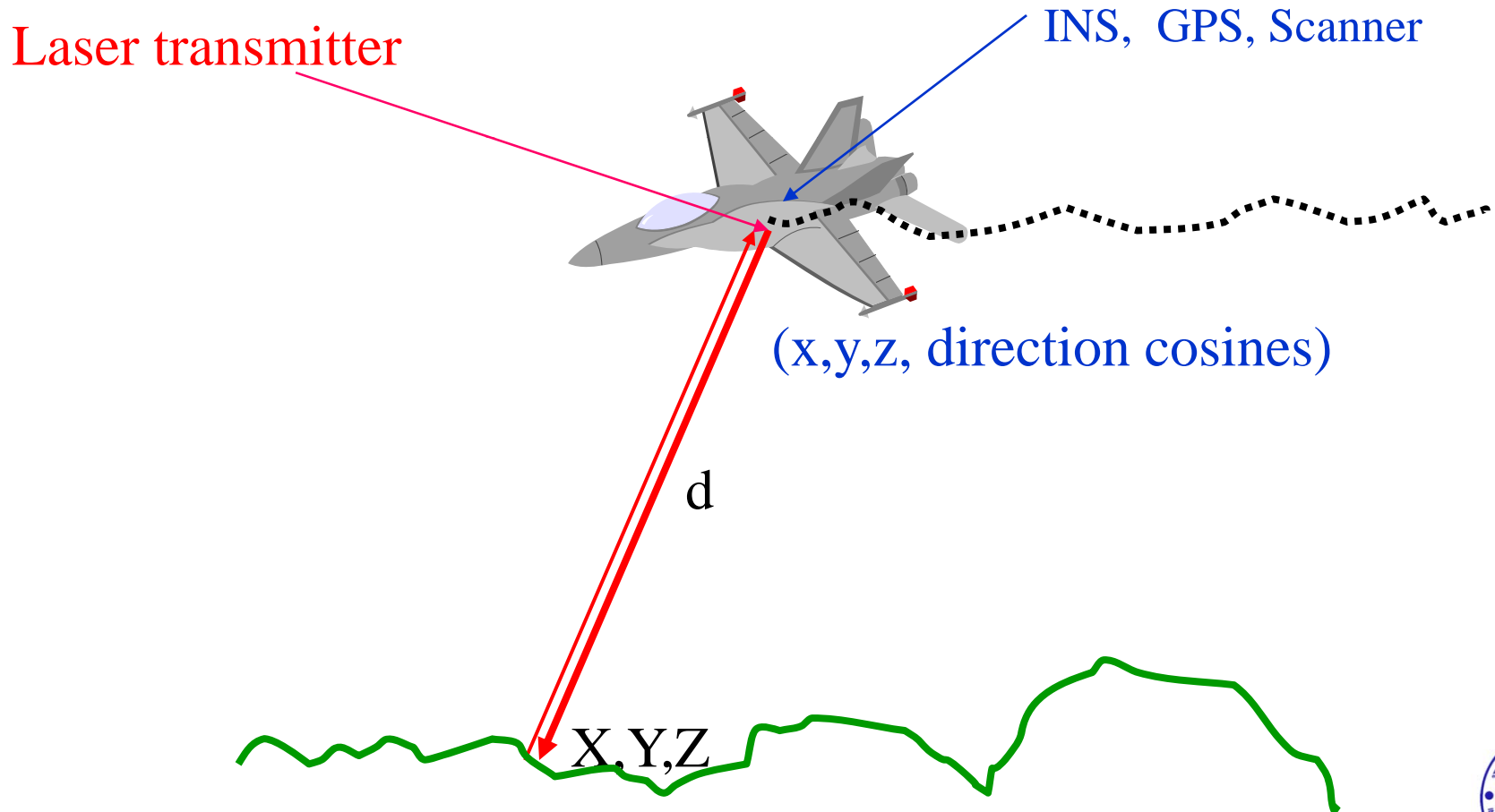


An Object-Oriented Software Development Approach to Design Simulator for Airborne Altimetric LiDAR

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Principle of LiDAR



LiDAR Technology

- ❑ Provides accurate topographic data at high speed
- ❑ Data collection with higher density, accuracy & less time
- ❑ Weather and light independent

Applications:

- DEM generation
- Flood hazard zonation
- Cellular networks etc.

Object-Oriented Software Development

Initial Investigation (Why simulator ?)

- ❑ LiDAR Instrument is very costly
- ❑ LiDAR data is not available in most of the countries
- ❑ LiDAR data is not available for teaching as required
- ❑ LiDAR data is not available for research as required
- ❑ Software for flight planning

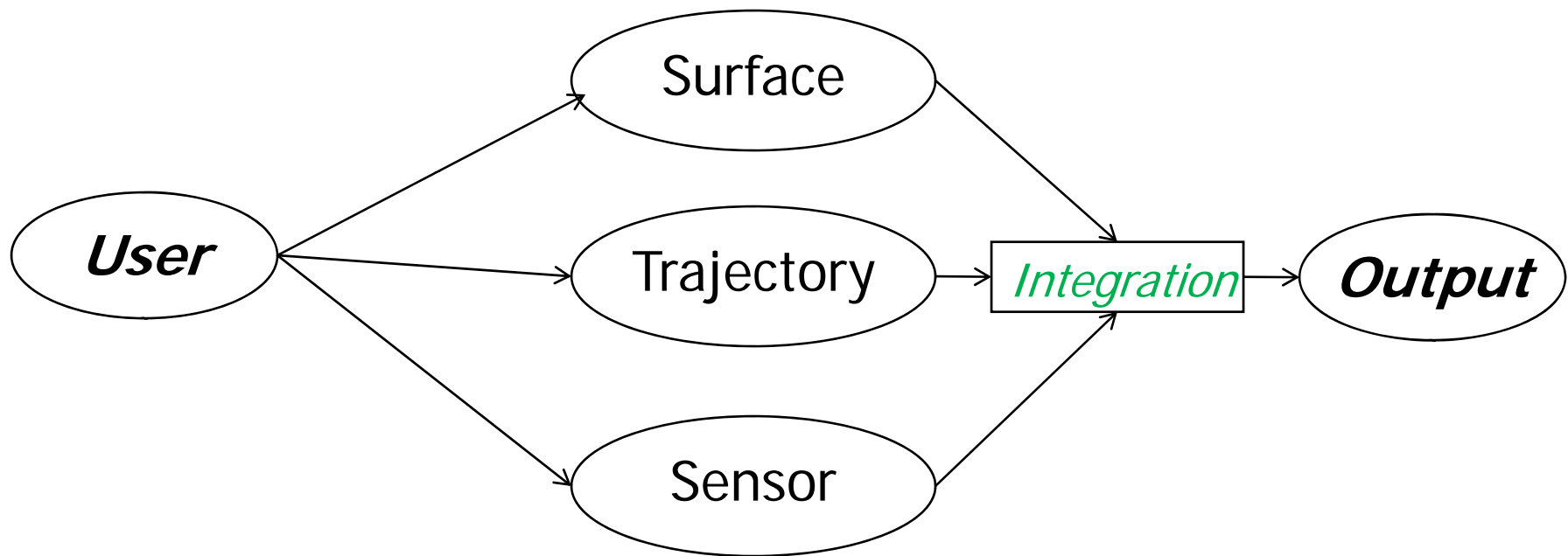
Requirements

- User friendly GUI
- Simulation of generic as well as commercial sensors
- Simulation of earth like surfaces
- Flight trajectory as in case of actual flight
- Possibilities of error introduction
- Output data in common format
- Help and tutorial

Feasibility study

- Sufficient background is available for the system development
- The system can be engineered using current technology
- Development can be done within the budget & time
- Developed system will be useful for the user group

