Geotech

Development of Geospatial Smart Cities and Management

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Topics

Geotech

Introductory Remarks

01

This presentation provides an introduction to a unique cutting-edge 3D Geospatial Solution for local governments, governmental agencies and various industries followed by an overview of successful case studies using the introduced solution.

The provided methodology and solution are based on high resolution intelligent, object-based 3D geospatial data for smart cities.

Our data sets incorporate:

- High resolution imagery, geometry and geospatial semantics
- Artificial intelligence (including deep learning), high-performance computing, computational fluid dynamics, simulation technologies, automation and topology.

The system also allows for powerful analyses such as contour maps, noise pollution, integrated planning, flooding and so forth. This helps developers meet various demands related to smart cities such as utility management, green environments, resource management, urban planning and so forth.

CitiGenius Technical Architecture

02

CITIGENIUS Technical Architecture utilizes state-of-the-art Technologies and combines the practical solutions of various domains.

MULTIPLE APPROACH: In order to bring the smart solution to a next generation level, and to provide flexibility, a multiple approach method is designed and implemented.

Multiple Input	Multiple Process	Multiple Output	Multiple Usage
Citigenius uses multiple geospatial data sources ranging from aerial images to mobile mapping to generate 3D smart city model	Various Technologies such as Computer Vision, Machine Learning and supplementary manual work are utilized to convert geospatial content into smart city	Citigenius generates various outputs that address the requirements of different industries	Smart geospatial data helps many industries regarding planning, management and operations

CitiGenius Multiple Approach/ Multiple Input

02

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MULTIPLE INPUT: Citigenius uses multiple geospatial data sources ranging from aerial images to mobile mapping to generate 3D smart city model. Below image shows some of the data resources that are used by Citigenius production pipeline.

