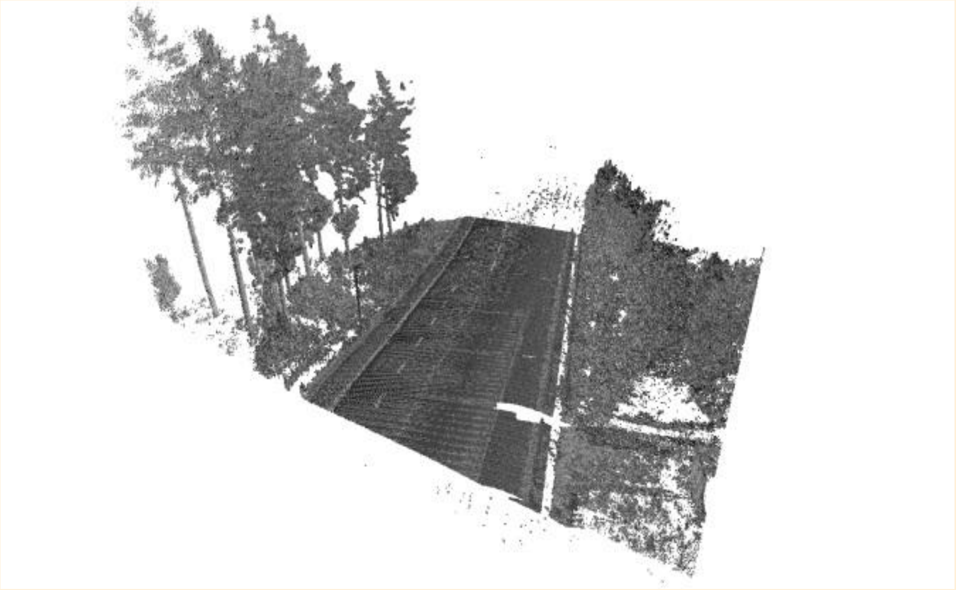
Survey Space



- IMU provides Pitch, Roll, Yaw (Bearing), Location and Altitude
- (X, Y, Z) in vehicle space is rotated and translated to locate the point in survey space (E, N, Alt)
- Software tool developed to carry out these transformations
- Resulting data set is a 3D point cloud (x, y, z, r, g, b)

