TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Chair of Air Transport Technology and Logistics, TU Dresden

Validating LiDAR sensor surveillance systems for airport operations

LiDAR versus conventional out-the-window view for safety critical airport operations

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Agenda

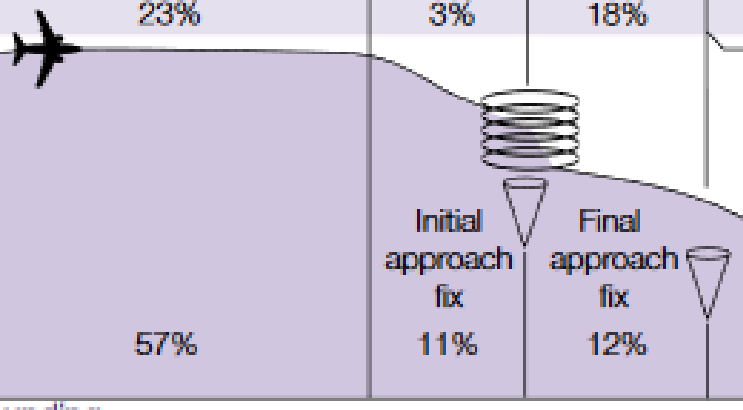
Background
Introduction to LiDAR sensing for Apron Surveillance
Experimental Design
Experimental Setup
Experimental Results
Conclusion & Outlook

Background

Fatal Accidents | Worldwide Commercial Jet Fleet | 2008 through 2017

Percentage of fatal accidents and onboard fatalities

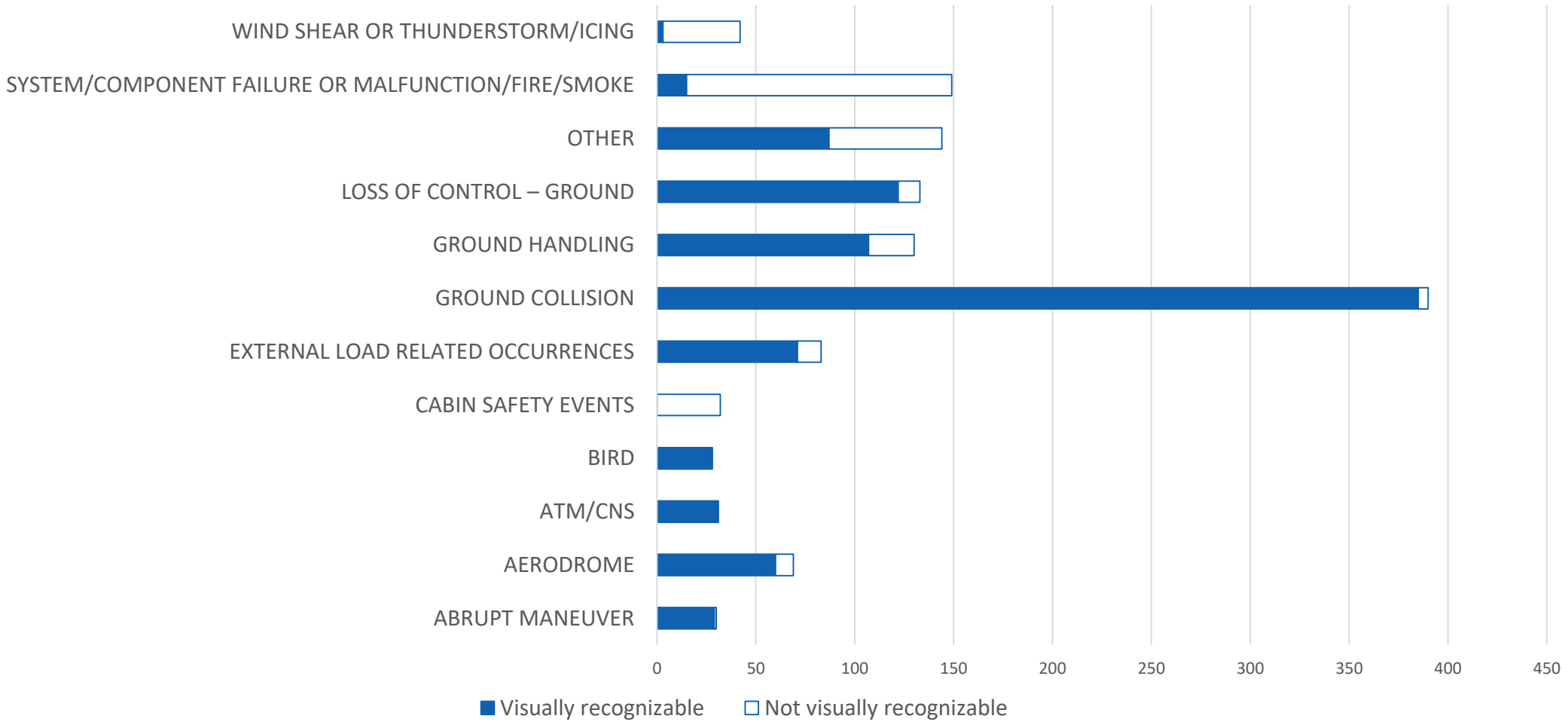
	Taxi, load/ unload, parked, tow	Takeoff	Initial climb	Climb (flaps up)	Cruise	Descent	Initial approach	Final approach	Landing
		14%						49%	
Fatal accidents	9%	7%	7%	5%	11%	4%	7%	27%	22%
Onboard fatalities	0%	7%	1%	4%	23%	3%	18%	32%	12%
		8%						44%	
Exposure (Percentage of flight time estimated for a 1.5-hour flight)		1%	1%	14%	57%	11%	12%	3%	1%



Note: Percentages may not sum to 100% because of numerical rounding.