Multiple Input

SATELLITE IMAGERY

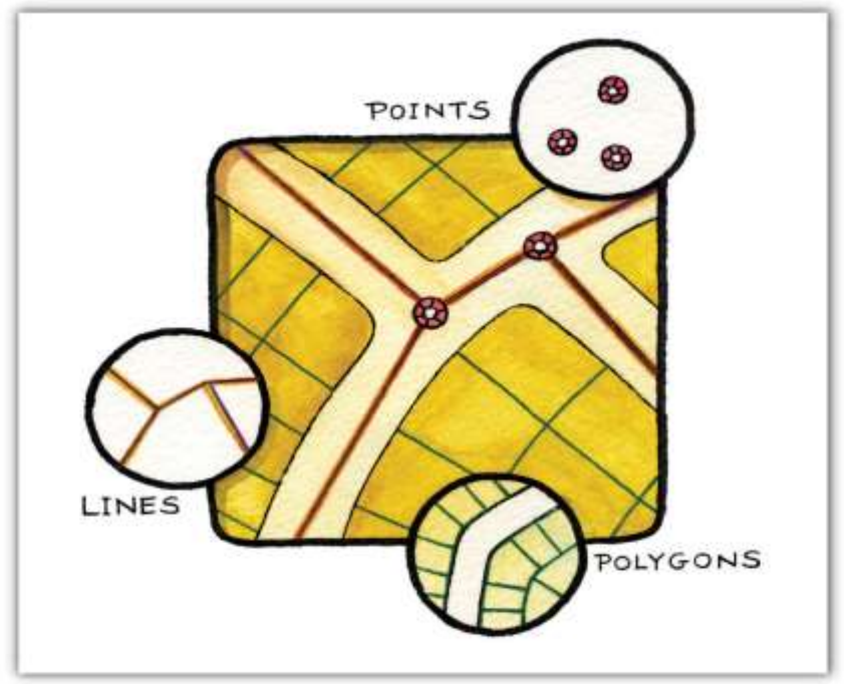
AERIAL IMAGERY

MOBILE MAPPING

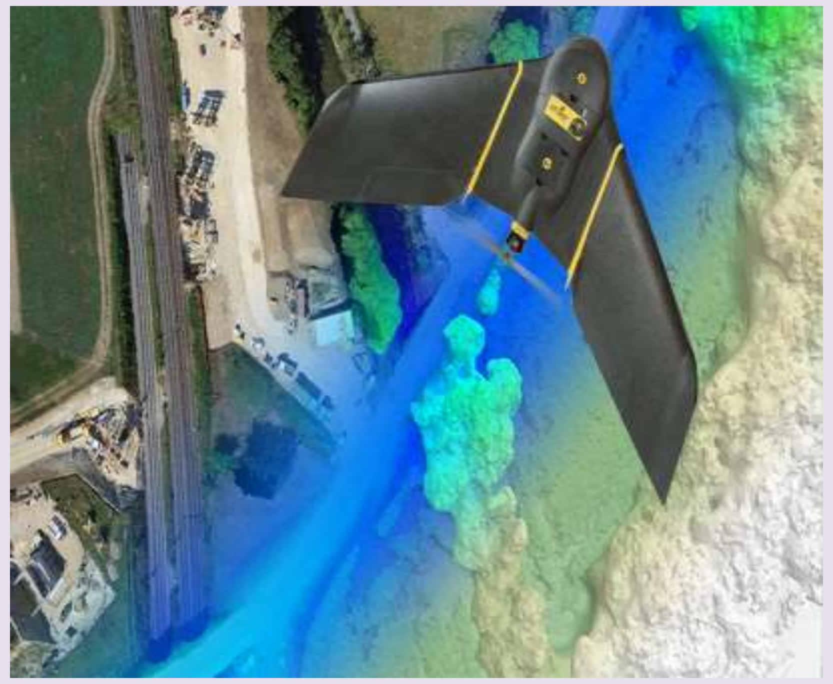
DATABASES

NADIR/OBLIQUE IMAGERY

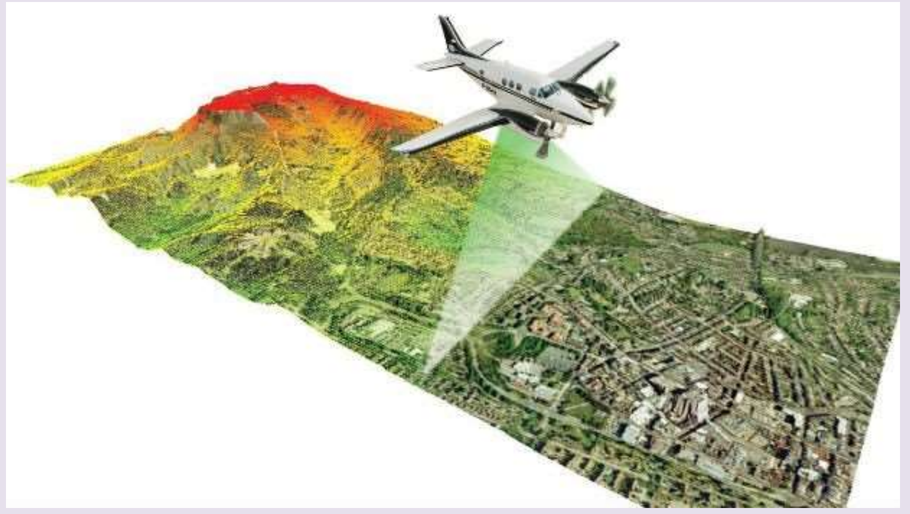
EXISTING VECTOR DATA



UAV IMAGERY



LIDAR



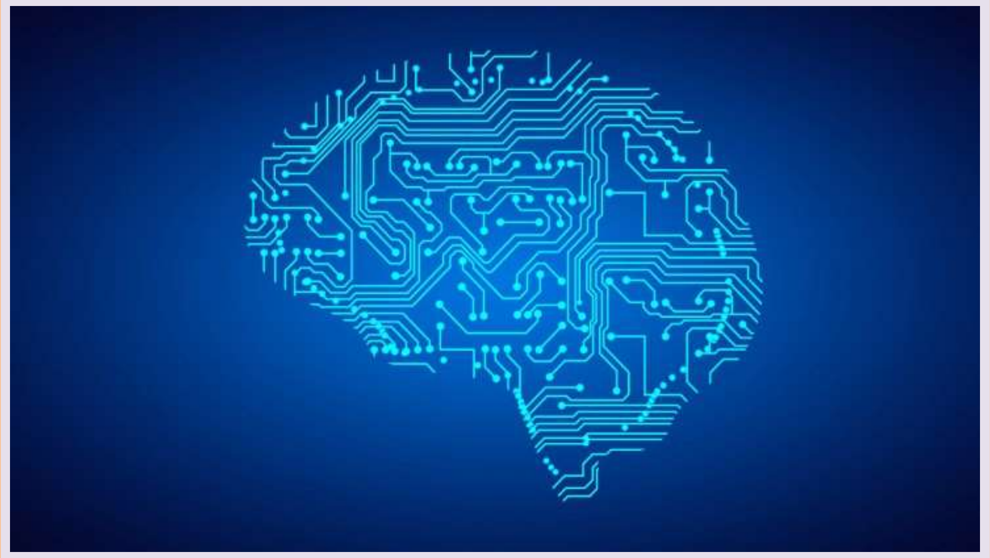
CitiGenius Multiple Approach/ Multiple Process

Geotech

MULTIPLE PROCESS: Various Technologies such as Computer Vision, Machine Learning and supplementary manual work are utilized to convert geospatial content into smart city