Results

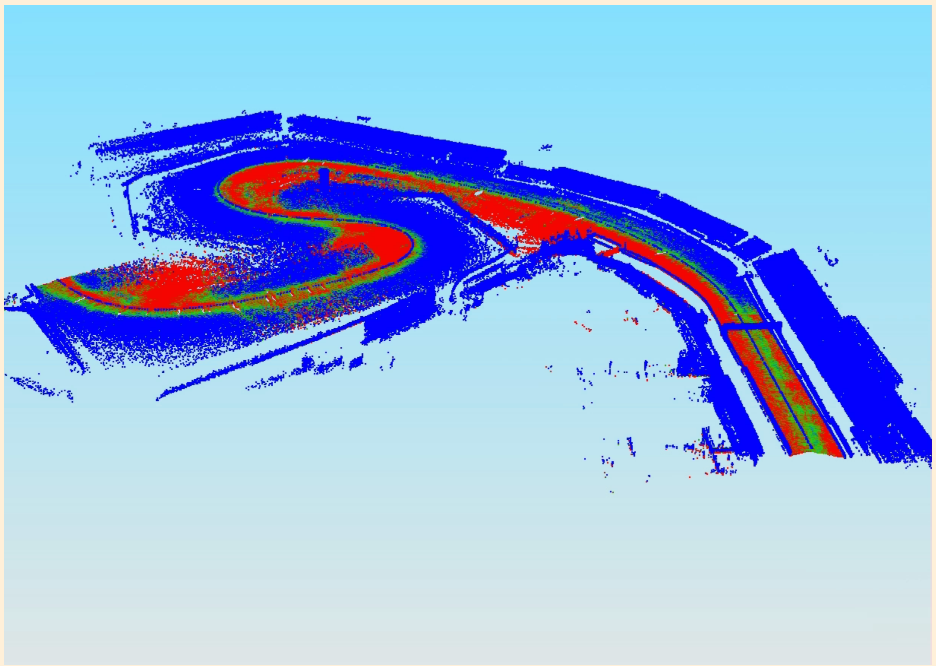




- LIDAR space

- Same data in Survey space

Results



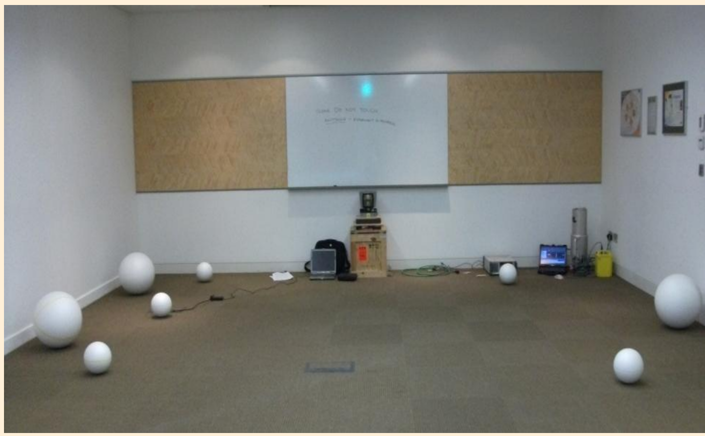
Applications - measuring assets

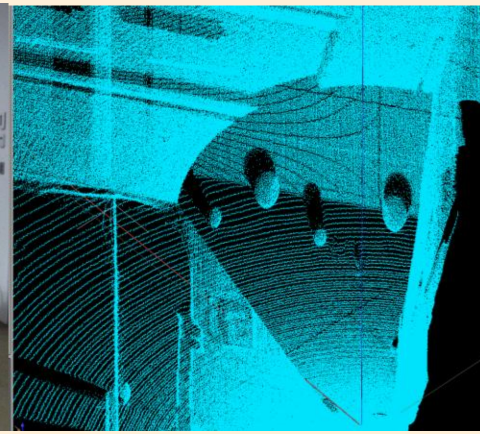
- Easier to collect routinely, with potential to (e.g.)
  - Locate signs and signals.
  - Generate a geo-referenced database of signals and signs
  - Locate and measure bridges, gantries etc
  - Enhance right of way video data for quantitative assessment

Applications - pavement condition assessment

- E.g. Potential to
  - Automatically identify the edges of the road.
    - Measuring road width and
    - Identify narrow locations automatically
  - Measure overall shape
    - But still may not be suitable for condition assessment

How accurate is it (ideal conditions)?