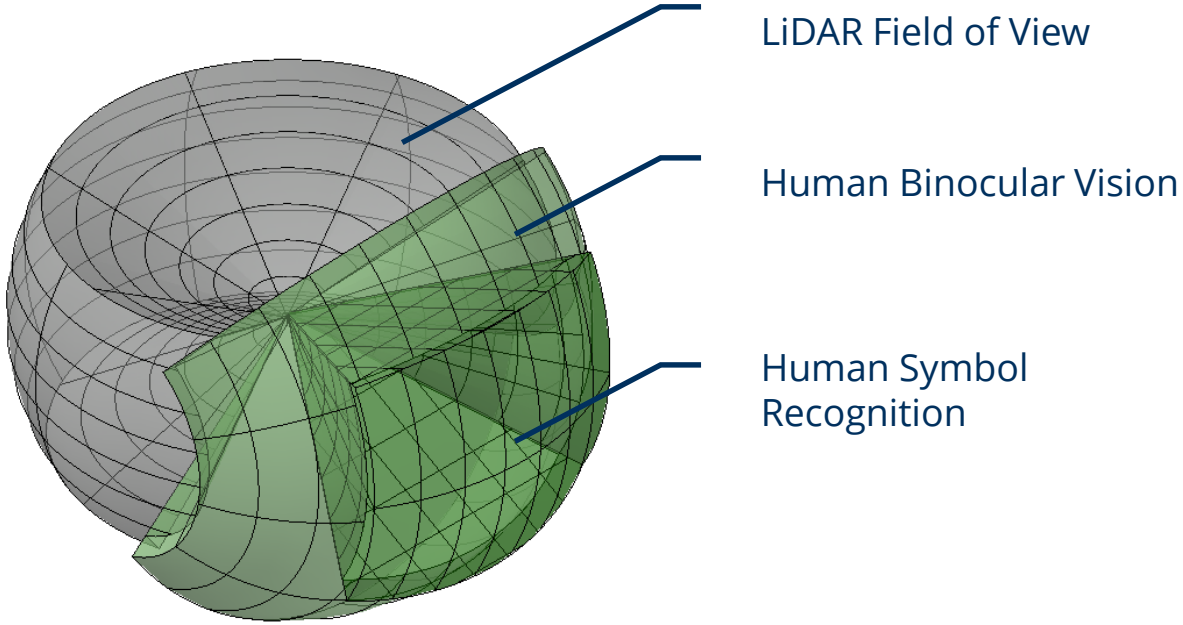
Source: BOEING Statsum 2017

Background
Accidents and Incidents on Apron

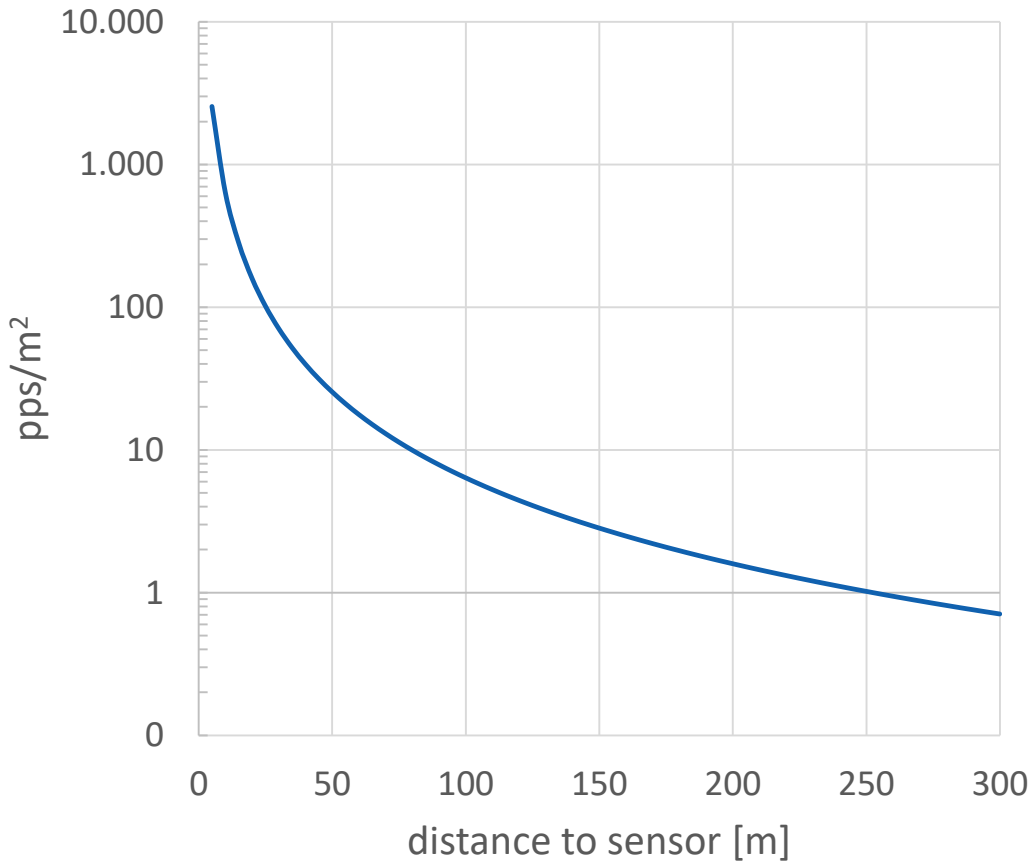


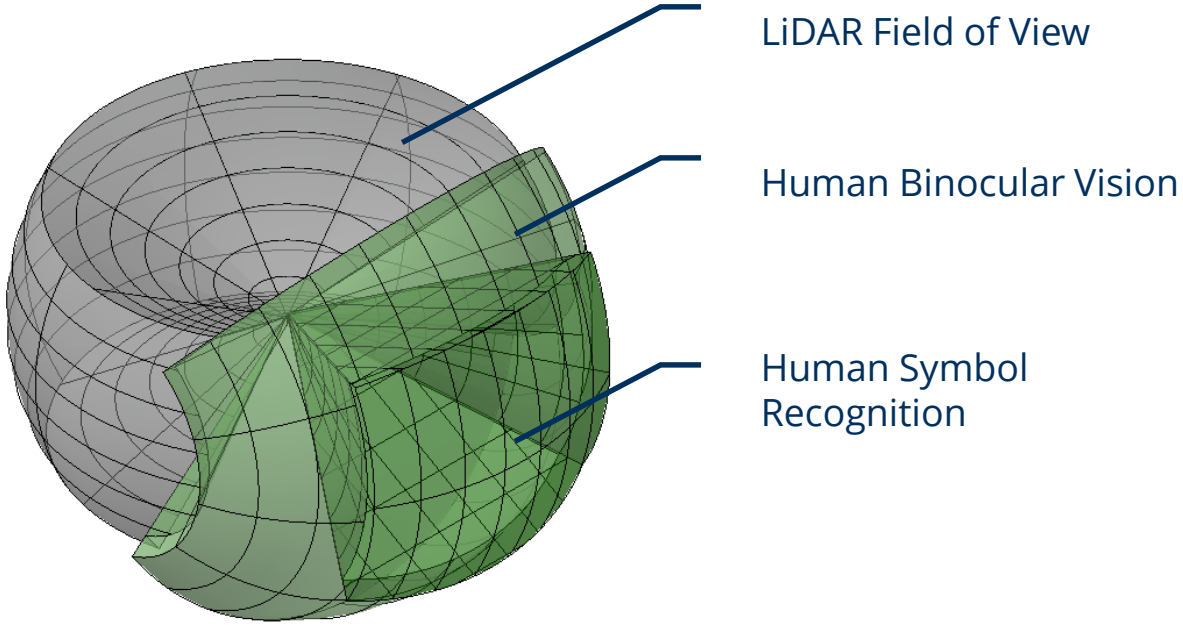
Introduction to LiDAR sensing
Advantages

- Non-cooperative environmental scanning
- Large angles of detection
- Accuracy of position and pose at millimeter range level (?)
- Independent from light conditions (?)
- Less sensitive to weather conditions (?)



Introduction to LiDAR sensing
Temporal resolution





Lidar Equation

$$P_{return}(r,\lambda) = \underbrace{P_0 \times A\eta \times \frac{c \times \tau}{2}} \times \underbrace{\frac{O(r)}{\pi \times r^2}} \times \underbrace{\beta(\theta,\lambda)} \times \underbrace{\exp\left(-2\int_0^r \alpha(r,\lambda)dr\right)}$$

LiDAR system: const.

Backscatter coefficient

Measurement geometry

Transmission term

Reflection values for different surfaces

Description:	Reflectance
Bare aluminum metal that is weathered and scratched/scored	81,21%
Galvanized steel from roof and vent covers	47,37%
Gray and white weathered runway concrete	38,52%
Approximately 30-year-old runway construction concrete with (mostly granite) aggregate showing.	37,84%
Weathered, galvanized bare steel from roof and vent covers	27,27%
Frost. (Particle size 10 µm)	22,52%
Weathered, galvanized steel from roof and vent covers	16,52%
Fine snow (Particle size 24 µm)	9,99%
Unweathered, transparent construction plate window glass	8,65%
Medium granular snow (Particle size 82 µm)	2,03%
Tap water	2,00%
Ice	1,61%
Coarse snow (particle size 178 µm)	0,63%

Source: NASA spectral library for 1540 nm

Lidar Equation

$$P_{return}(r,\lambda) = \underbrace{P_0 \times A\eta \times \frac{c \times \tau}{2}} \times \underbrace{\frac{O(r)}{\pi \times r^2}} \times \underbrace{\beta(\theta,\lambda)} \times \underbrace{\exp\left(-2\int_0^r \alpha(r,\lambda)dr\right)}$$

LiDAR system: const.