Multiple Process

MACHINE LEARNING



COMPUTER VISION

MANUAL EDITING

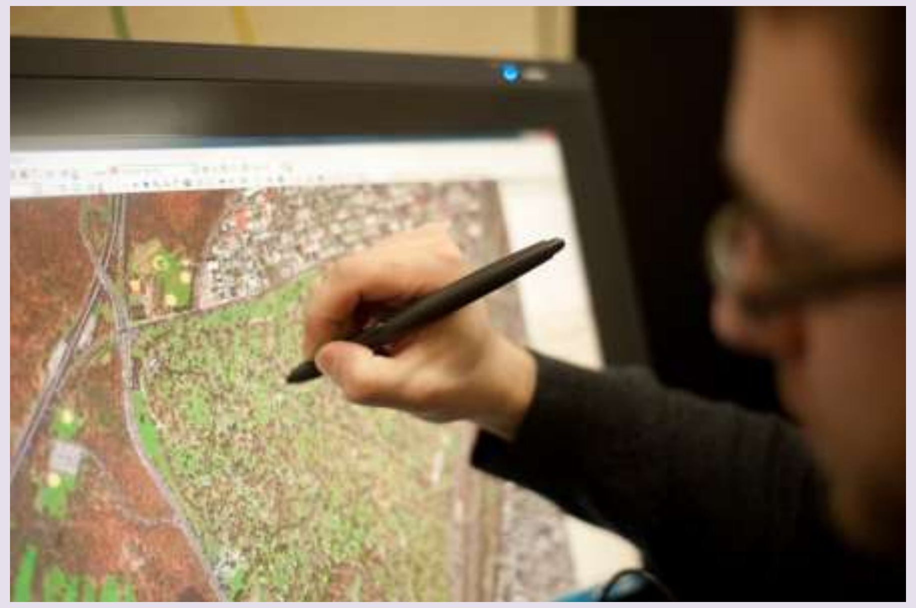
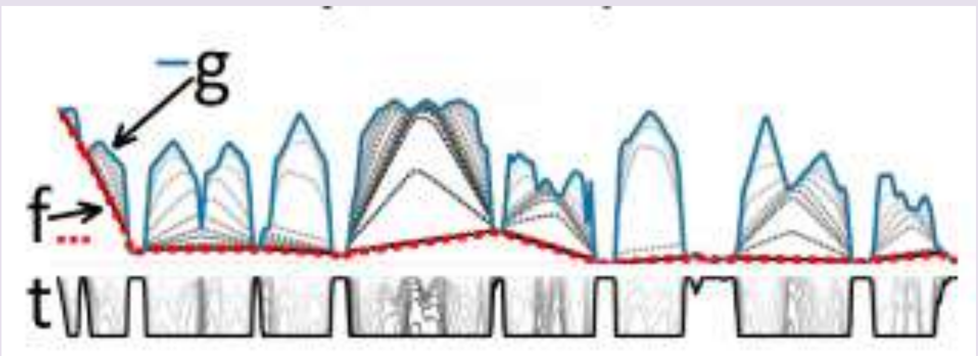