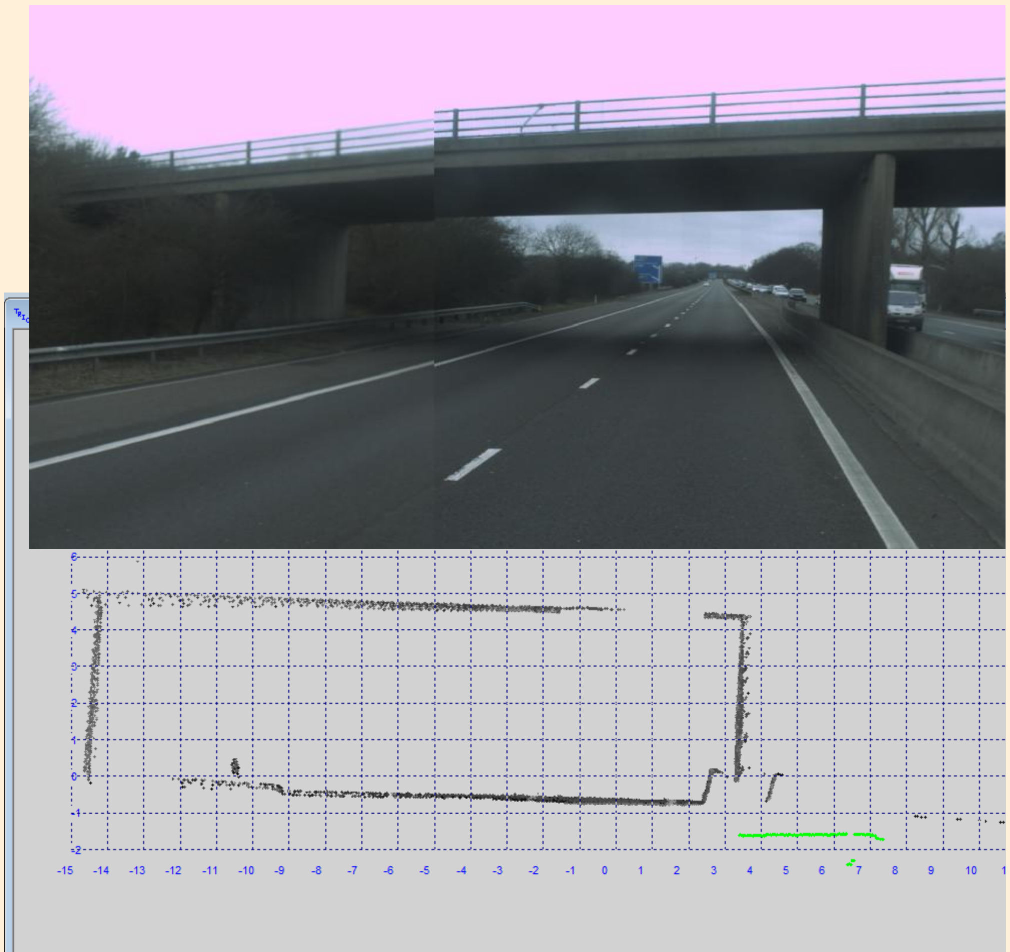


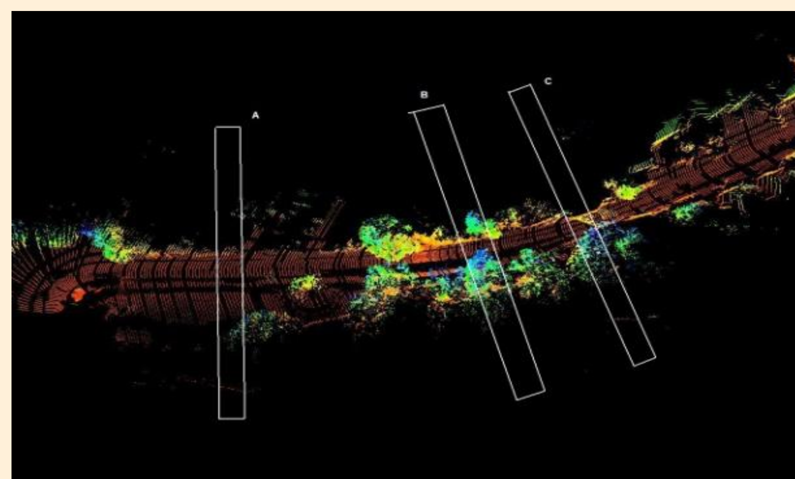
Sphere	Riegl LIDAR measured (cm)			True Dimensions (cm)		
	Radius	X	Y	Radius	X	Y
A (20cm)	20	548	307	20	560	300
B (20cm)	20.2	549	114	20	560	120
C (10cm)	11.2	488	369	10	500	375
D (10cm)	11.7	464	175	10	500	210
E (10cm)	N/A[2]	*N/A*[5]	*N/A*[5]	10	500	55
F (10cm)	12.7	120	409	10	120	425
G (10cm)	11.9	140	98	10	140	100
H (20cm)	21.1	30	287	20	30	300

- **Performance linked to quality of:**
  - **LIDAR head**
  - **IMU**
  - **Algorithms**
  - **Vehicle mounting**
  - **IMU / LIDAR coupling hardware**
- **In static conditions:**
  - **Overall we observe cm accuracy**
- **Therefore still restricted in application for pavement condition assessment?**

How accurate is it (real application)?

- **Assessment of bridge / gantry clearance**
- **Using the LIDAR Slice approach**





How accurate is it in a real application?