Backscatter coefficient

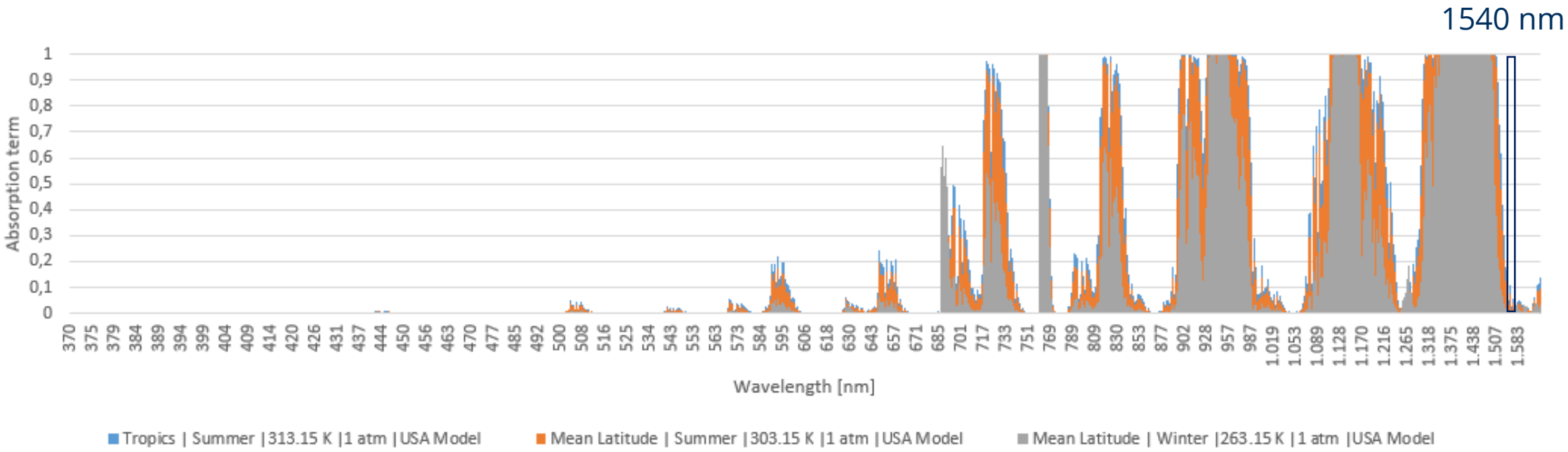
Measurement geometry

Transmission term

C - atmospheric composition

Introduction to LiDAR sensing

Transmission term/Absorption term



Weather condition	Transmission term for r = 500m
Mean Latitude | Winter |263.15 K	$1 - 0.0017 = 0{,}9983$
Mean Latitude | Summer |303.15 K	$1 - 0.0017 = 0{,}9983$
Tropics| Summer |313.15 K	$1 - 0.0019 = 0{,}9981$

Source: simulated spectra from HITRAN data

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Video available on www.linkedin.com/in/hannesbrassel

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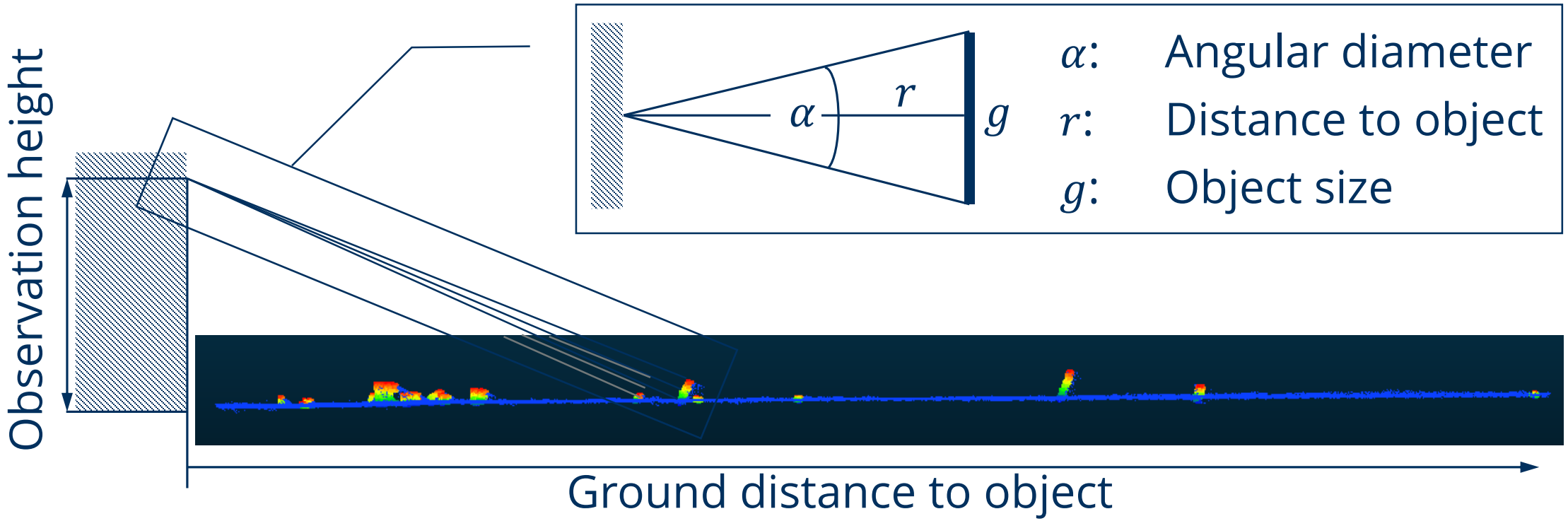
Experimental Design



$$1° = 60 \text{ arcmin } [']$$

$$\alpha = 2 \arctan\left(\frac{g}{2r}\right) \cdot 60['].$$

Experimental Design

Visibility Scenario	Description
Clear/Day:	Clouds and visibility okay (CAVOK) according to Meteorological Terminal Air Report (METAR) during daytime.
Clear/Night:	CAVOK during nighttime.
Rain/Day:	“Precipitation in the form of liquid water drops, varying in size from 0.5 to a maximum of 6 mm in diameter [...]” during daytime.
Rain/Night	Rain during nighttime.

Experimental Design

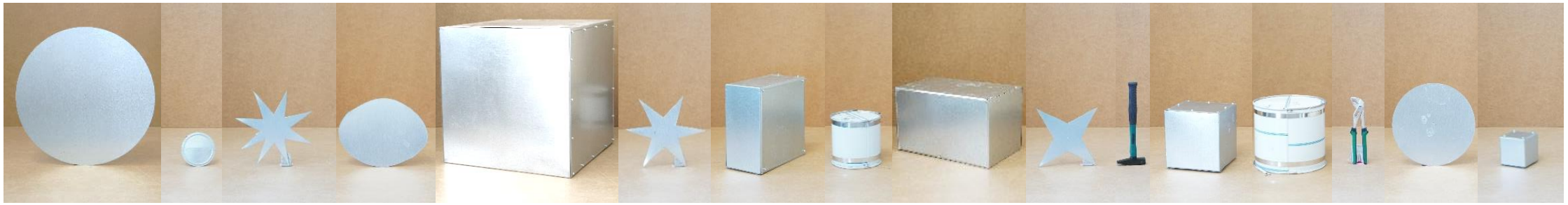
Detection (‘is there an object?’)