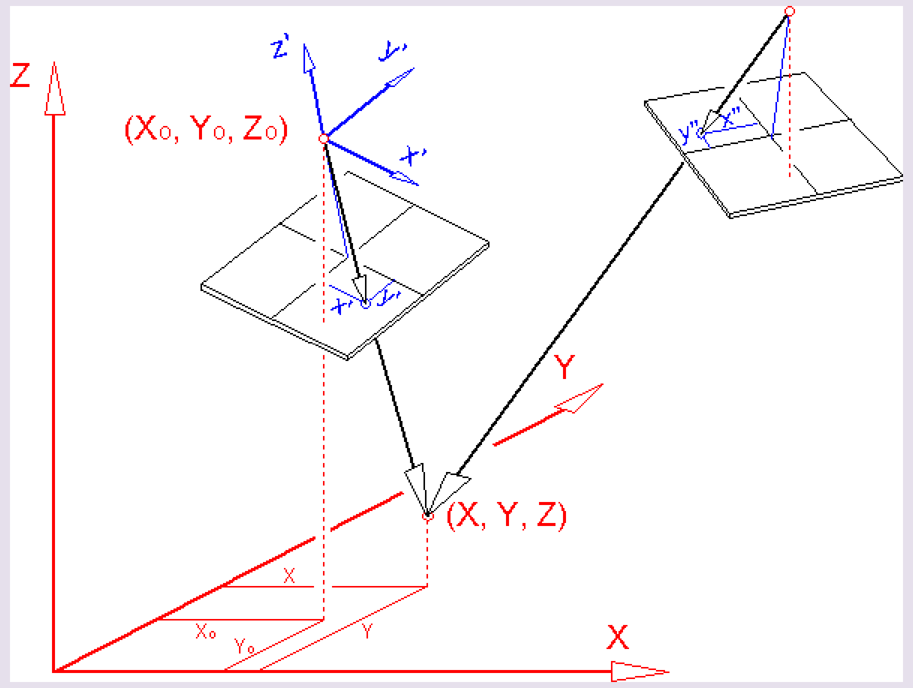
IMAGE PROCESSING

DEEP LEARNING

SPARSITY-DRIVEN DTM EXTRACTION



ADJUSTMENT



DATA CONVERSION and OPTIMIZATION

CitiGenius Multiple Approach/ Multiple Output

02

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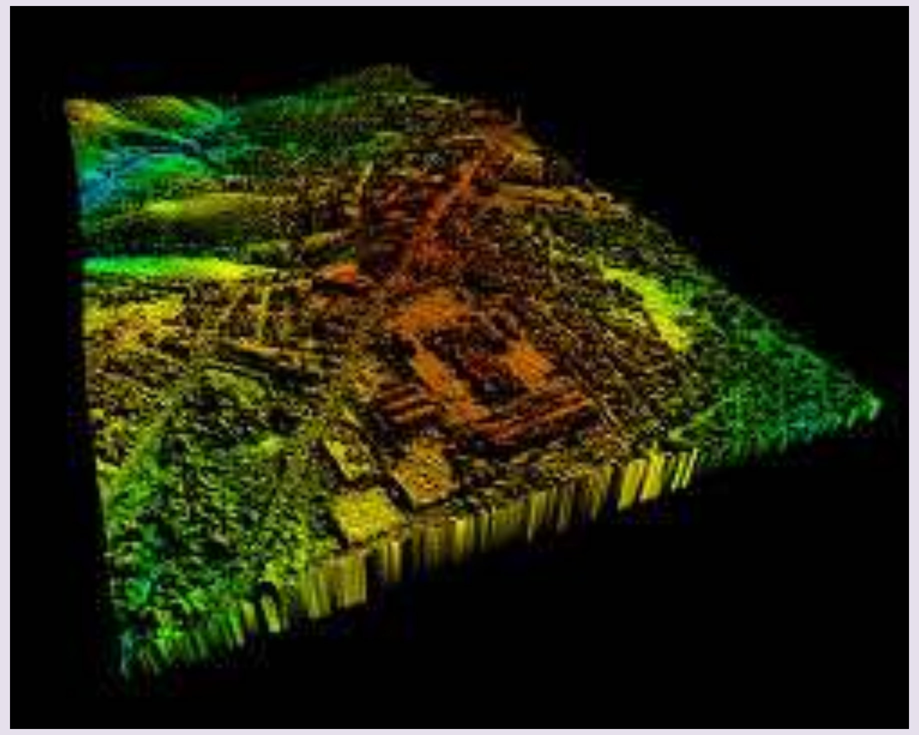
MULTIPLE OUTPUT: Citigenius generates various outputs that address the requirements of different industries