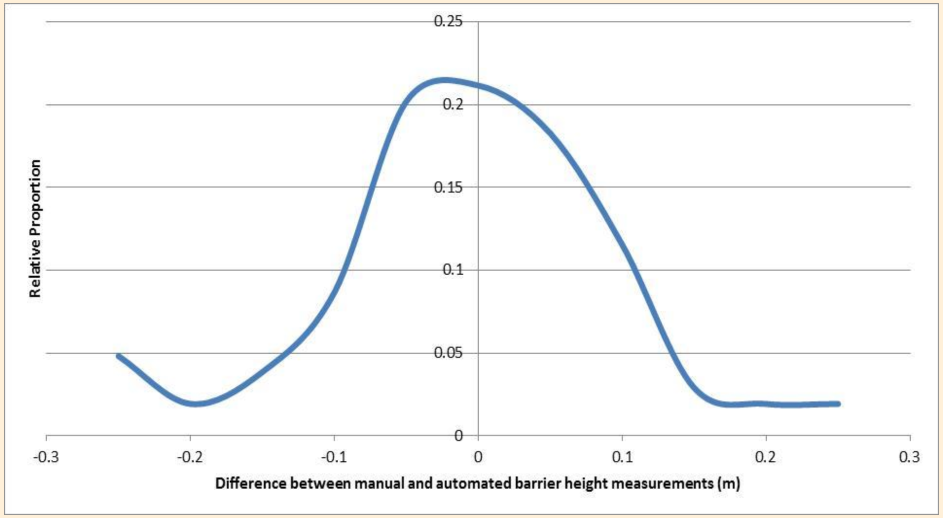
	Closest Point	5^{th} Percentile	10^{th} Percentile	Reference
Height	5.152	5.156	5.159	5.05 (nearside) to 5.16 (offside)
Width	15.161	15.215	15.267	15.7 (at the road barrier) to 15 (at the bridge deck)

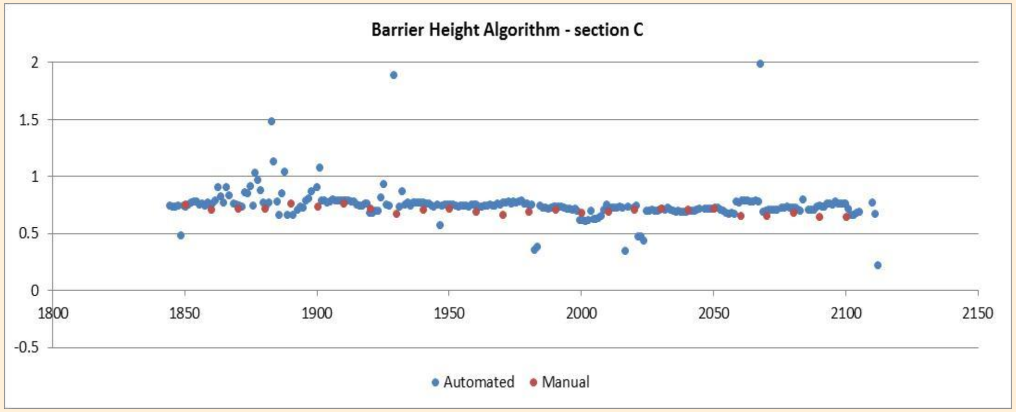
- **Example on a sample bridge**
- **LIDAR results obtained using an algorithm to radially assess each slice**
- **Reference data using a laser distance tool on site**
- **Reasonable results – few cm accuracy**

An example "routine" application

- Manual assessment of barrier height and offset
- Using the LIDAR Slice approach
- 200km of M25 surveyed in 1 day
- Manually determine heights and offsets
  - Using software tool
  - A few day's analysis

