Hazard Avoidance Algorithm for a 3D Imaging Flash Lidar Utilizing Multi-Frame Super-Resolution Technique

Alexander Bulyshev
Coherent Applications, Inc
Farzin Amzajerdian
Nasa Langley Research Center

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Outline

- Flash Lidar
- Super-resolution
- Hazard Detection Algorithm Goals
- Hazard Detection Algorithm Structure
- Performance Analysis and Simulation
- Experimental Data Processing
- Conclusion

Flash Lidar as a tool for Hazard Detection for safe landing on unprepared surface

- Flash lidar is capable to record full 3-D images with a single laser pulse, freezing the scene on every frame by removing all motion of the transmitter/receiver platform.
- Each pixel in the FPA takes independent measurements of the lidar pulse time of flight to the target. Therefore, the flash lidar permits much higher frame rates without any blurring or inaccuracies due to platform motion.
- Potentials of Flash Lidar technology have been demonstrated through aircraft flight tests and most notably, onboard Morpheus, a terrestrial rocket-powered vehicle.

3D Super-Resolution

- Super-Resolution is a technique which allows to convert a set of low resolution images into high resolution image
- 3D Super-Resolution Algorithm was developed to process Flash Lidar Data to produce high resolution DEM specifically for hazard detection and avoidance
- Based on the SR results, an algorithm for hazard detection and avoidance was developed and tested

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Goal: to find hazard free areas

The main criteria:

- Data statistically significant
- Deviation from flat surface
- Slope

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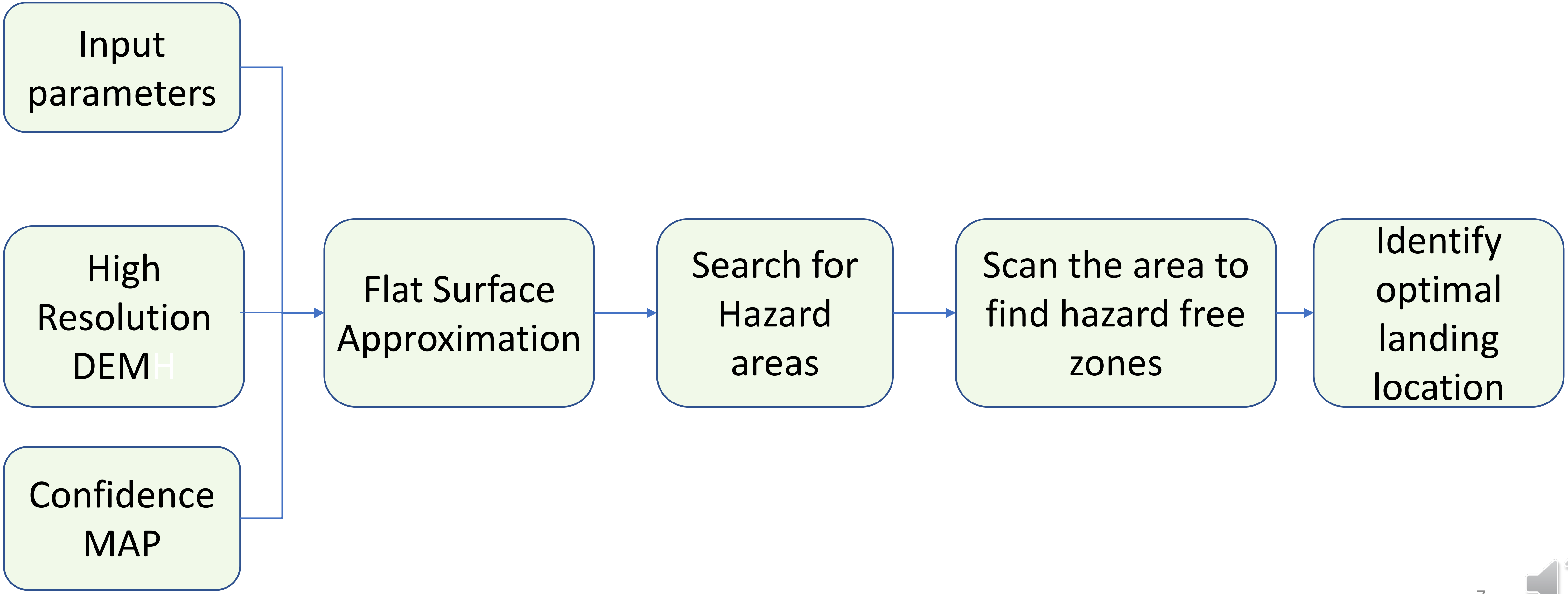
Algorithm description:

- SR algorithm modification to provide confidence map
- Choice of input parameters: radius of the safe area, elevation tolerance, slope tolerance, discrete grid for safe space centers, level of significance for the confidence map
- Flat surface approximation
- Applying threshold method to find hazards to the areas with high level of significance
- Scanning the area to find landing safe spots
- Sorting landing sites by roughness and find the best landing spot

HDA BLOCK DIAGRAM

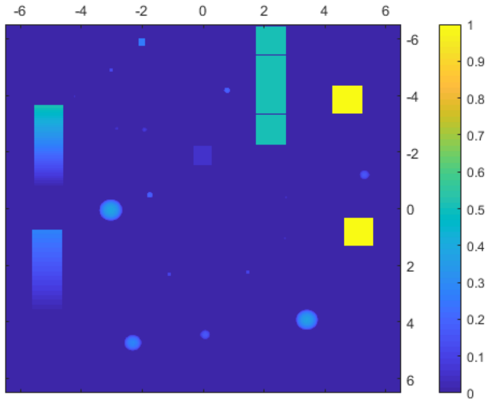


Modeling plan:

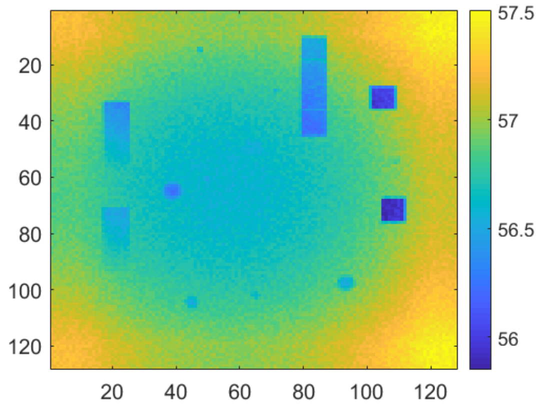
Computer generated data

- ➢ Create the DEM model
- ➢ Chose the trajectory
- ➢ Simulate Flash Lidar frame data using camera model
- ➢ Solve the inverse problem and restore high resolution DEM
- ➢ Chose HDA parameters
- ➢ Apply HDA code to find optimal landing site

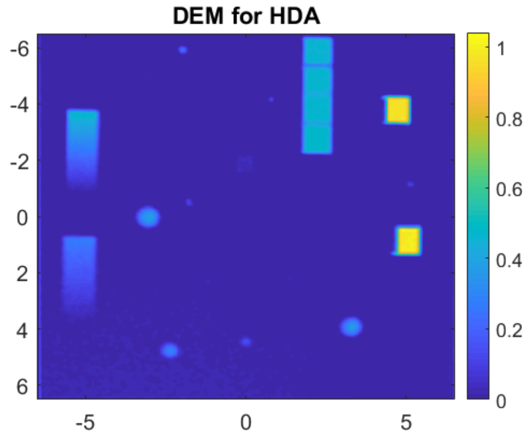
Using Computer Generated Data, SR Part, no “bad” pixels



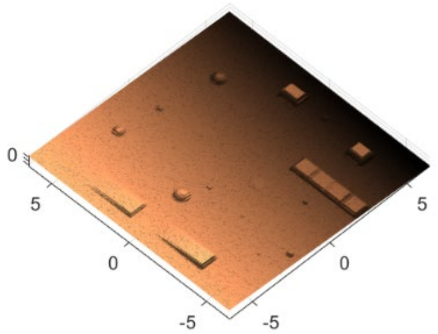
Gentry site elevation model, m

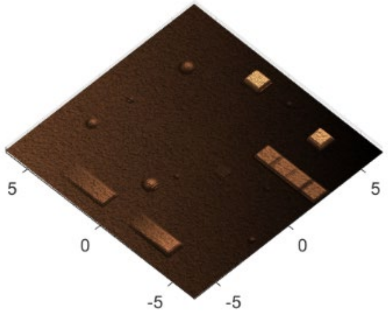


Lidar Range Frame, m



SR DEM, 20 frames used





Example of data modeling and SR software use. Close to vertical trajectory was used. Simulated normally distributed noise with standard deviation of 10 cm.