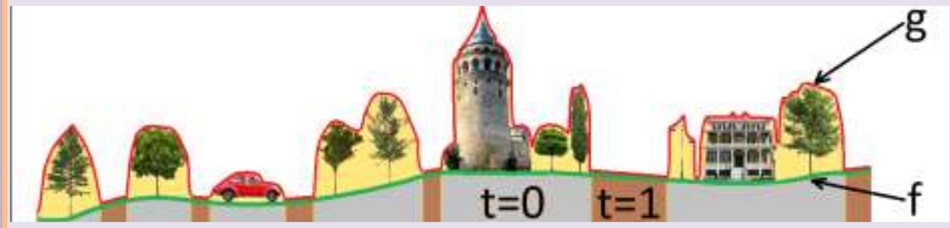
Multiple Output

Point Cloud

DSM



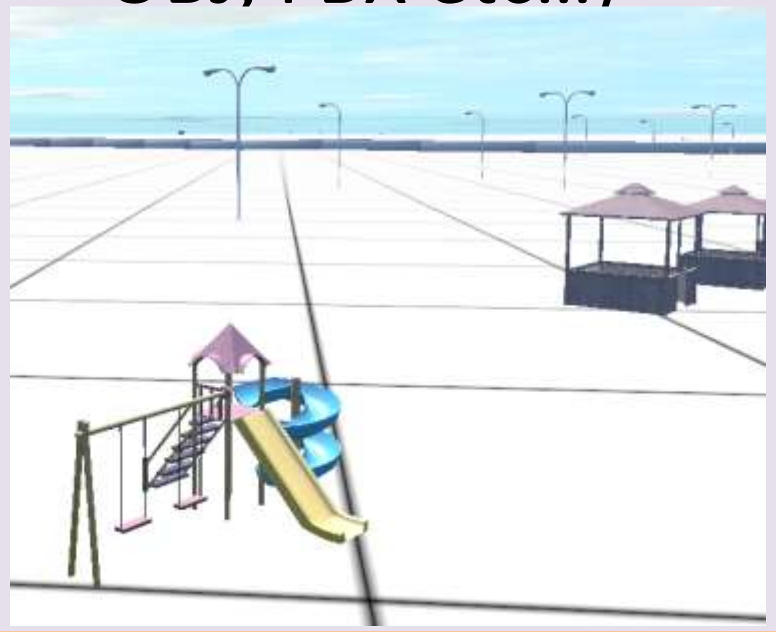
Perfect DTM



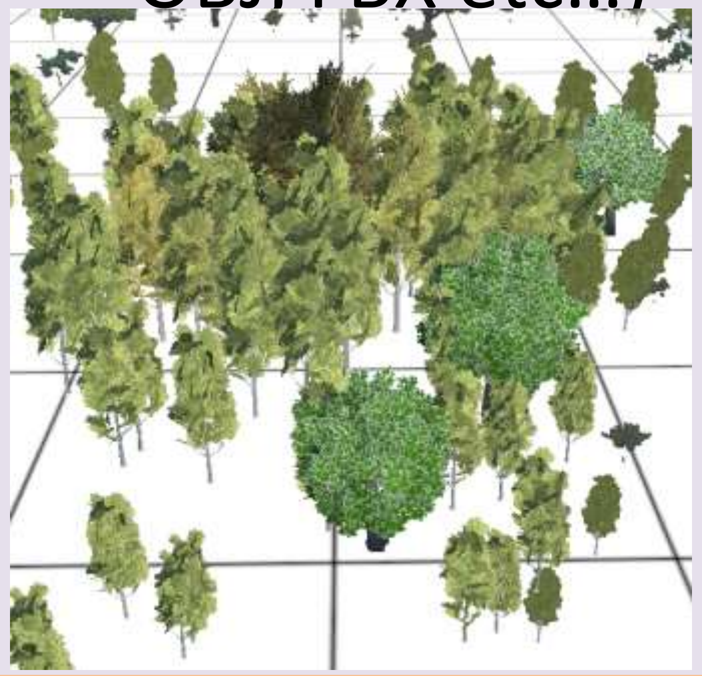
True Orthoimagery

3D BUILDINGS (CityGML, OBJ, FBX etc...)

CITY FURNITURE (CityGML, OBJ, FBX etc...)



Vegetation (CityGML, OBJ, FBX etc...)



REPORTS

CitiGenius Multiple Approach/ Multiple Usage

Geotech

MULTIPLE USAGE: Smart geospatial data helps many industries regarding planning, management and operations

Multiple Usage

Municipalities and Local Governments

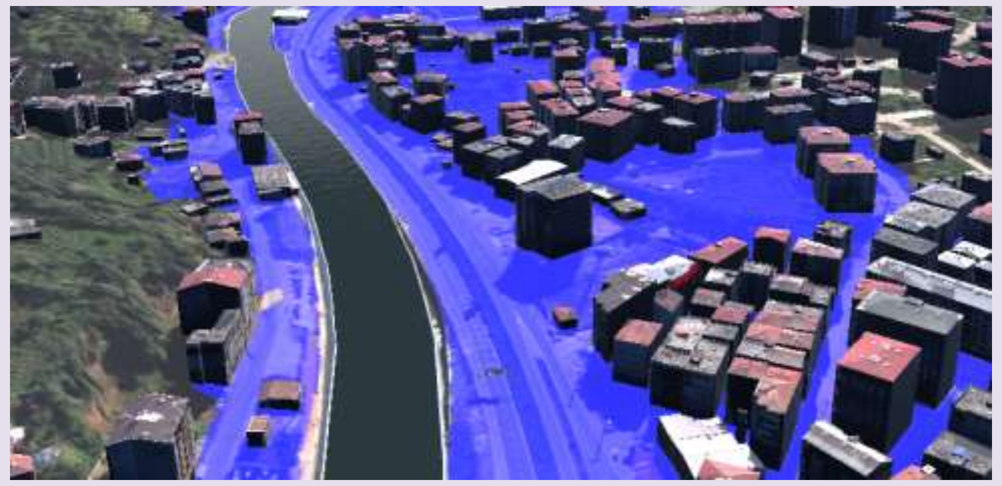
Large-scale Construction

Parametric Design (City Planning)