An example “routine” application

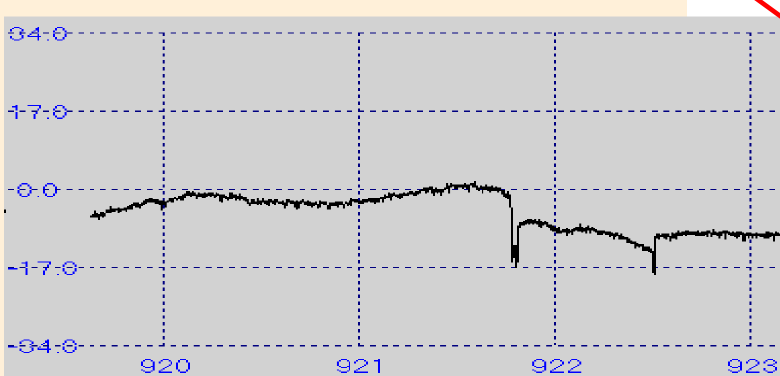


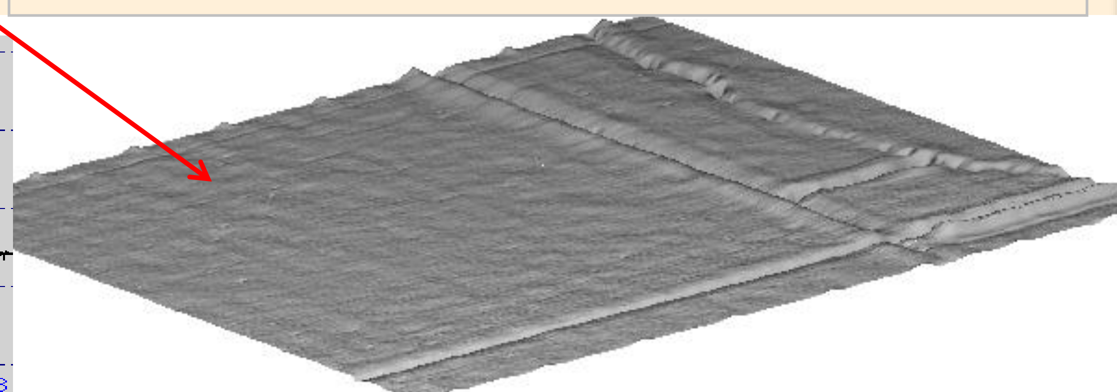


- Automatic assessment of barrier height
- Using the LIDAR Slice approach
- Developed algorithms to estimate the height of the road and the barrier in each slice
- Processing takes a few minutes
- Compare with manual assessment of the LIDAR data
- >75% within 10cm

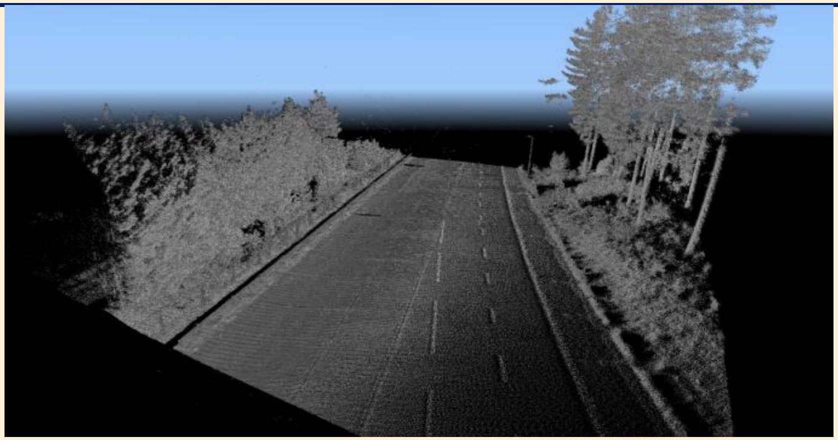
Can it be used for pavements?

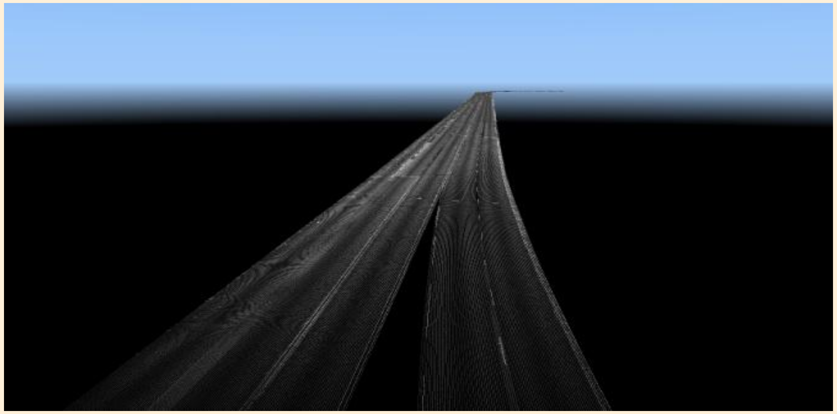
- Profilers survey the lane
  - 20-1000 points across the lane
  - To 1/10th mm accuracy
  - Every 5-100mm along the road
- Can only assess in-lane condition
- Desirable to survey the whole carriageway to this level
  - Handling models
  - Water depth
  - Splash/spray