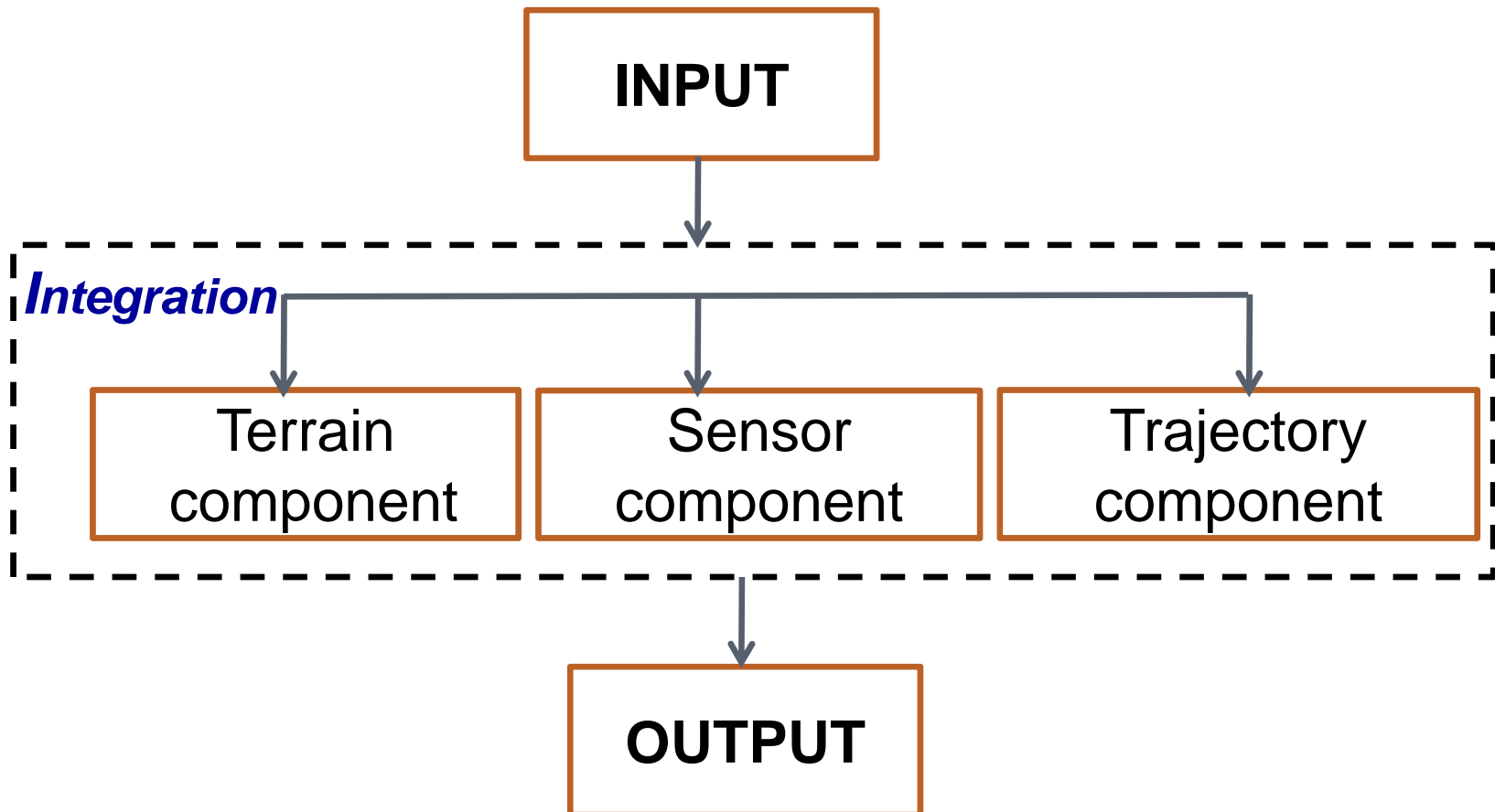
Object-Oriented analysis



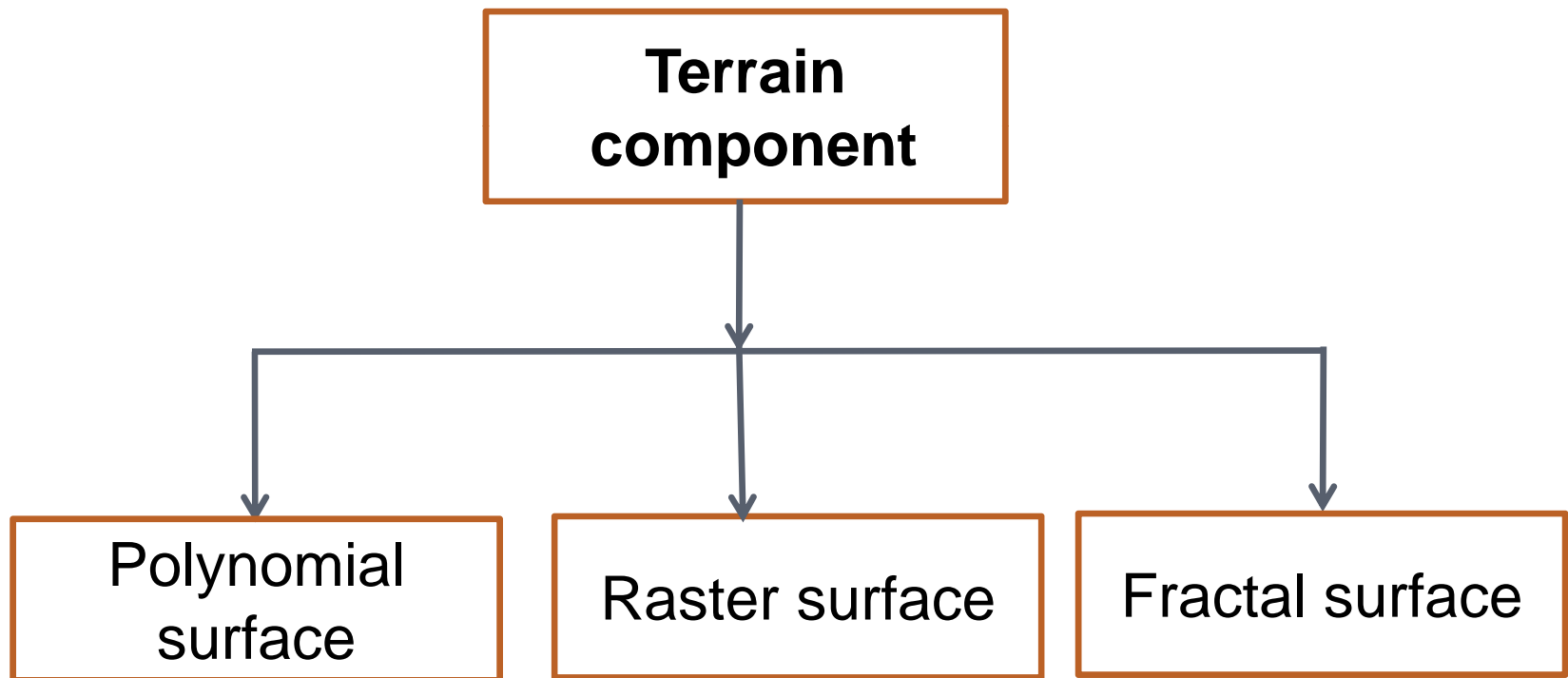
Use case diagram

-
- ❑ Objects in the problem domain is identified
 - ❑ Object relationships are made
 - ❑ Object state table is developed
 - ❑ Inheritance diagram for objects is made

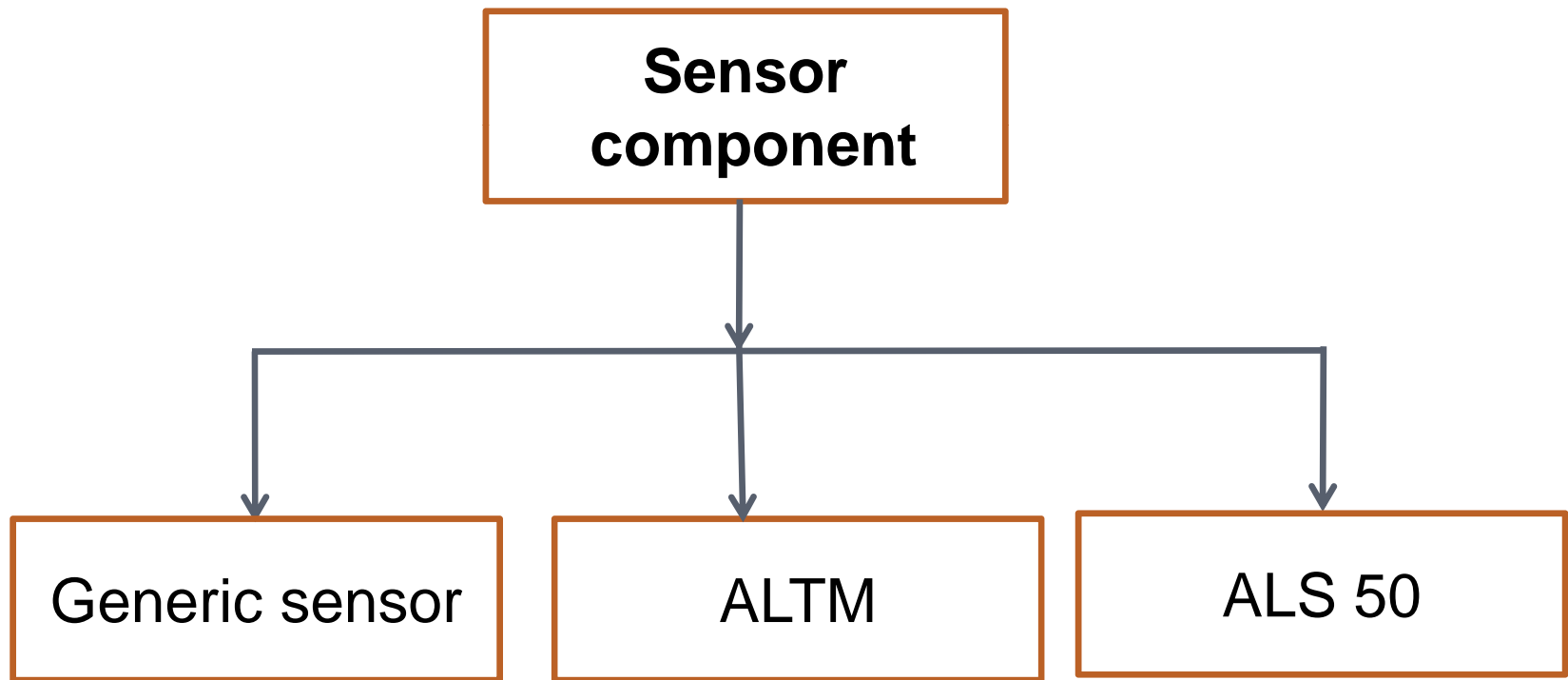
Object-oriented design



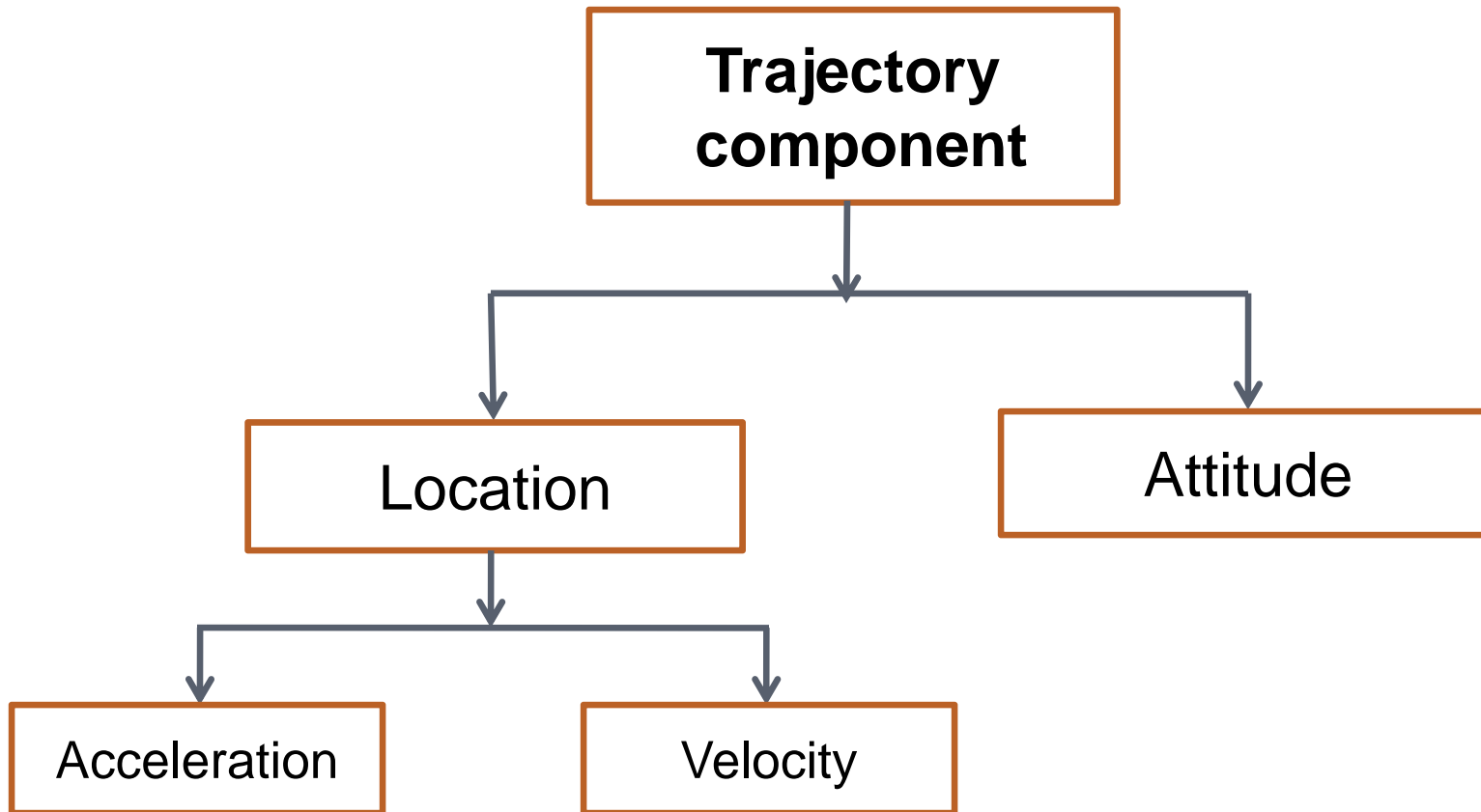
Terrain components



Sensor components



Trajectory components



Class design

- ❑ Identify classes from the components

- ❑ Identify subclass within each class

- ❑ Identify abstraction in each class

- ❑ Identify the common behaviour of classes

System implementation

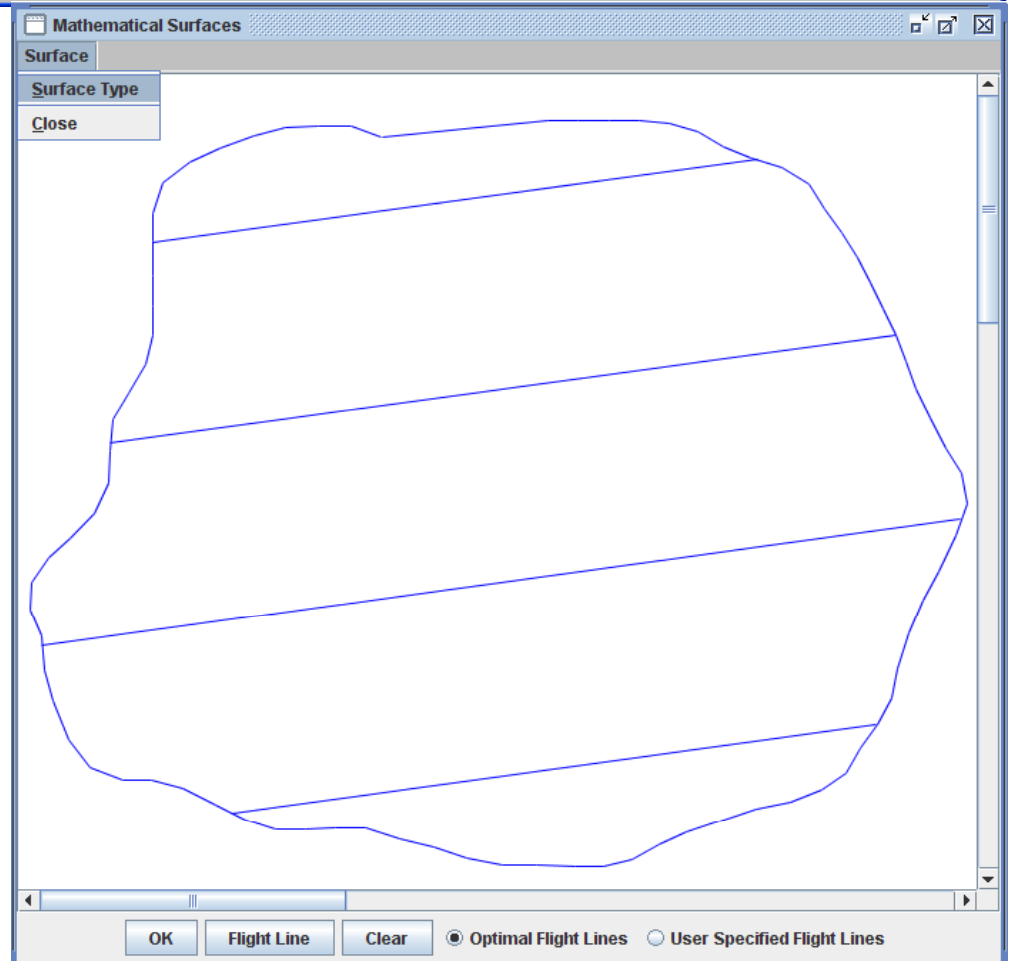
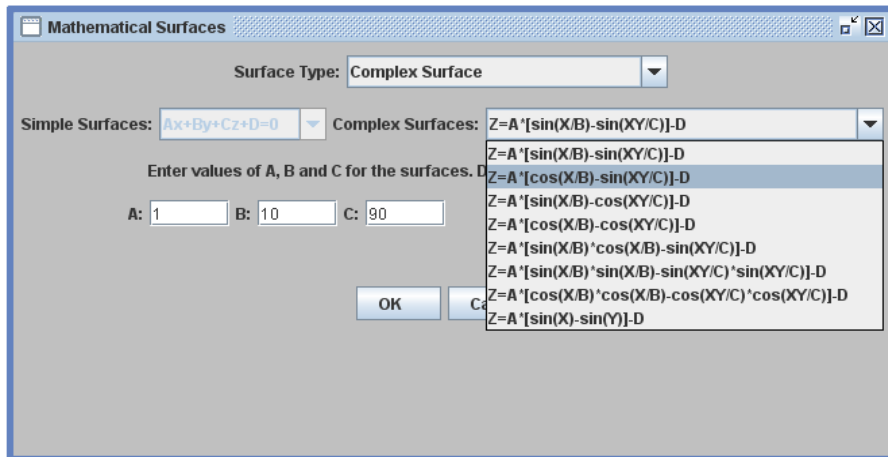
- Java is used to realize the design
- Each classes are implemented with its relationship
- Standard way of coding is used
- Methods are designed for each basic task