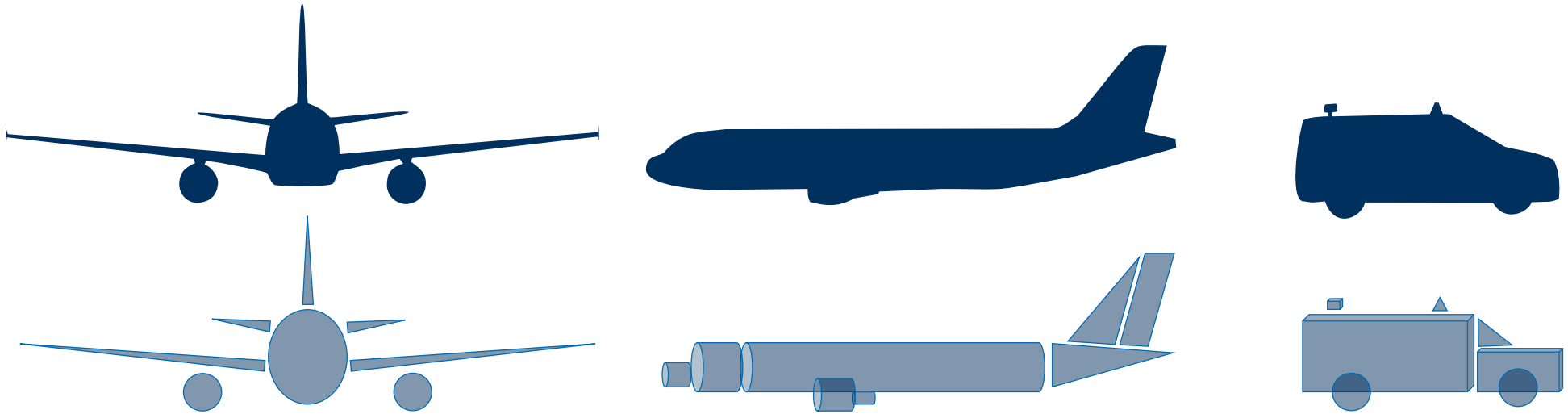
Recognition (‘is the detected object an aircraft?’)

Identification (‘is the recognized aircraft an A320?’)

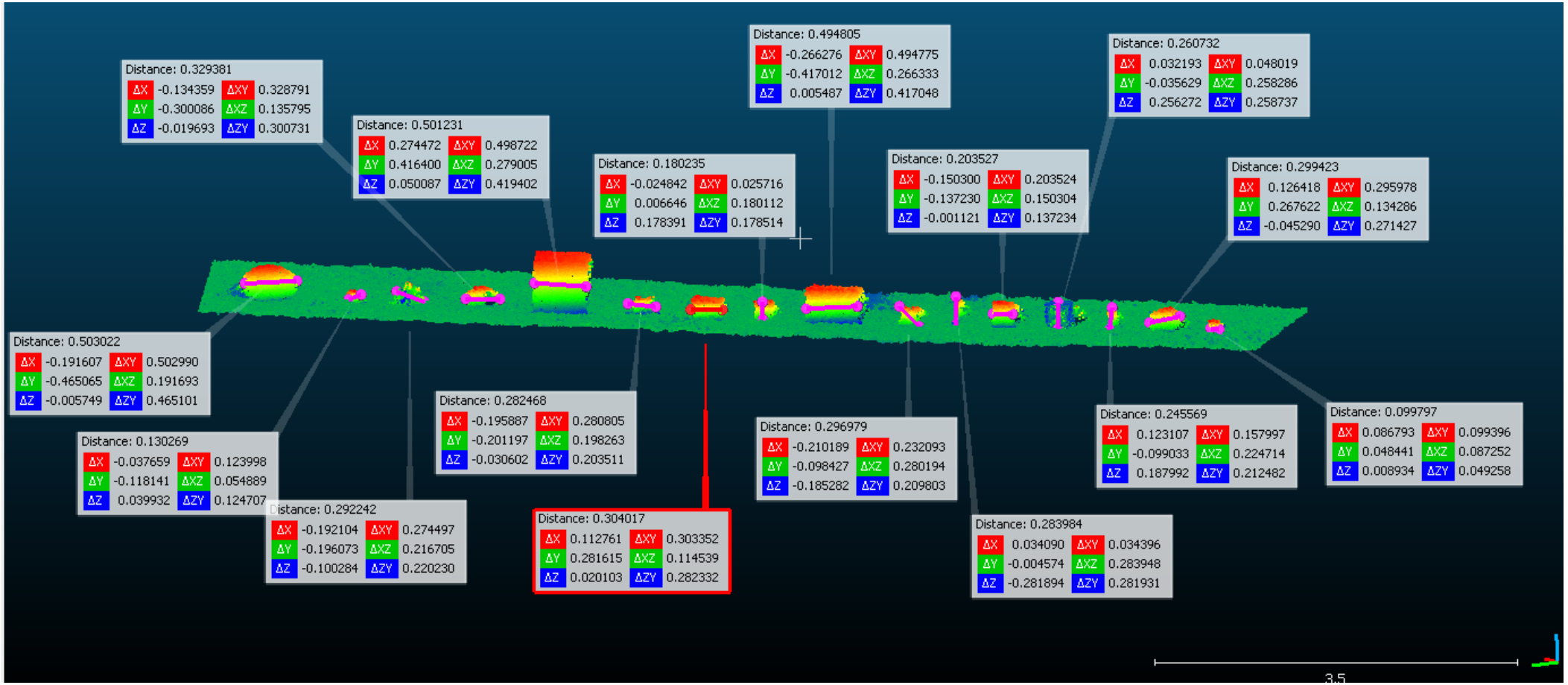
Size Estimation (‘how large is a detected object?’)