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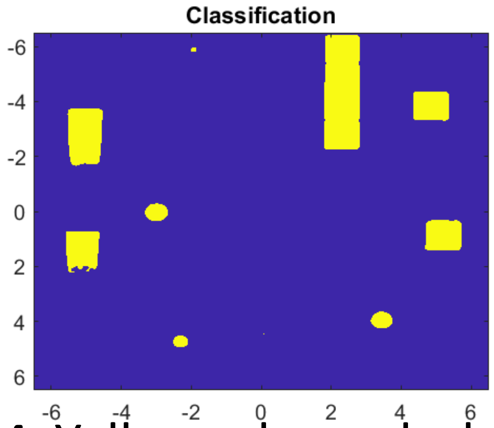
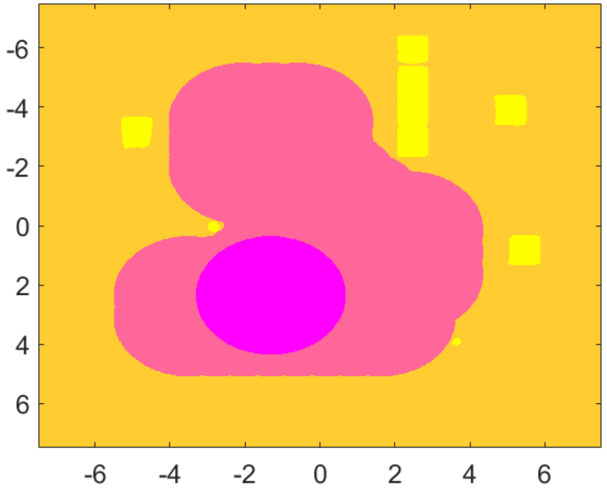
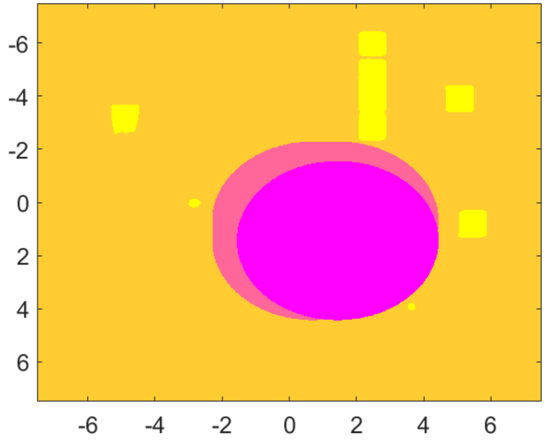
Using Computer Generated Data, Hazard Detection Part, no “bad” pixels



Classified DEM. Yellow – hazards, blue – hazard free



Radius = 2 m



Radius = 3 m

Map shows hazards and hazard-free areas. Yellow– hazards, brown + magenta – available for landing area, magenta – optimal landing spot.

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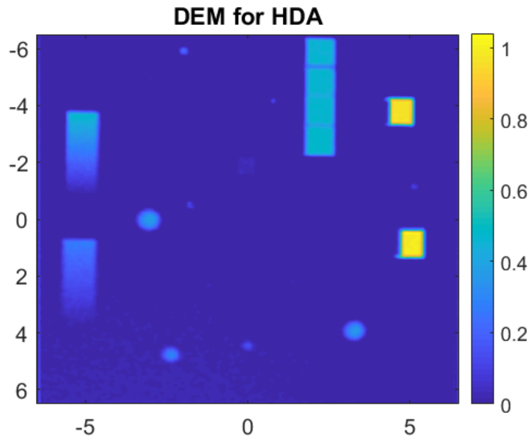
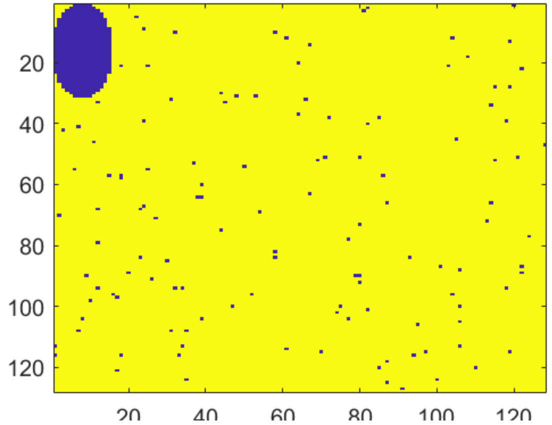
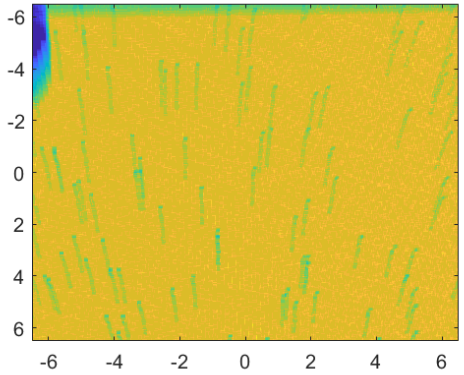
Using Computer Generated Data, "bad" pixels present