Complexities handled

- ❑ Efficient algorithms are designed
- ❑ Threads are used to optimize software execution
- ❑ Special data structures are designed to handle memory problems
- ❑ New file formats are designed to improve I/O

Software Screenshots

Polynomial surface



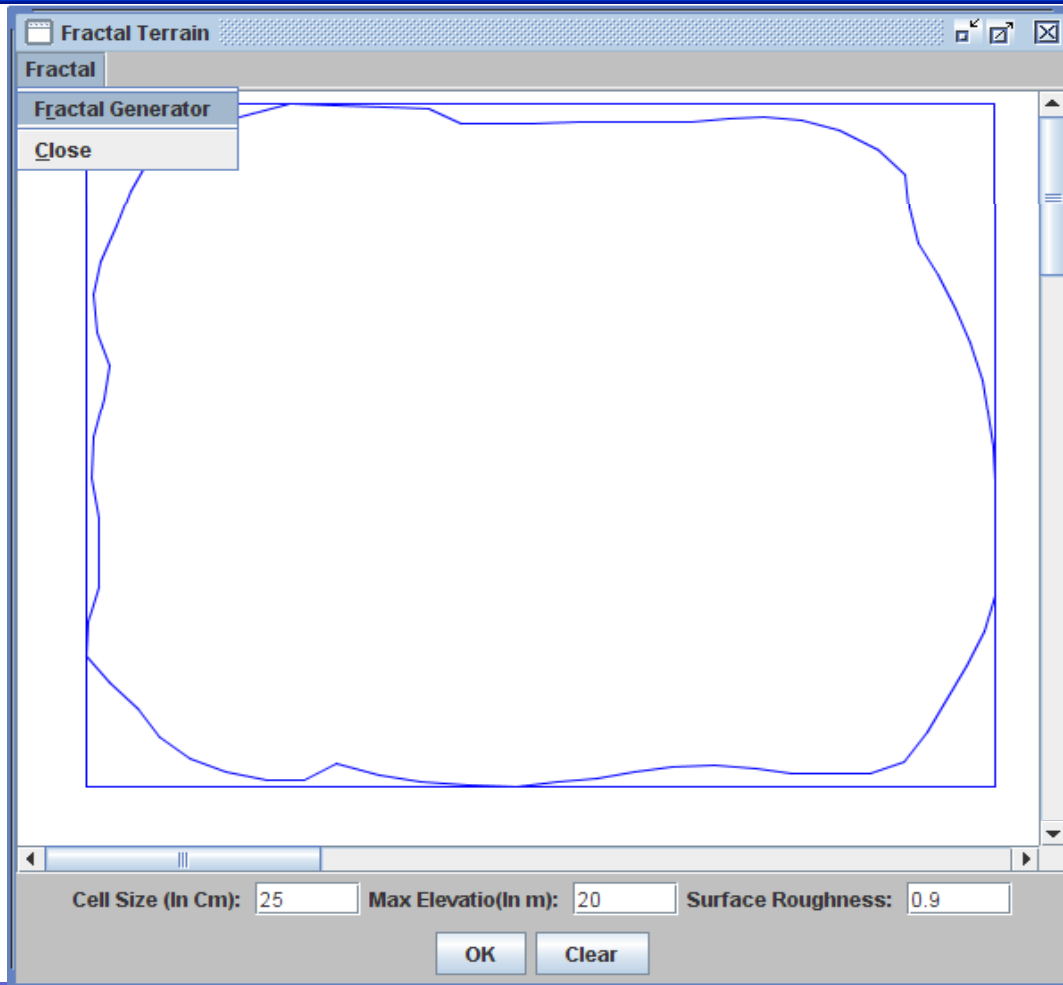
Raster surface(City model)

The screenshot displays the 'Airborne Altimetric LiDAR Simulator' software interface. At the top, there is a menu bar with 'File', 'Menus', and 'Help'. Below the menu bar is a toolbar with icons for 'Surface', 'City Model', 'Fractal Terrain', 'Flight', 'Sensor', a 3D coordinate system (Roll, Pitch, Yaw), 'Error Simulation', and 'Output'. The main workspace contains a grid of geometric shapes (rectangles, circles, triangles) representing a city model. A blue outline highlights a specific area on the grid. A status bar at the bottom shows 'Cell Size (In Cm): 25' and buttons for 'OK', 'Draw Area', 'Rotate', 'Delete', and 'Clear'. Below the status bar are radio buttons for 'Optimal Flight Lines' and 'User Specified Flight Lines'.

Overlaid on the main interface are several dialog boxes:

- Mathematical Surfaces For Raster:** A dialog box with 'Surface Type: Complex Surface'. It has two dropdown menus: 'Simple Surfaces: $Ax+By+Cz+D=0$ ' and 'Complex Surfaces: $Z=A*\sin(Y/C)$ '. Below these are four equations: $Z=A*\sin(Y/C)$, $Z=A*\cos(Y/C)$, $Z=A/2*\sin(X/b)+\cos(Y/C)$, and $Z=A/2*\sin(X/b)*\cos(XY/BC)+\cos(Y/C)$. There is an 'Enter value of A:' field with the value '5' and 'OK' and 'Cancel' buttons.
- Flight Direction:** A small dialog box with a 'Clear' button.
- Writing Raster Data:** A progress dialog box showing a progress bar at 32%.
- Input:** A dialog box with a question mark icon and the text 'Enter height of the building (meter)'. It has an input field and 'OK' and 'Cancel' buttons.

Fractal surface



Acceleration

Airborne Altimetric LiDAR Simulator

File Menus Help

Surface City Model Fractal Terrain Flight Sensor Error Simulation Output

Platform Component

Flight

Acceleration Choice

Select Acceleration Type

Simulated Acceleration Without Acceleration

OK Cancel

Acceleration Parameters

Enter values of acceleration parameters

A, B, C & D values for accelerations:

	A	B	C	D
ax:	1.05	2.38	0.51	2.77
	0.25	4.45	0.27	3.88
	0.3	80	0.2	100
ay:	0.05	3.38	0.51	3.77
	1.25	2.45	1.07	2.88
	0.3	85	0.2	95
az:	0.85	1.38	1.51	4.77
	0.25	4.45	1.07	0.88
	0.2	80	0.3	100
m:	0.0			

OK Cancel

Sensor component

Airborne Altimetric LiDAR Simulator

File Menus Help

Surface City Model Fractal Terrain Flight Sensor Error Simulation Output

Sensor Types

- Generic Sensor
- ALS 50
- ALTM
- Close

Parameters for Generic Sensor

Flight Plan

Altitude (m AGL): 1100

Overlap (%): 1.5

Velocity (m/s): 60

LiDAR Settings

Scan Pattern: Sinusoidal

Firing Frequency (kHz): 20

Scan Frequency (Hz): 48

Scan Angle (deg): +/- 25

OK Cancel

Parameters for ALS50 Sensor

Flight Plan

Altitude (m AGL): 1100

Overlap (%): 1.5

Velocity (m/s): 60

LiDAR Settings

Firing Frequency (kHz): 20

Scan Frequency (Hz): 30

Field of View (deg): 5

OK Cancel

Parameters for ALTM Sensor

Flight Plan

Altitude (m AGL): 1100 (Up to 2000 m)

Overlap (%): 1.5

Velocity (m/s): 60

LiDAR Settings

Firing Frequency (kHz): 20 (Up to 100 kHz)

Scan Frequency (Hz): 30 (Up to 35 Hz)

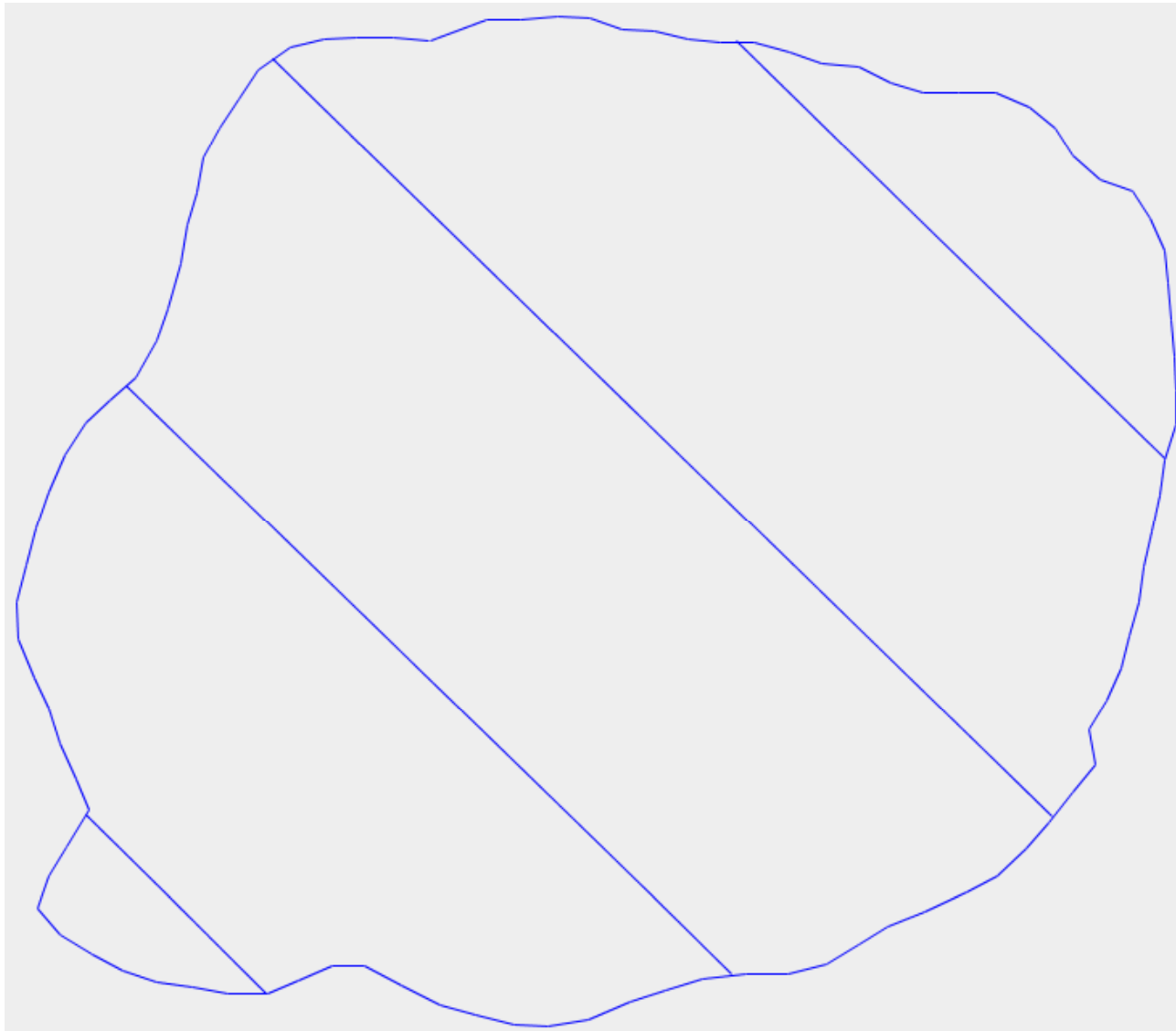
Scan Angle (deg): +/- 25 (Up to 30 deg)