Real Estate

DEFENCE

Water Management



3D Cadastre

Geospatial Industry

SAMPLE ANALYSES: Citigenius supports ~100 geospatial analyses

02

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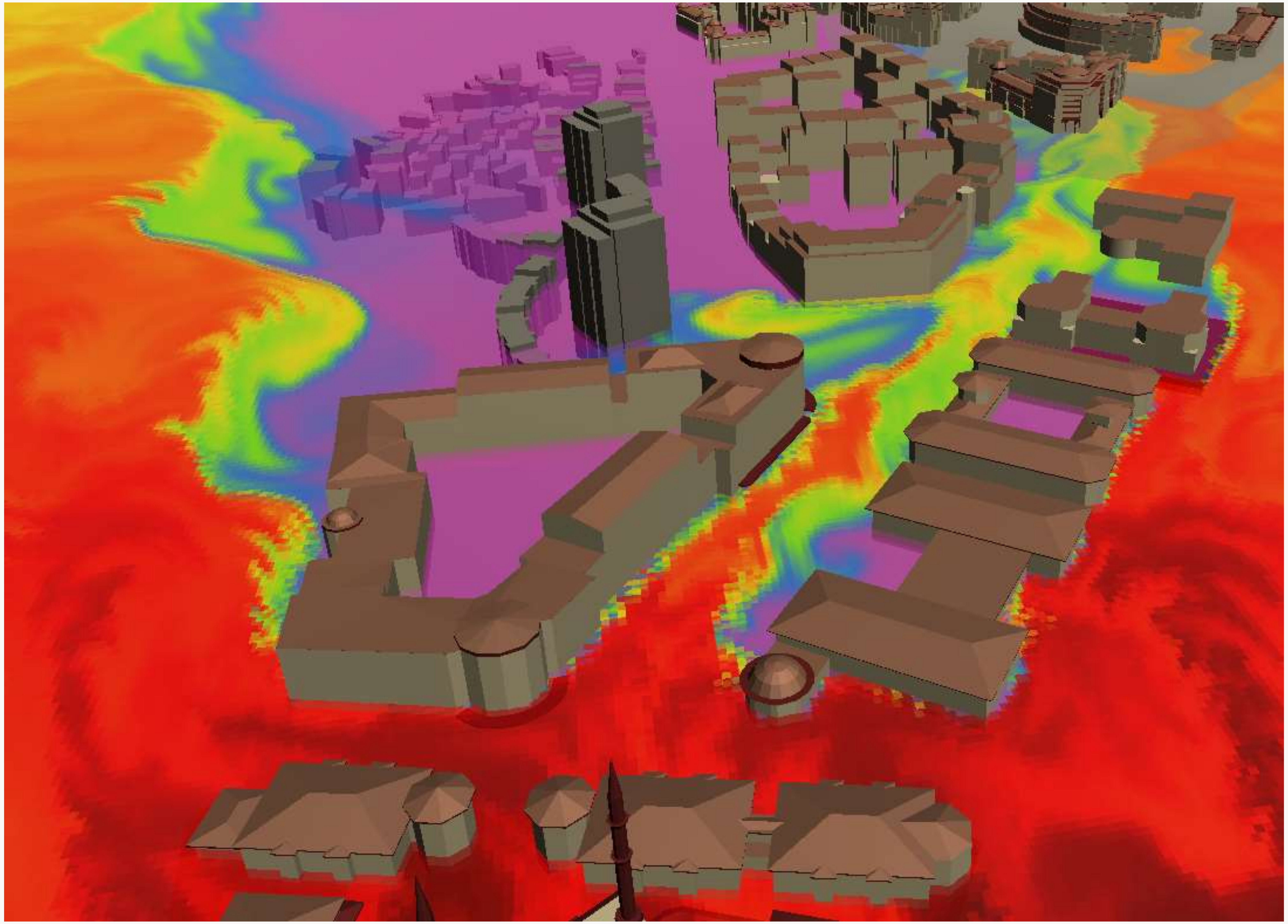
Wind analyses:

A built-in computational fluid Dynamics solution generates real-time wind simulation.