Experimental Setup
Recognition by components

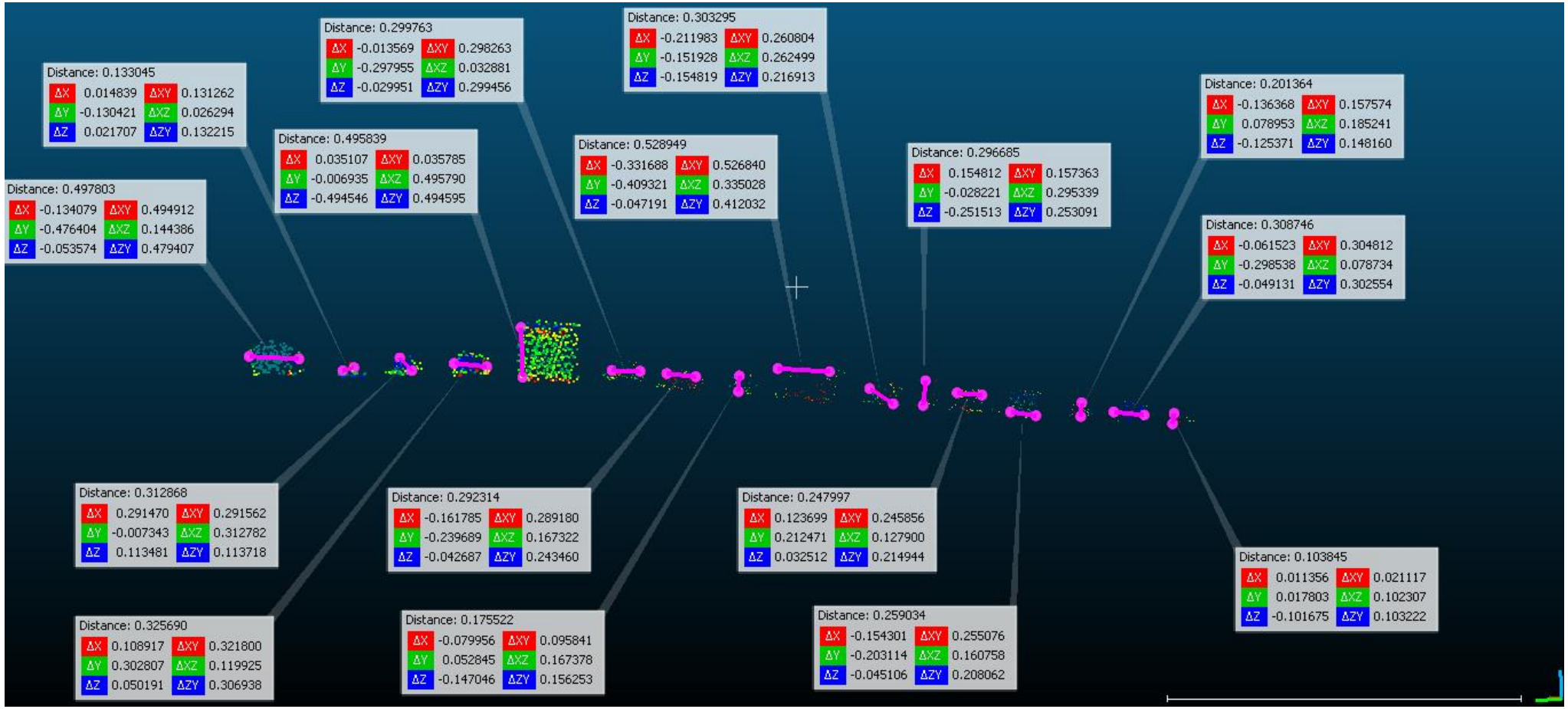




Experimental Results

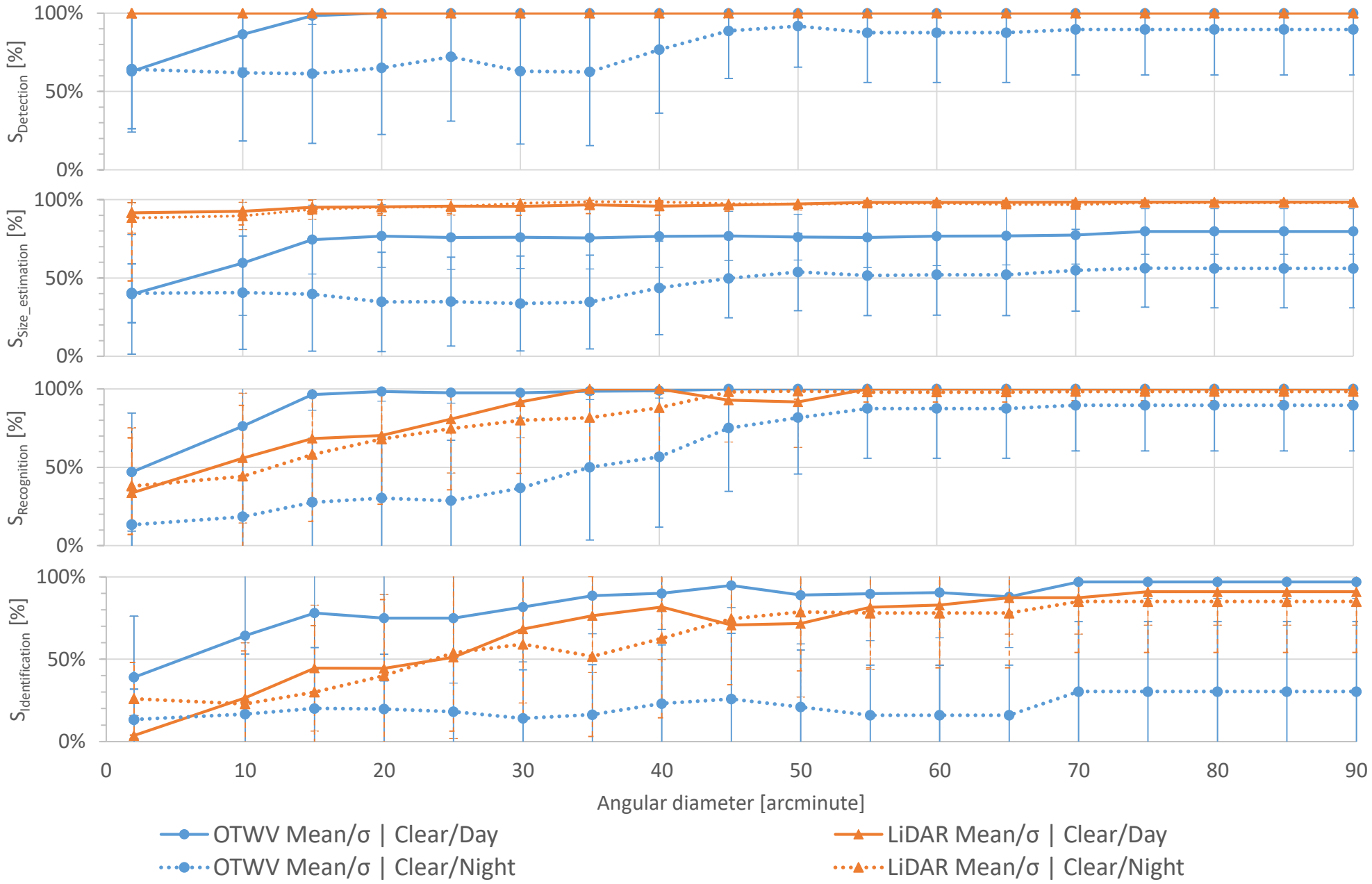


Experimental Results