OK Cancel

System defined optimal flight lines



User defined optimal flight lines



Attitude

Roll, Pitch and Yaw Parameters

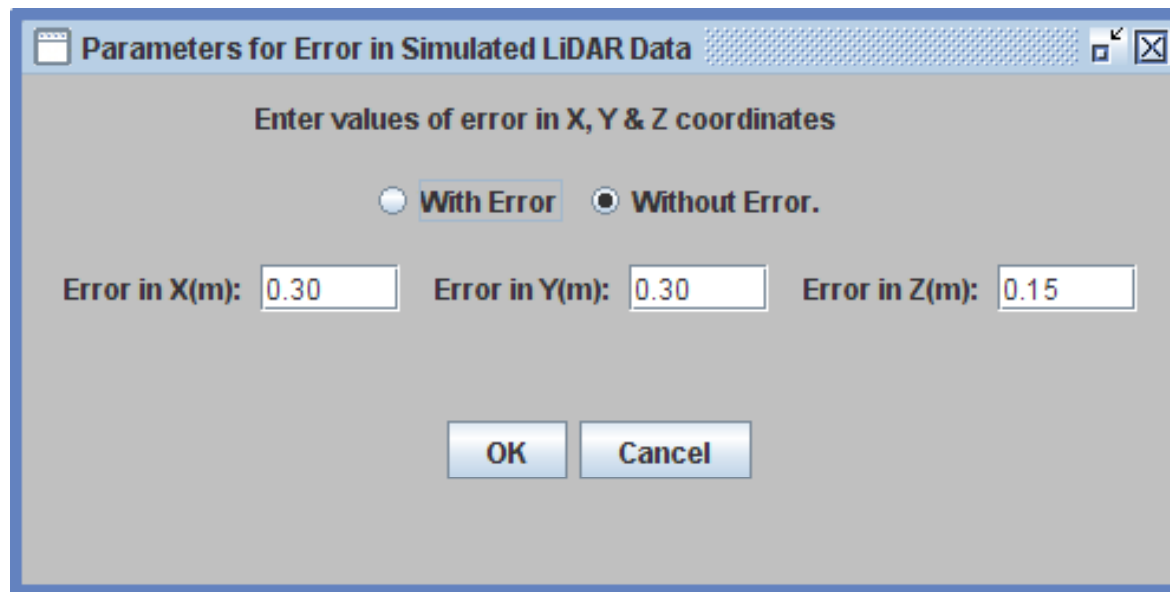
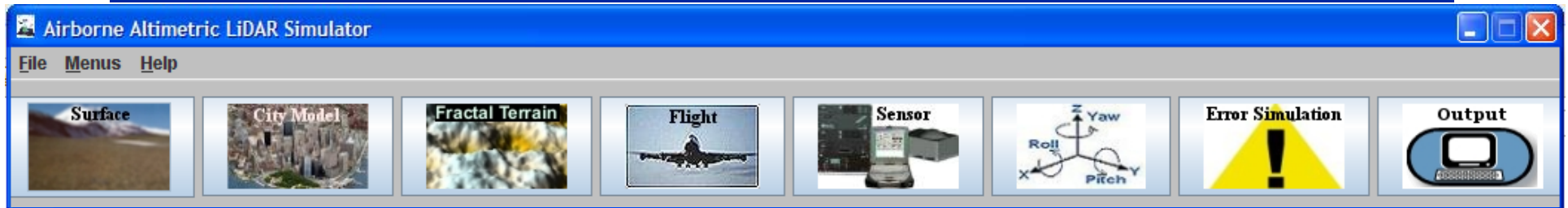
Enter values of RPY parameters

A, B, C & D values for RPY:

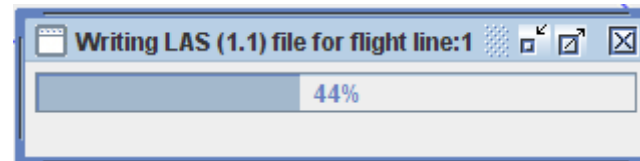
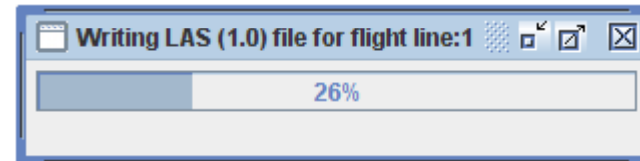
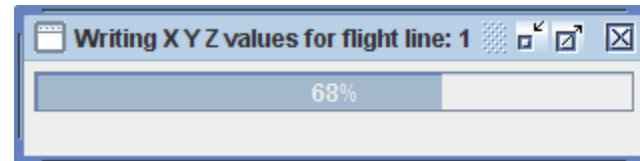
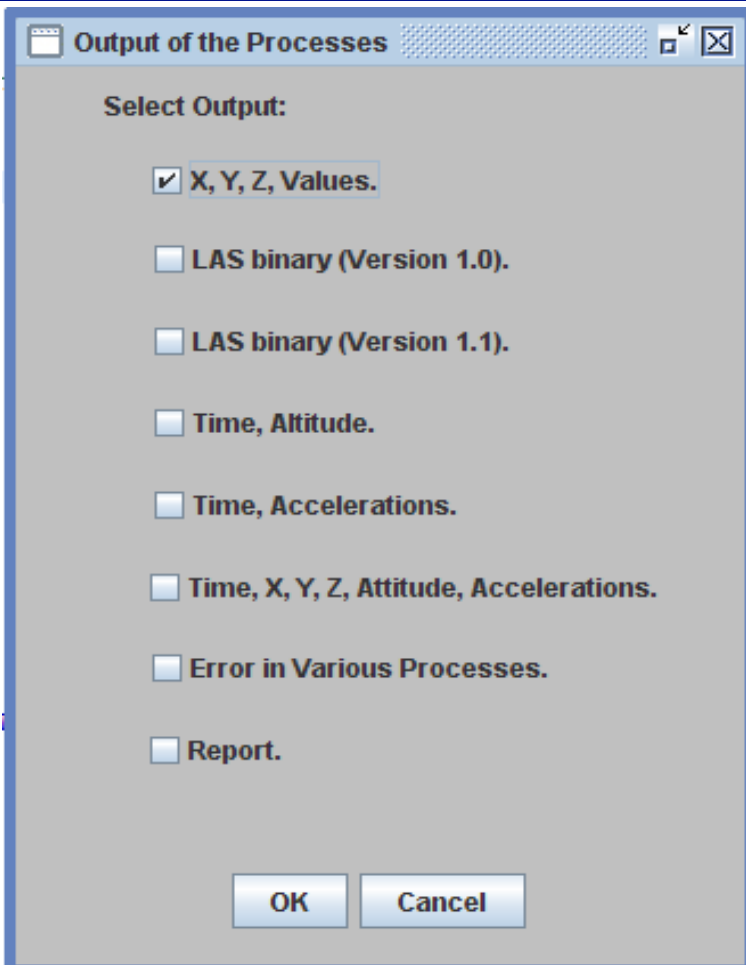
	A	B	C	D
Roll:	0.05	1.38	0.51	1.77
	0.25	0.8	0.27	0.88
Pitch:	0.7	0.5	0.51	1.4
	0.25	0.7	0.57	0.7
Yaw:	0.85	0.4	0.51	1.3
	0.8	0.8	0.7	0.7
m:	0.0			

OK Cancel

Error simulation

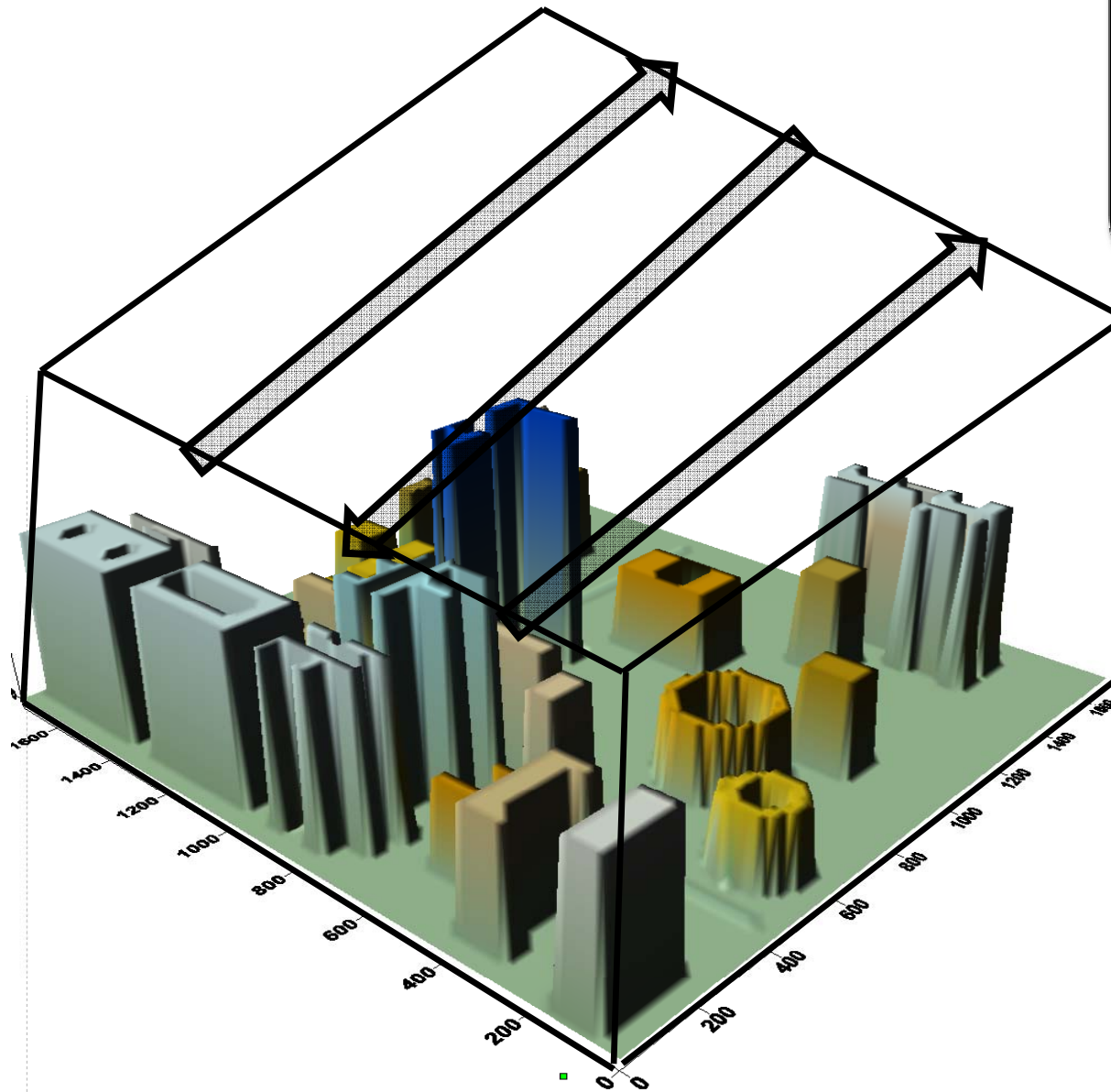


Output generation



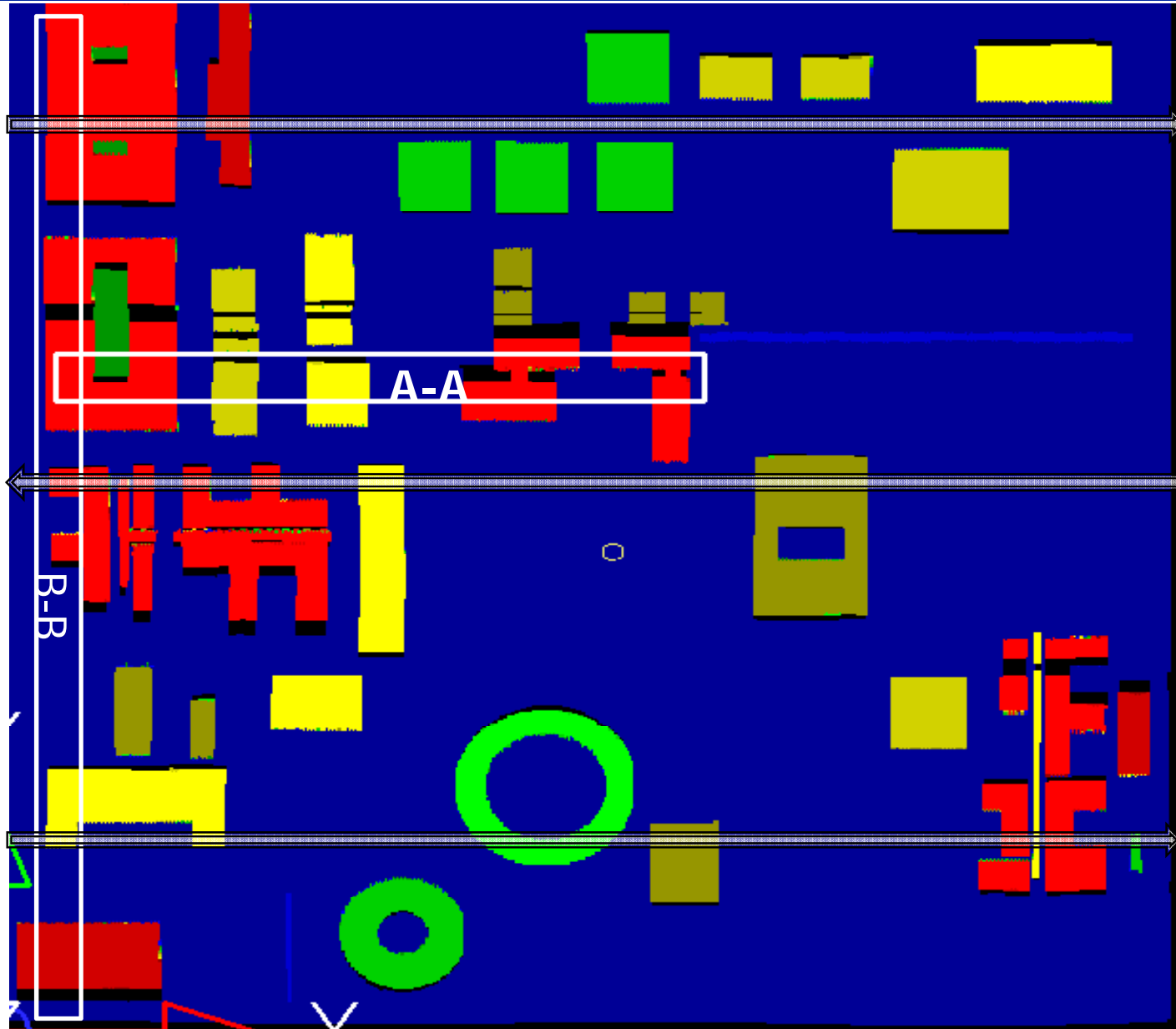
Software Results

3D Raster terrain (Displayed in Surfer)