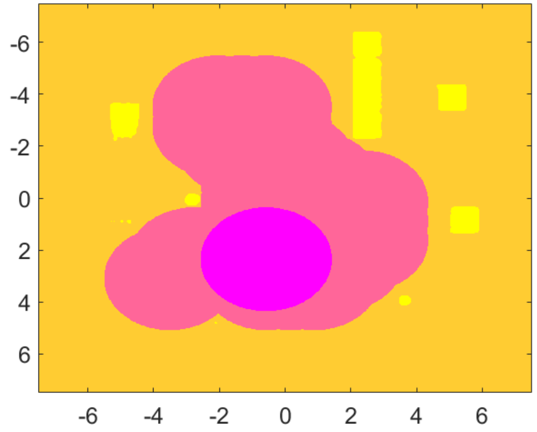




"Bad" pixels map



Confidence Map



Hazard/hazard free Map

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Flash Lidar Gantry Test

Hazard field view

General view

Gantry Tests Data Processing

- Chose the set of frames
- Restore high resolution DEM
- Chose HDA parameters
- Apply HDA code to find optimal landing site.

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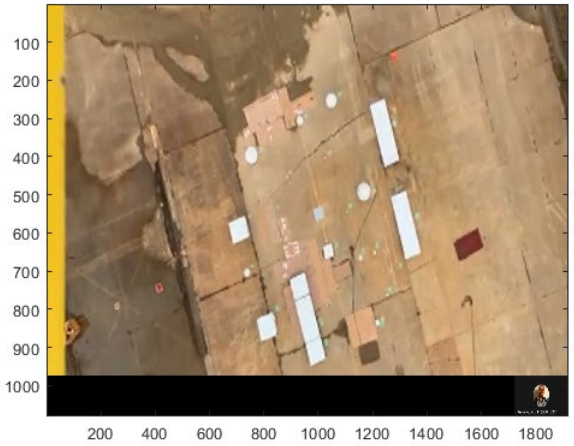
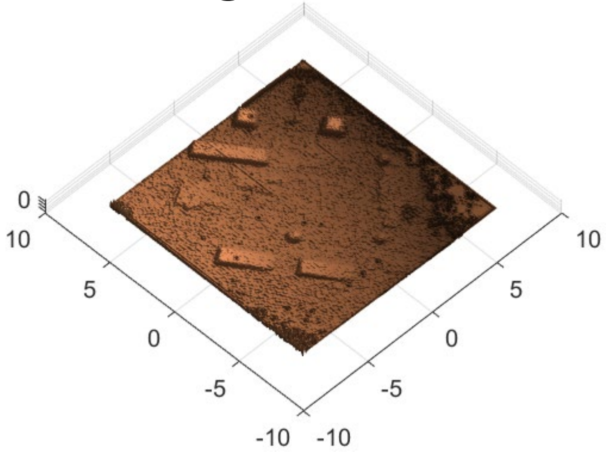
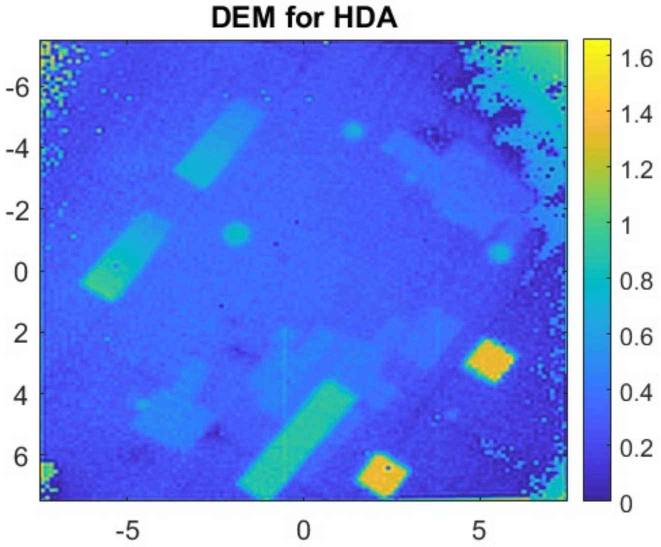
Using Gantry Tests Data from 01/27/2021, SR Part