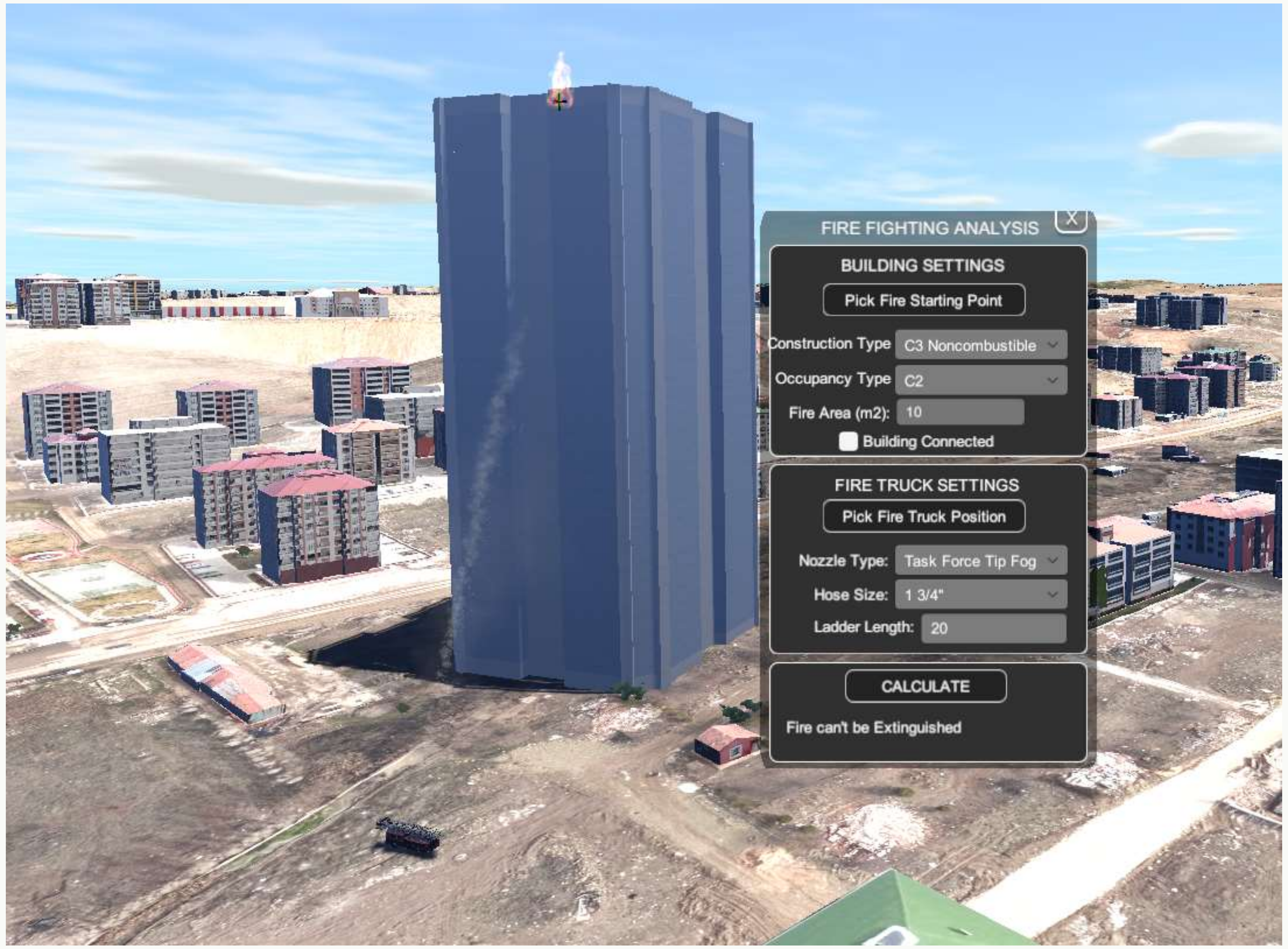


Urban Heat Island Analysis:

Shows the possible raise in heat after a new construction.

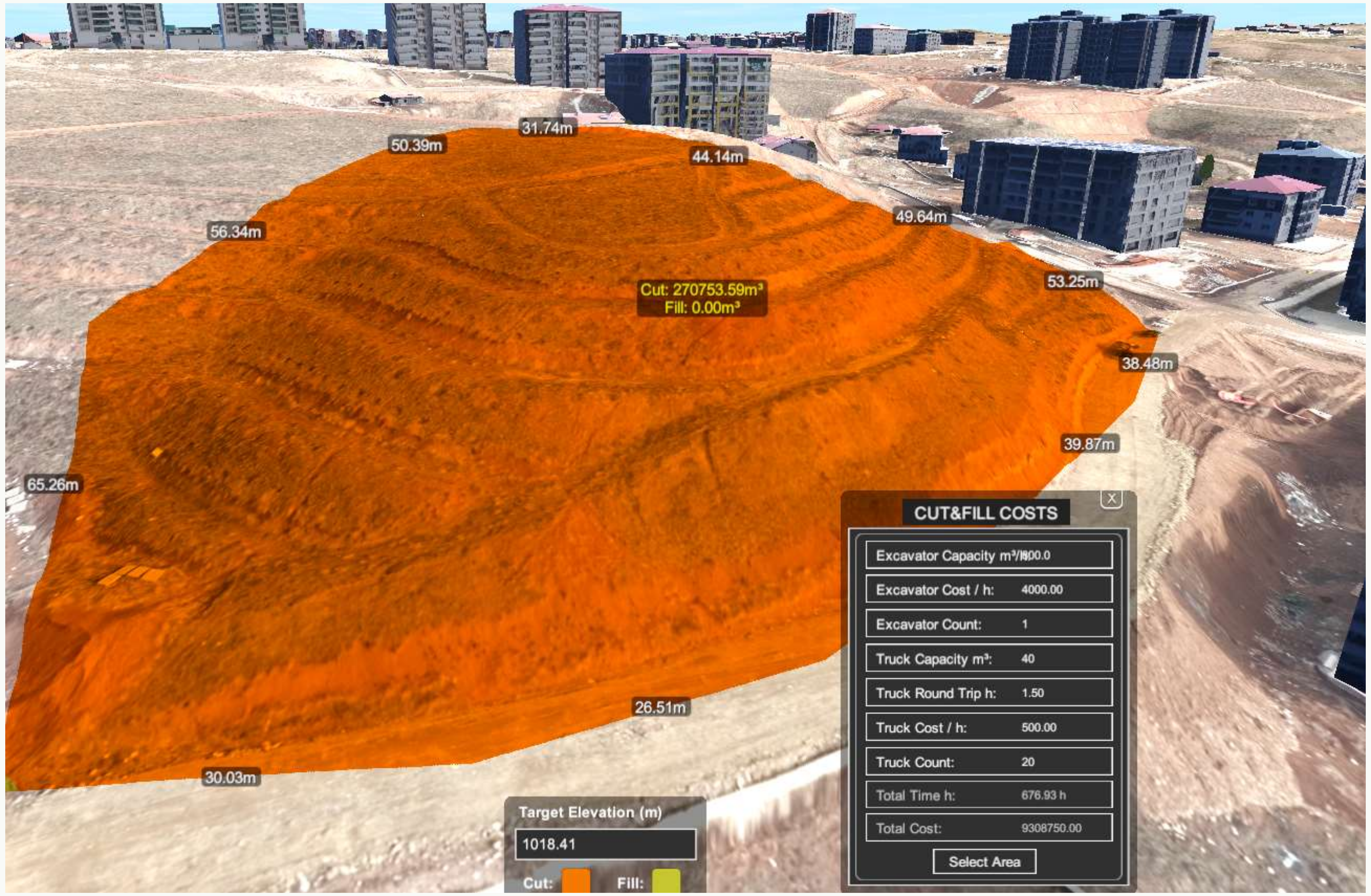
Uses several parameters such as sun rays and buiding facade material