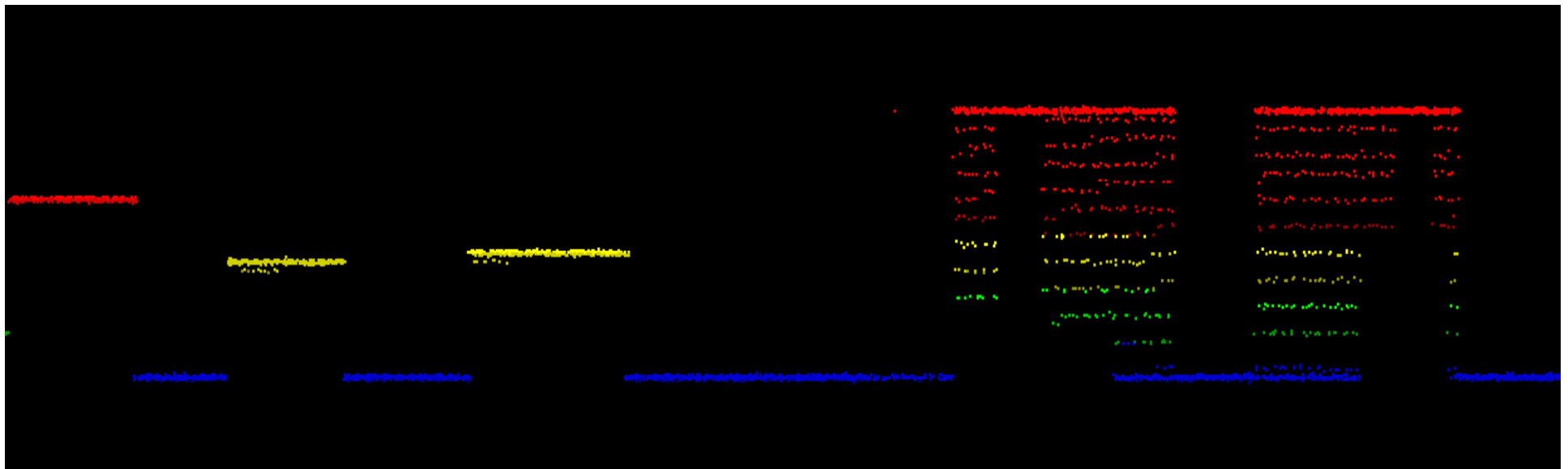
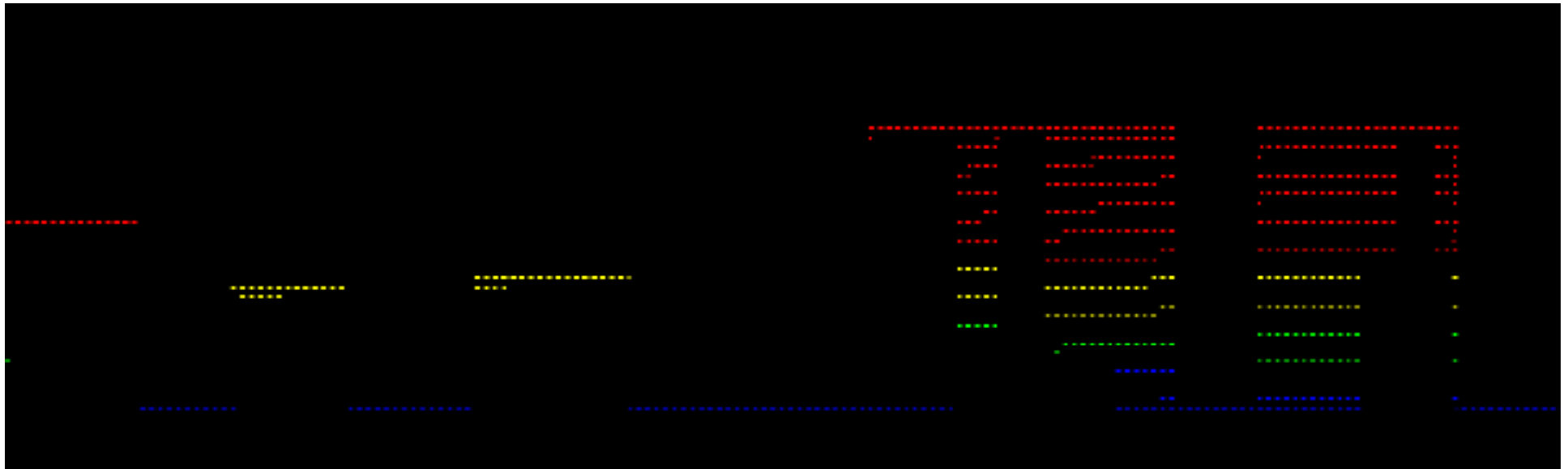


Altitude=210m
Overlap=4%
Velocity=60m/s
Sensor-ALS-50
Firing frequency=20KHz
Scan frequency=48Hz
Scan angle=40°
Flight area=430m×430m