Hazard Field, general view



SR DEM,3D view



SR DEM, m

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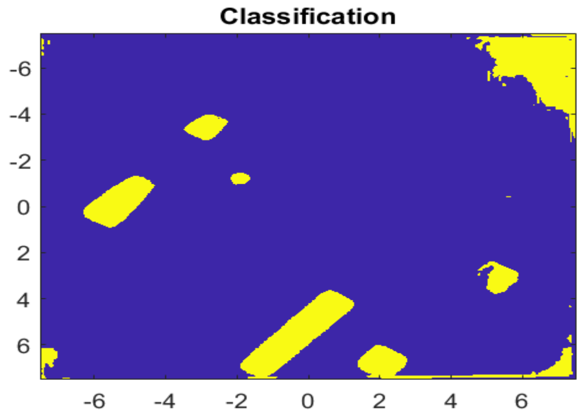
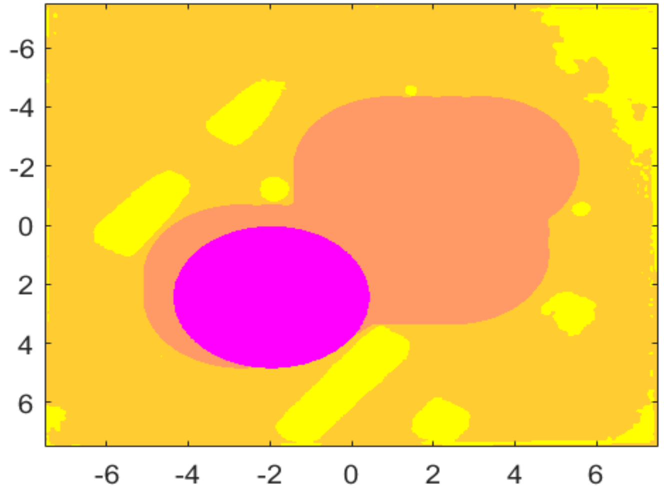
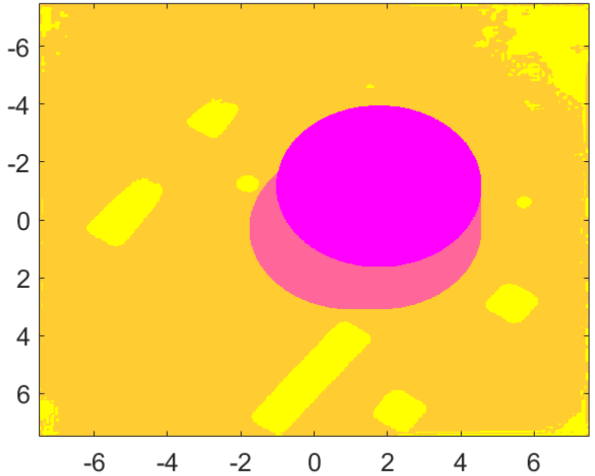
Using Gantry Tests Data from 01/27/2021, Hazard Detection Part



Classified map, yellow – hazards, blue - hazard free



R = 2 m



R = 3 m

Map shows hazards and hazard free areas.
Yellow– hazards, brown + magenta – available for landing area, magenta – optimal landing spot.

Conclusion:

1. An algorithm for detecting terrain hazards and identifying hazard-free areas has been developed based for Flash Lidar generated Super-Resolution DEMs
2. The algorithm was tested on computer generated data and data obtained from Gantry Tests showing very promising results