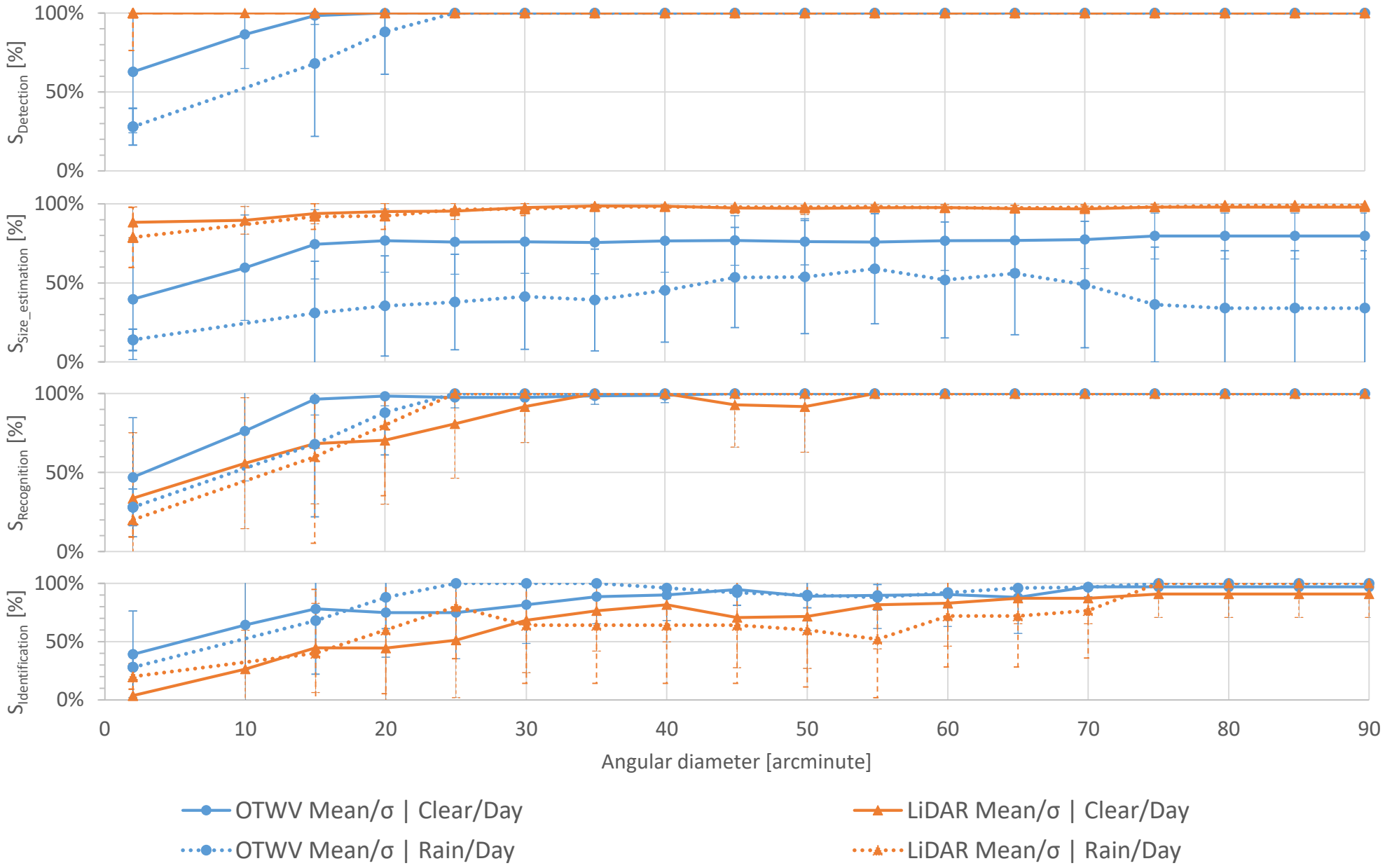
Experimental Results

Influence of **illumination** on object detection/size estimation/recognition/identification:

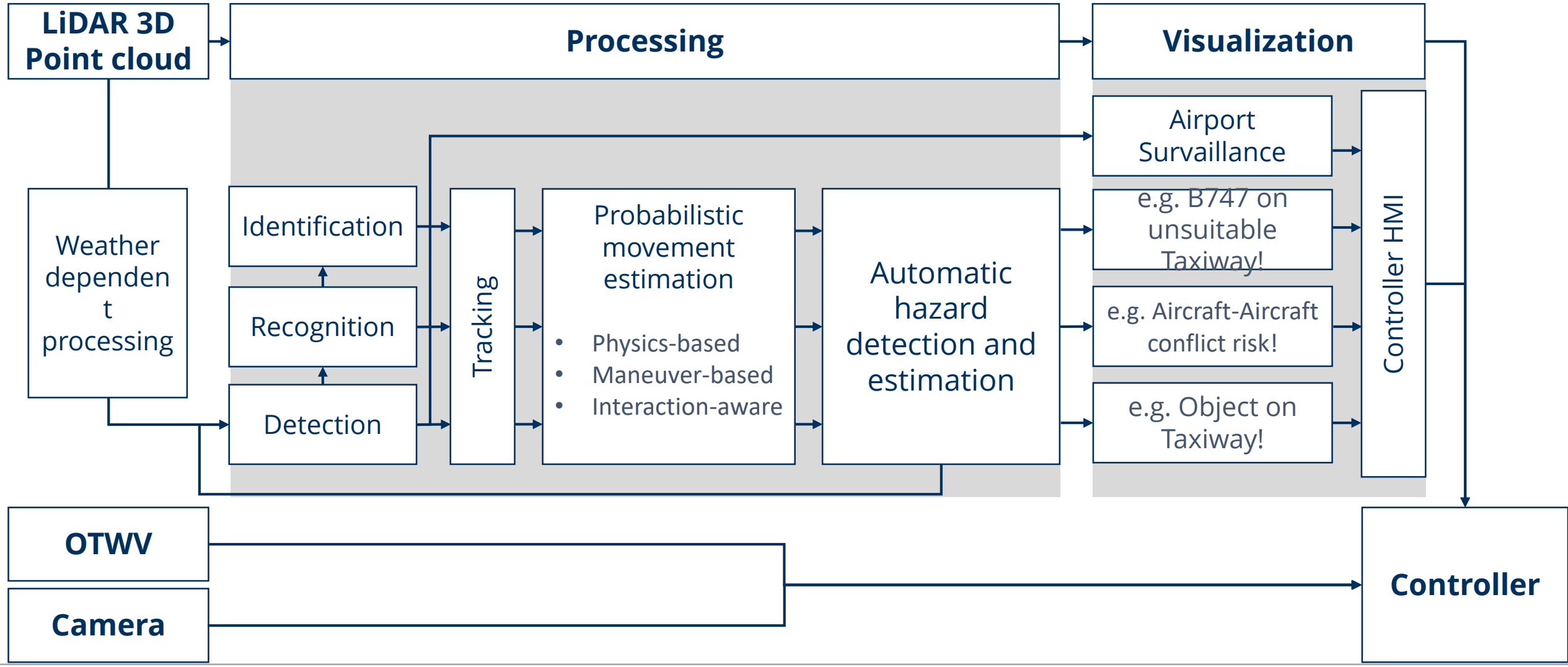

100%
50%
0%
$S_{Detection}$ [%]
$S_{Size\_estimation}$ [%]
$S_{Recognition}$ [%]
$S_{Identification}$ [%]
0
10
20
30
40
50
60
70
80
90
Angular diameter [arcminute]
OTWV Mean/σ | Clear/Day
OTWV Mean/σ | Clear/Night
LiDAR Mean/σ | Clear/Day
LiDAR Mean/σ | Clear/Night

Experimental Results

Influence of **rain** on object detection/size estimation/recognition/dentification:


100%
50%
0%
$S_{Detection}$ [%]
$S_{Size\_estimation}$ [%]
$S_{Recognition}$ [%]
$S_{Identification}$ [%]
0
10
20
30
40
50
60
70
80
90
Angular diameter [arcminute]
OTWV Mean/σ | Clear/Day
OTWV Mean/σ | Rain/Day
LiDAR Mean/σ | Clear/Day
LiDAR Mean/σ | Rain/Day

Outlook


LiDAR 3D Point cloud
Processing
Visualization
Weather dependent processing
Identification
Recognition
Detection
Tracking
Probabilistic movement estimation
• Physics-based
• Maneuver-based
• Interaction-aware
Automatic hazard detection and estimation
Airport Survaillance
e.g. B747 on unsuitable Taxiway!
e.g. Aircraft-Aircraft conflict risk!
e.g. Object on Taxiway!
Controller HMI
OTWV
Camera
Controller

Thank you for your attention.

Contact:

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