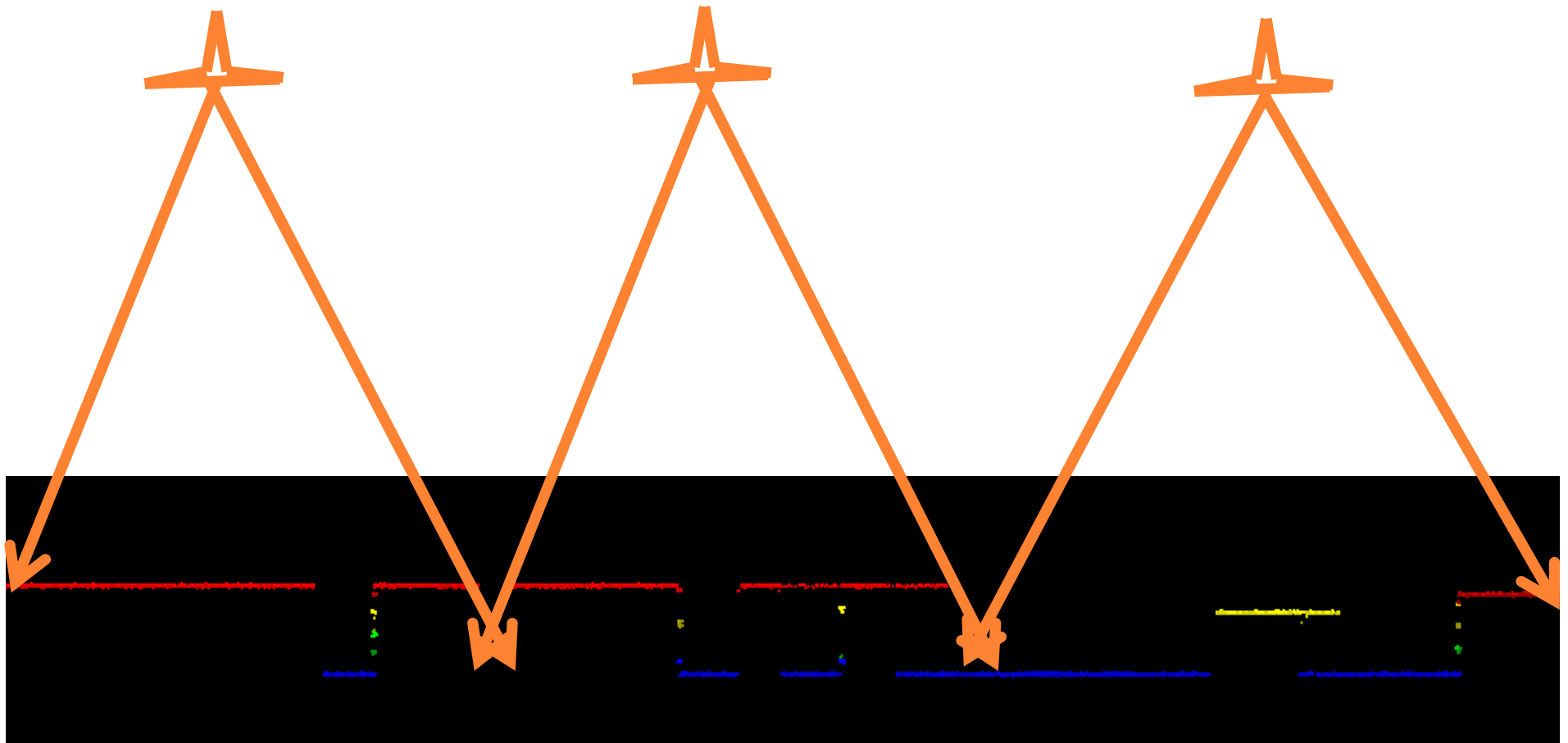
Lidar data plot in plan



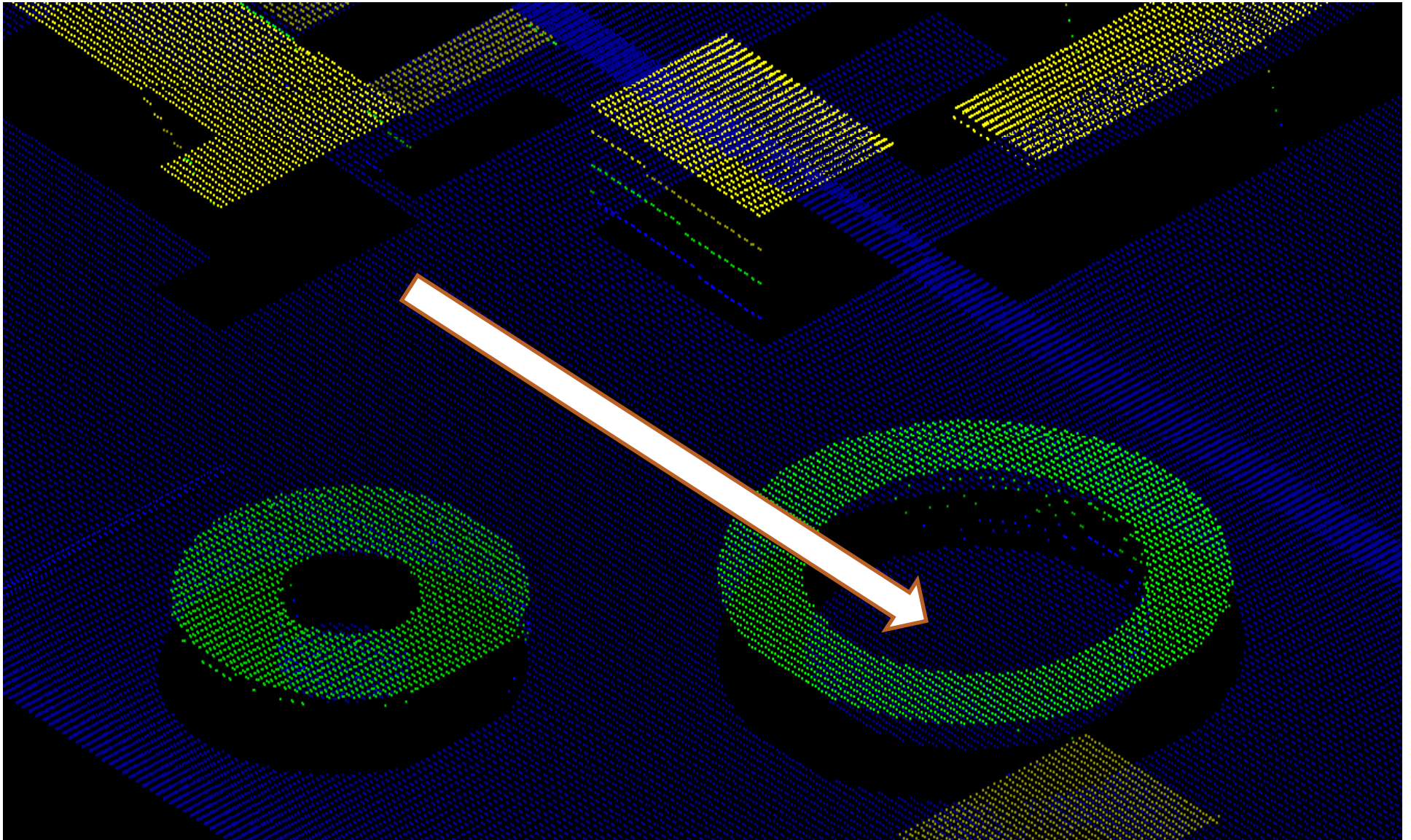
Profile A-A with and without error



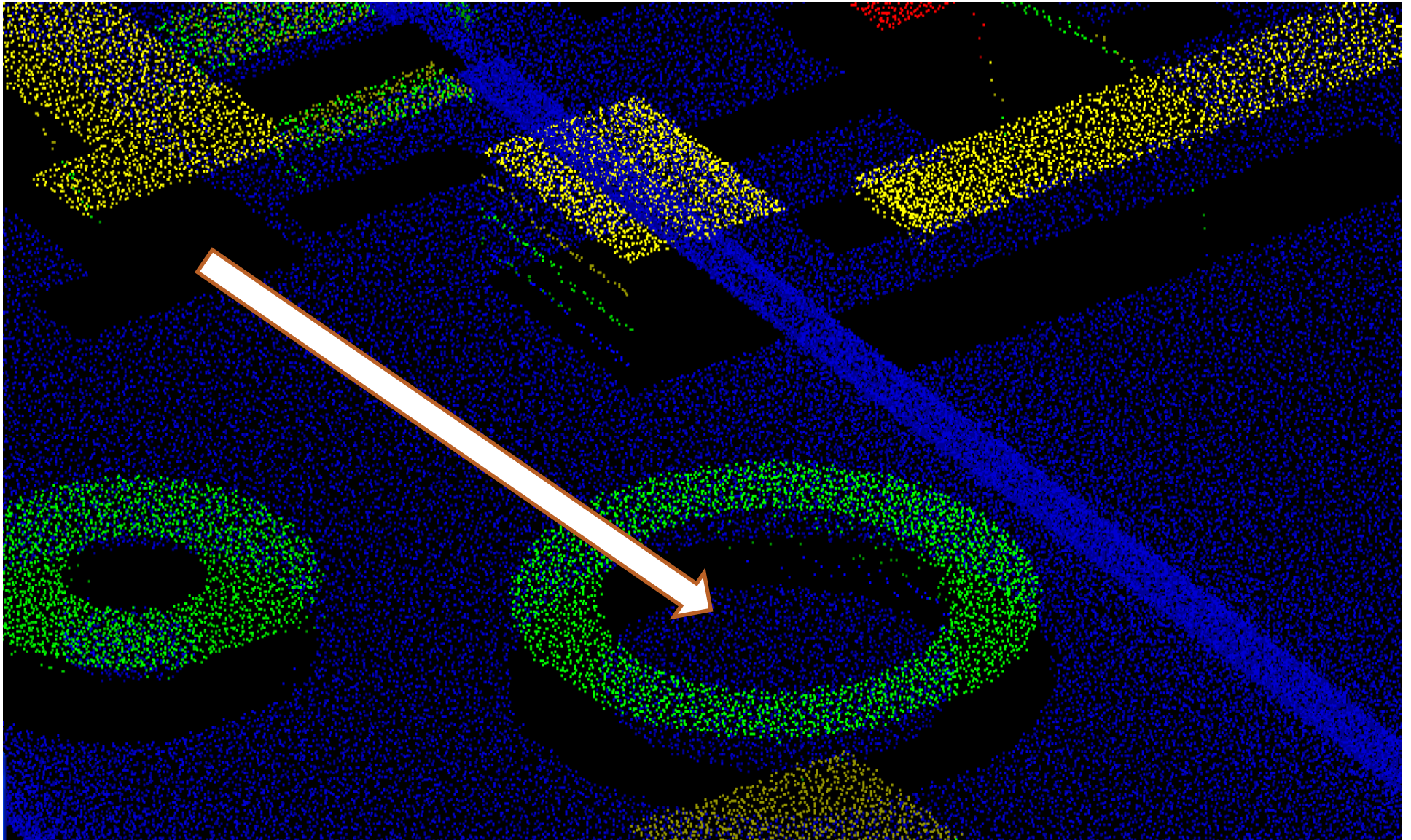
Profile B-B with respect to flight lines