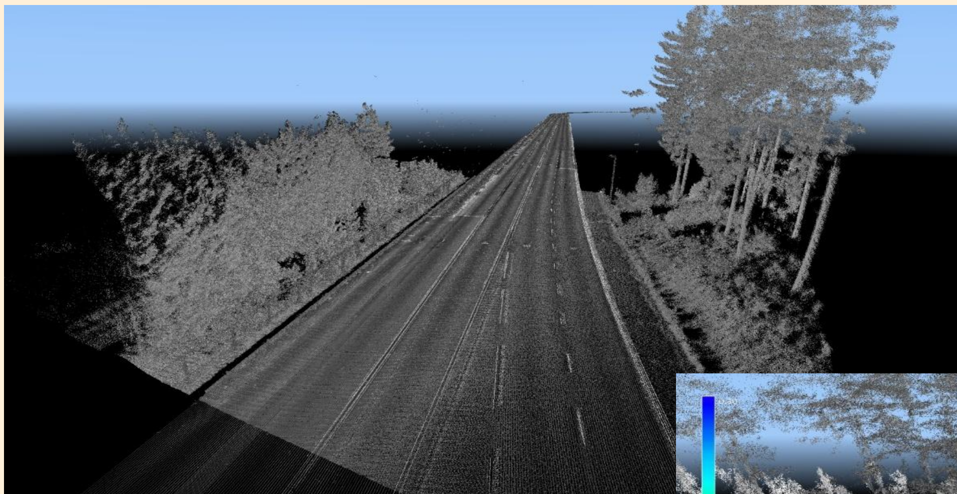
Fusion of LIDAR and profile



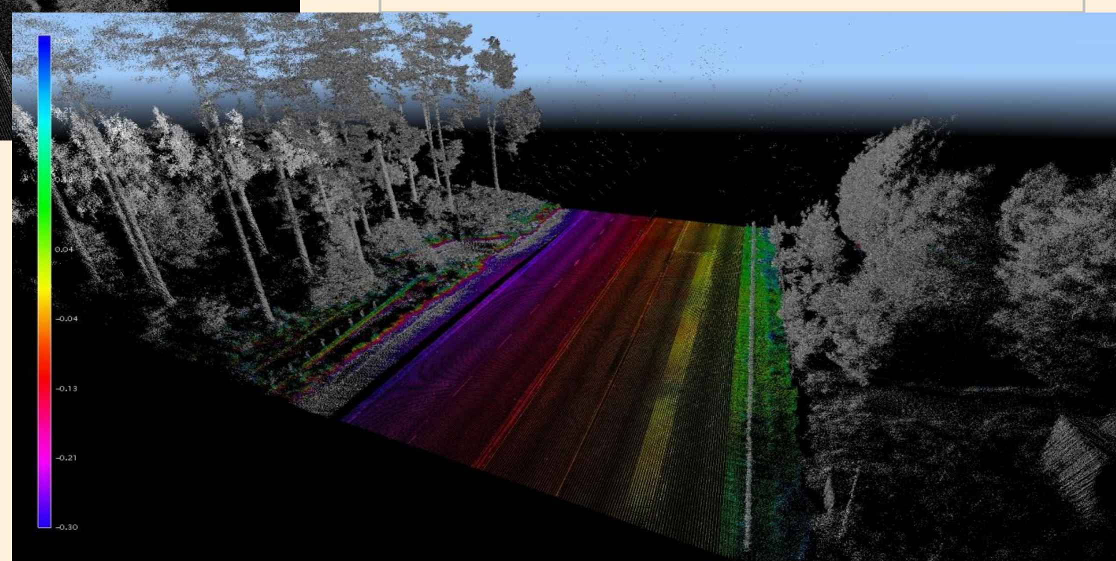


- Report the LIDAR and the profile data in the survey space
- A survey is made in each lane using the profiler and LIDAR
  - Cannot simply add together the proifle data due to drift and inacuracy
- A single lidar run selected to provide the baseline
- Each run of profile is “overlaid” onto this
- The profile is shifted to align using reference points identified in the LIDAR

Fusion of LIDAR and profile



- We get…….a single 3D dataset with
  - cm accuracy for the surrounding assets
  - mm accuracy for the pavement



- But we still have some problems!
  - Stepping still present
  - Need for manual intervention

Summary

- LIDAR is an established technology, used for planning and design
  - Often using airborne surveys
  - Little used in pavement assessment
- With developments in LIDAR, inertial GPS and cost reductions, it is a viable technique for installation on survey vehicles
  - With some advantages over airborne surveys
- Requires suitable equipment and algorithms to create the 3D data
- On its “own” it cannot yet replace high resolution profilers for pavement assessment
- But has some valuable potential in measuring assets adjacent to the pavement
- A multi-purpose vehicle combining LIDAR and profile could allow merging of the data to generate a full carriageway 3D profiler
- Further development of the approach is ongoing