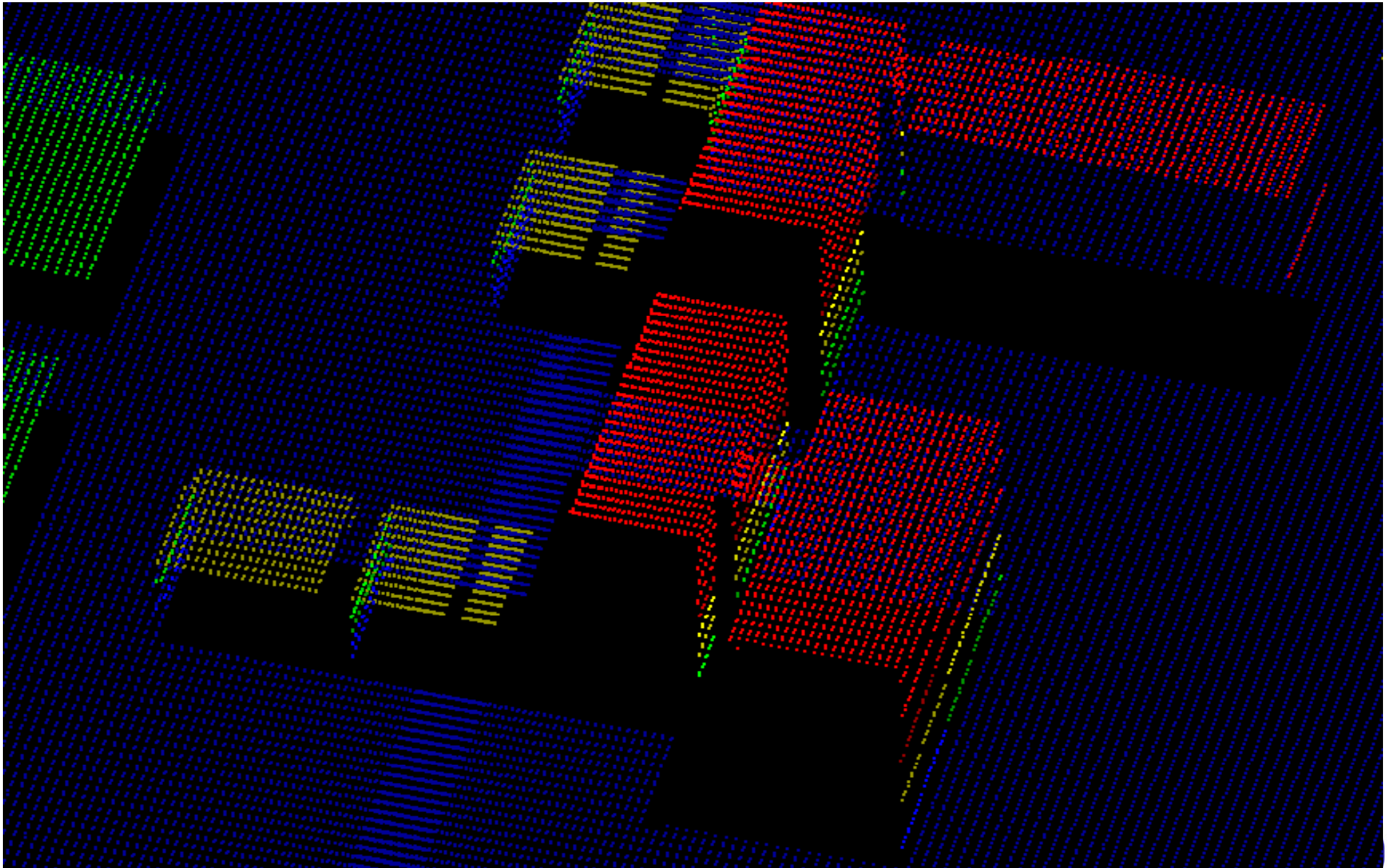
LiDAR data without error



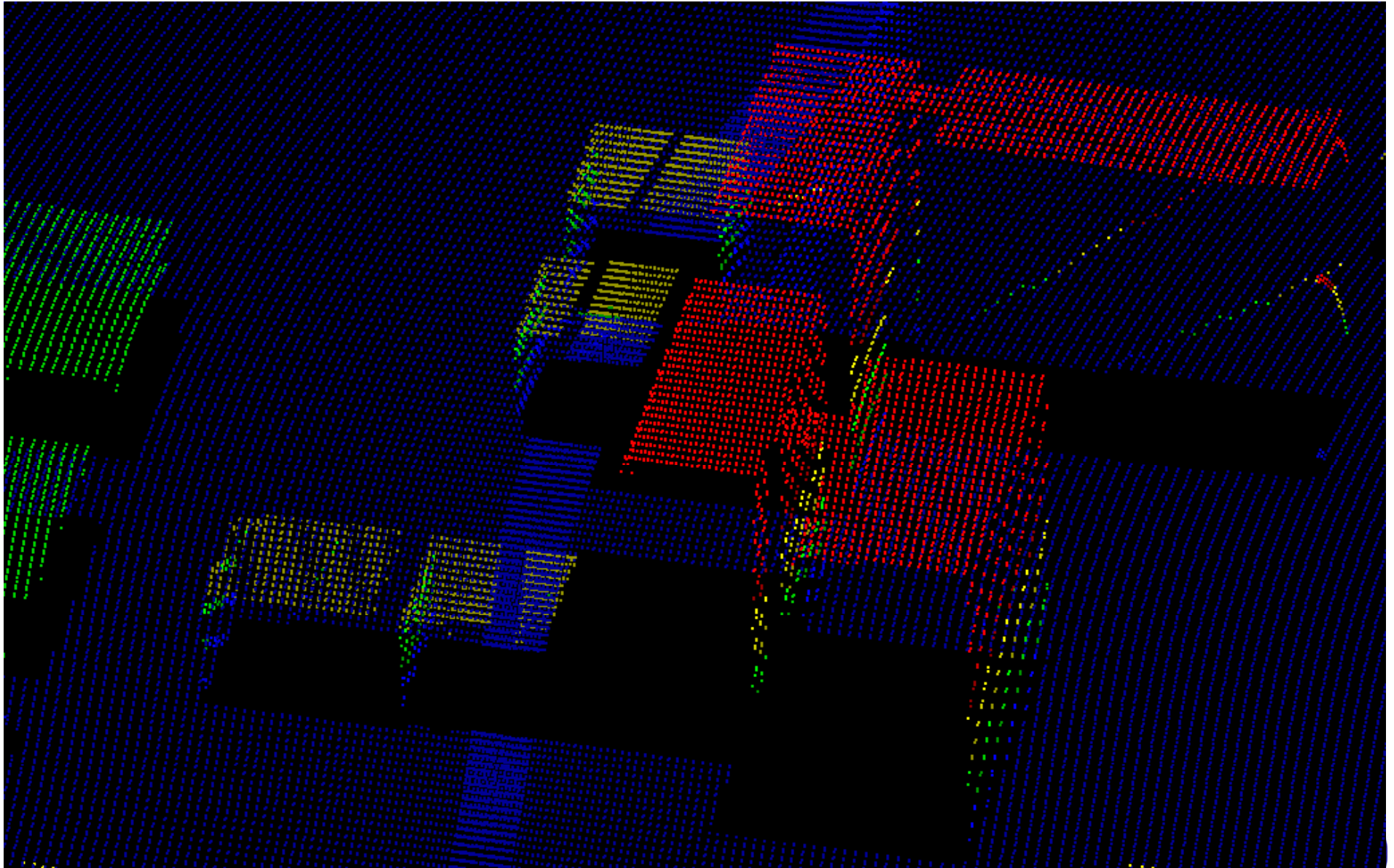
LiDAR data with error



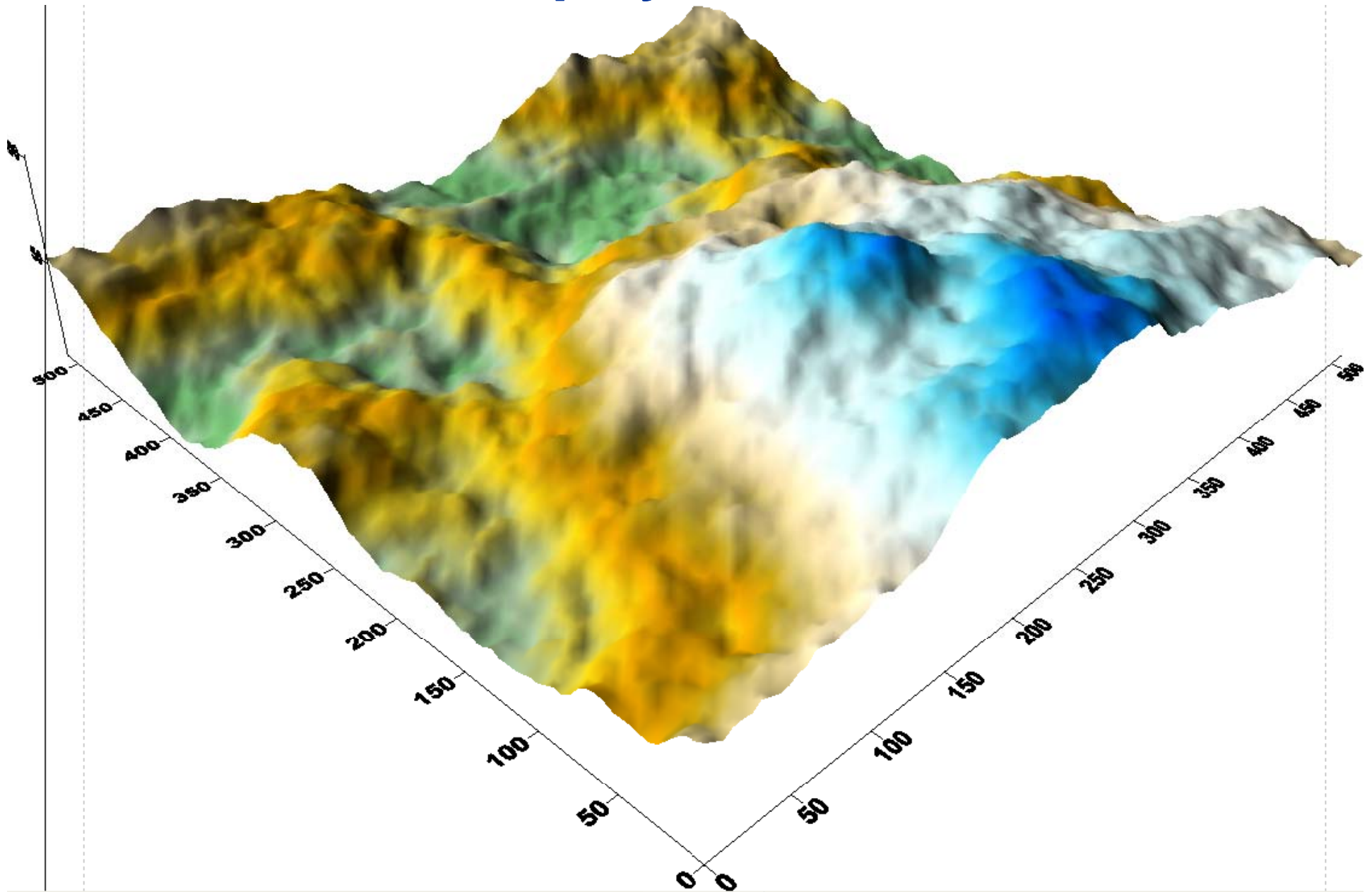
Data without attitude variation



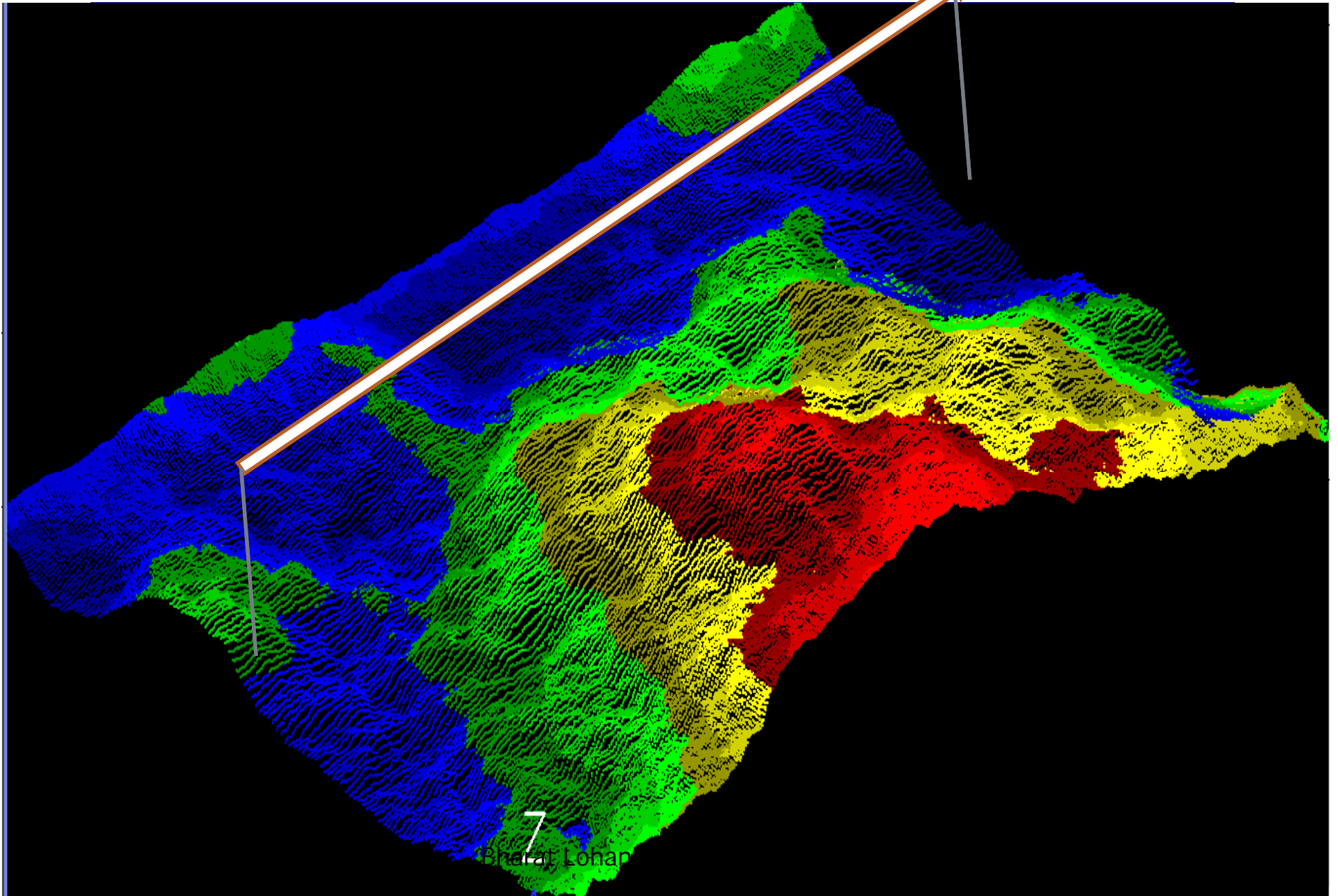
Data with attitude variation



Fractal surface displayed in Surfer

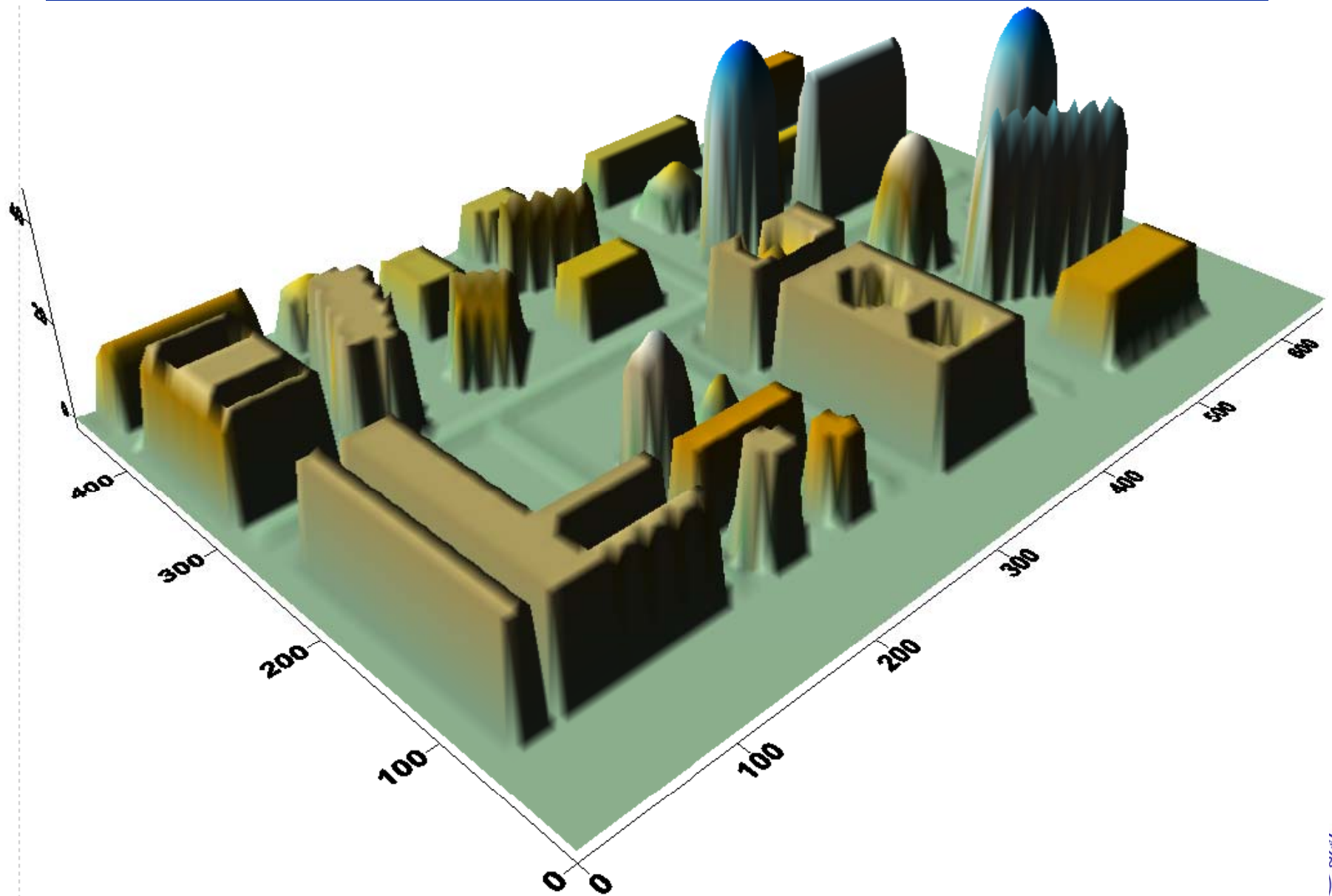


LiDAR data of fractal surface



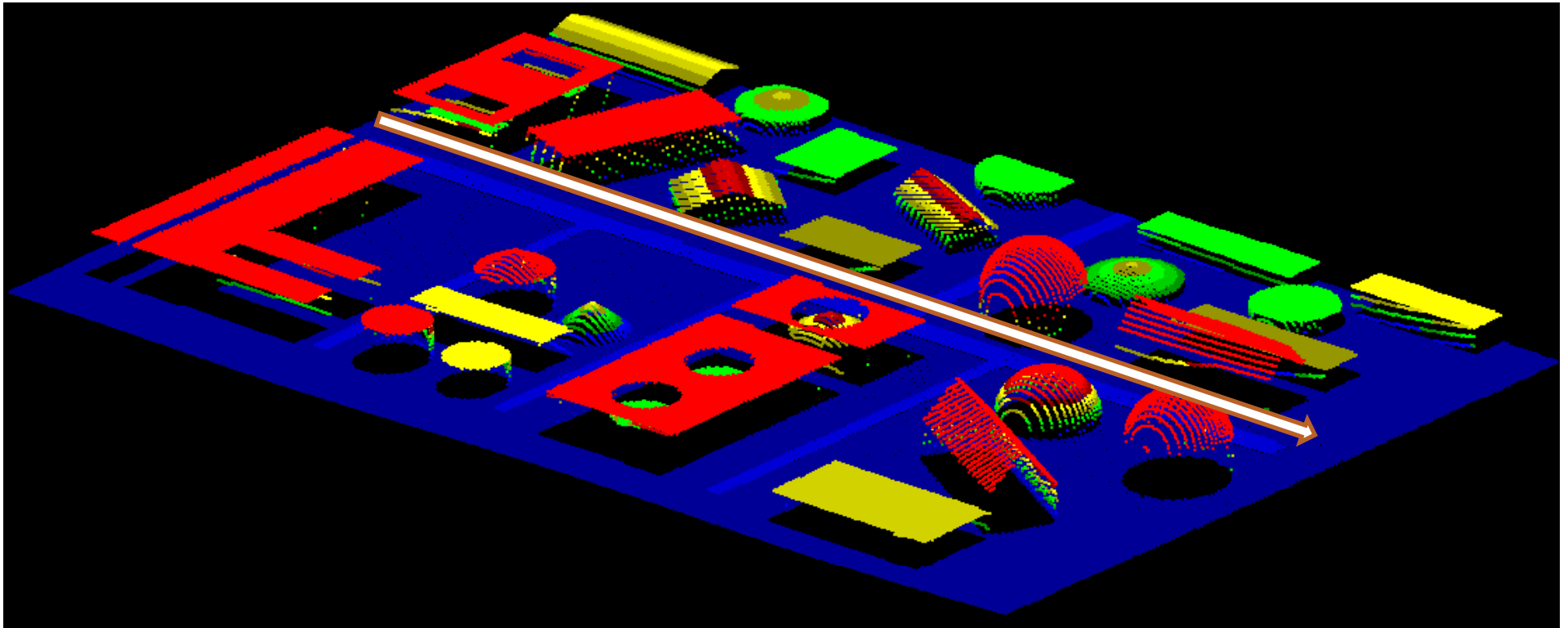
7
Bharat Lohan

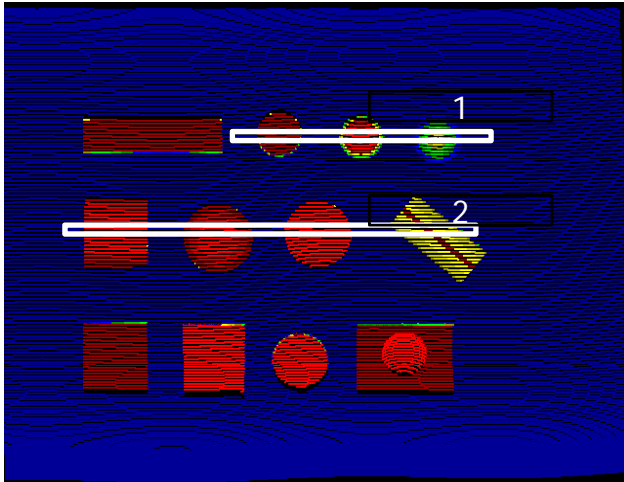
Terrain with objects



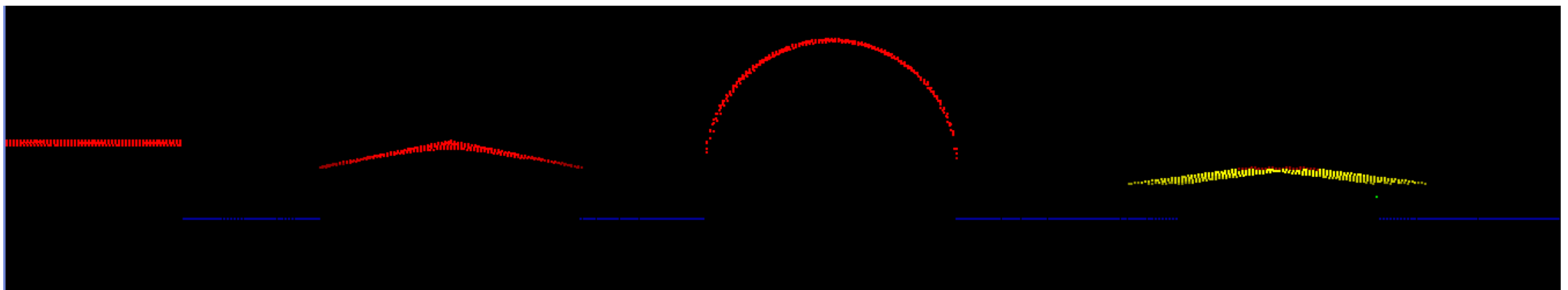
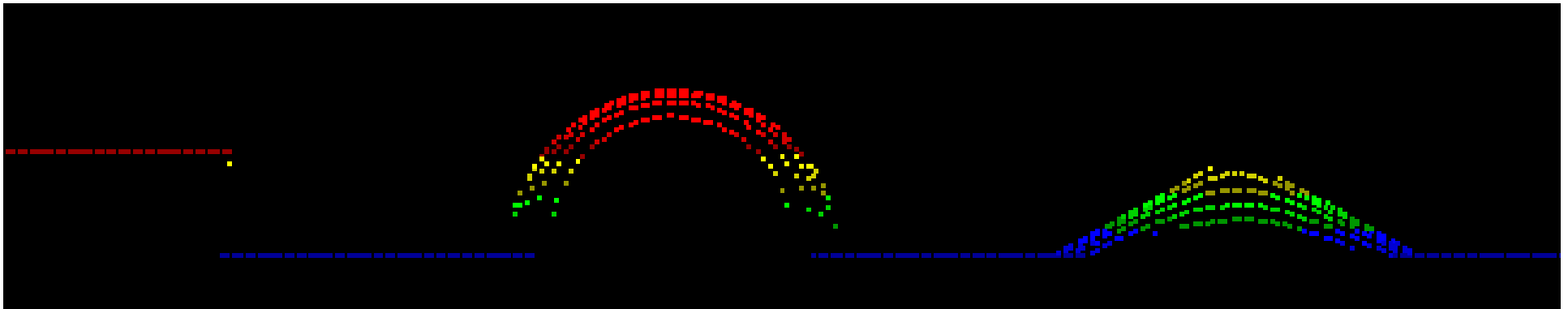
LiDAR data of terrain with objects

Altitude=490m
Overlap=2%
Velocity=60m/s
Sensor-ALS-50
Firing frequency=20KHz
Scan frequency=48Hz
Scan angle=50°
Flight area=640m×460m

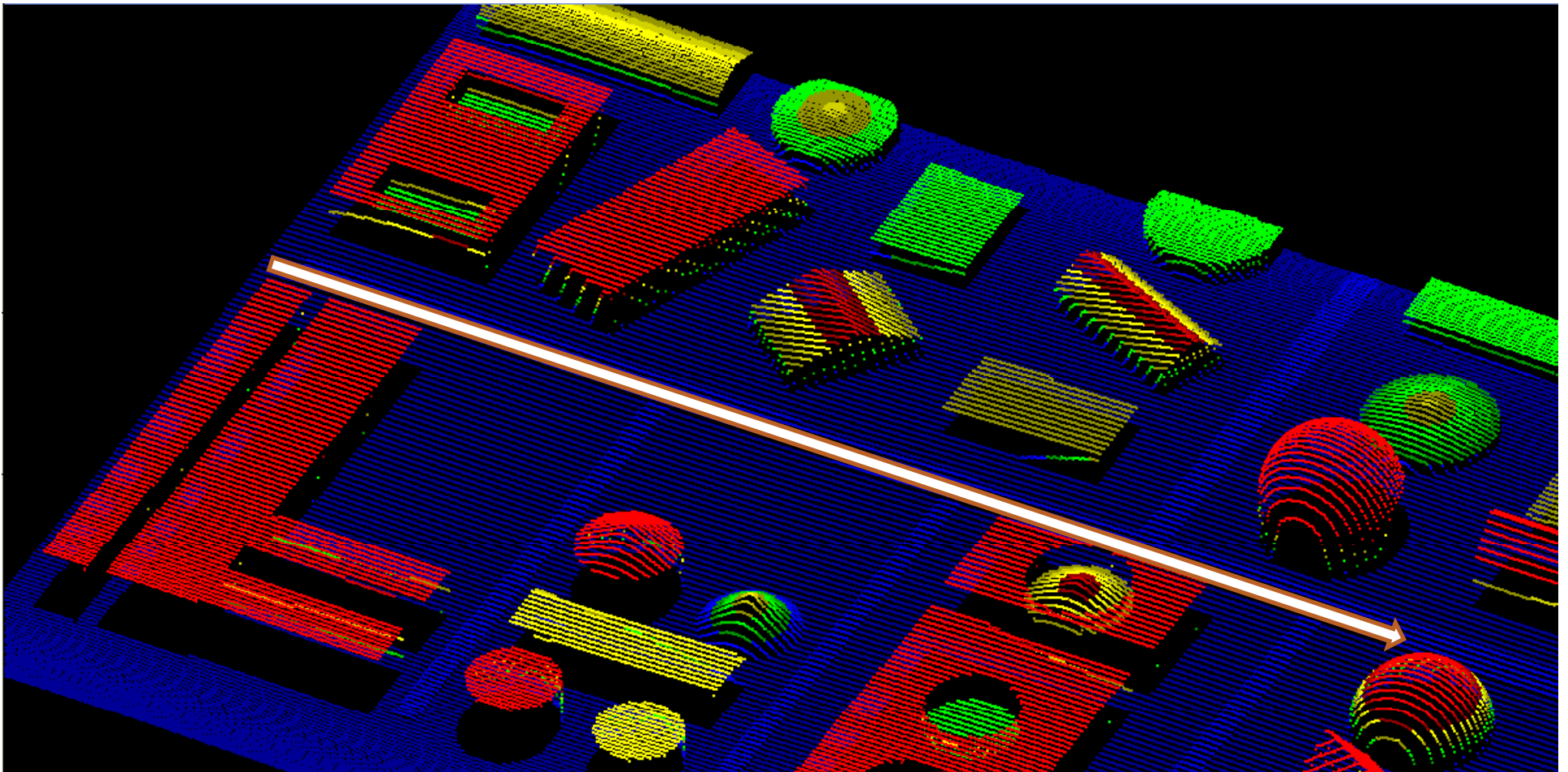


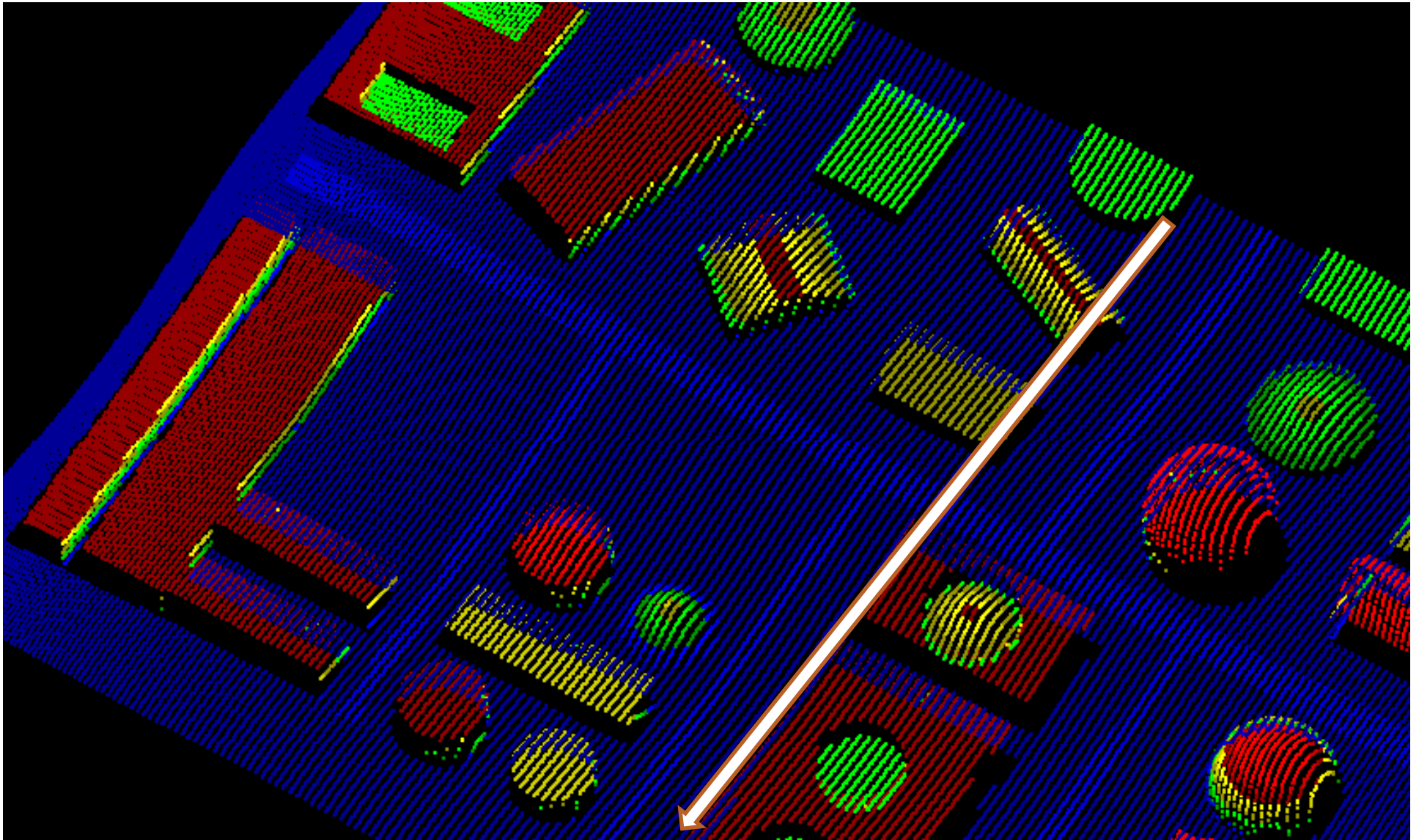


Profile view of buildings



Effect of different flight direction





Use of Simulator

Education

- Process of LiDAR data generation
- Effect of change in various parameters
- Effect of error in data
- Effect of different sensors on LiDAR data
- Generating data for known ground truth
- Conducting various lab exercises

Research

- ❑ Evaluation of information extraction algorithms
- ❑ Assessing effect of error on performance of algorithms
- ❑ Study the effect of parameters on data
- ❑ Generate data of different specifications with no cost
- ❑ Finding optimal data specification for an application

Flight planning

- Determine the optimal flight line
- Effect of sensor parameters on data
- Effect of data density
- Determine the optimal sensor parameters

Conclusion

- ❑ Offers a user friendly GUI based interface
- ❑ Simulate the process of LiDAR data collection
- ❑ Freedom to set the sensor parameters
- ❑ Many data sets can be generated for the same terrain
- ❑ Ideal software tool for LiDAR research and education
- ❑ OOSD makes it easily maintainable and scalable software

Thanks !!

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