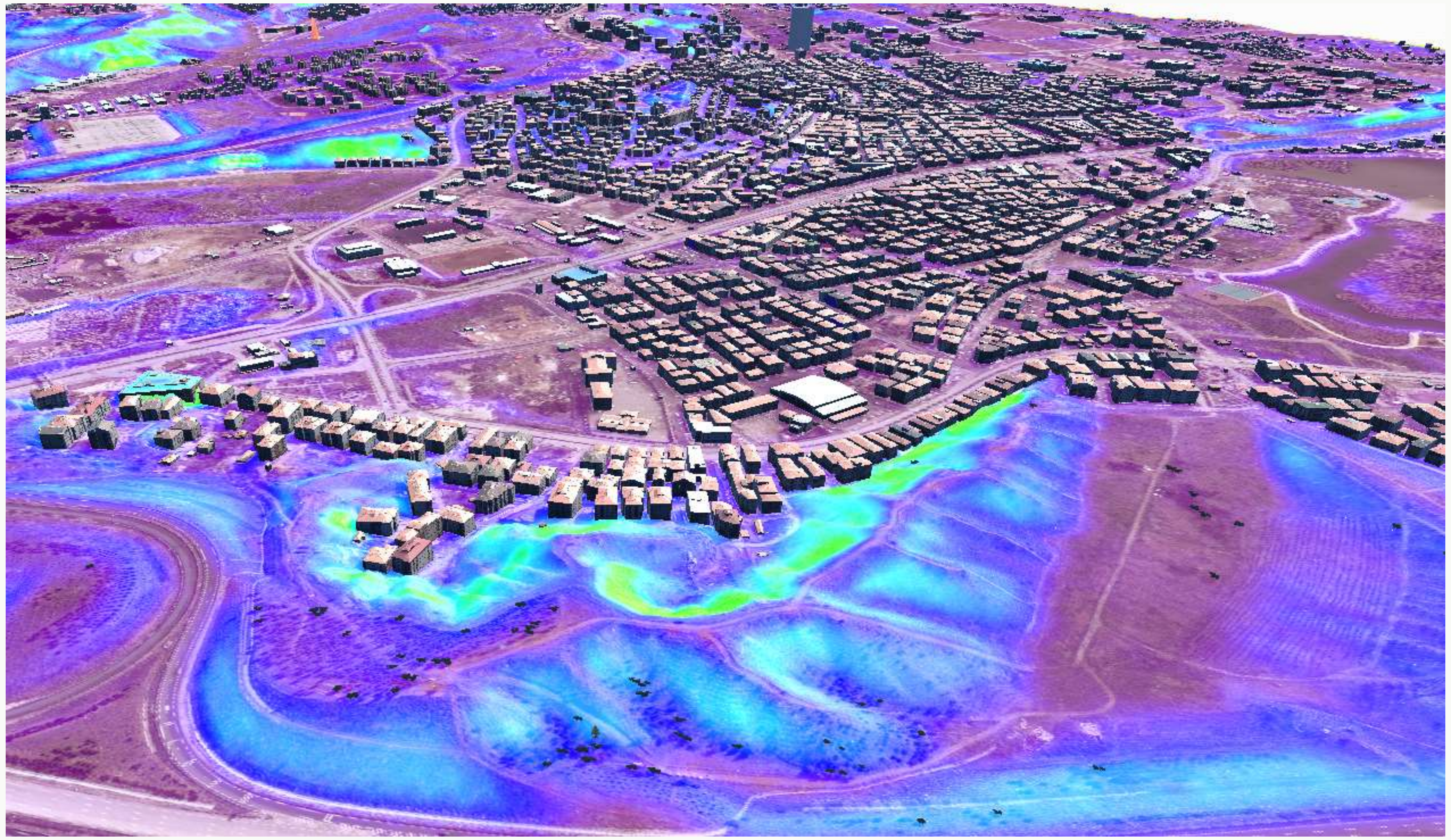
Heat raise at the surrounding area and buildings



Fire Fighting Analysis

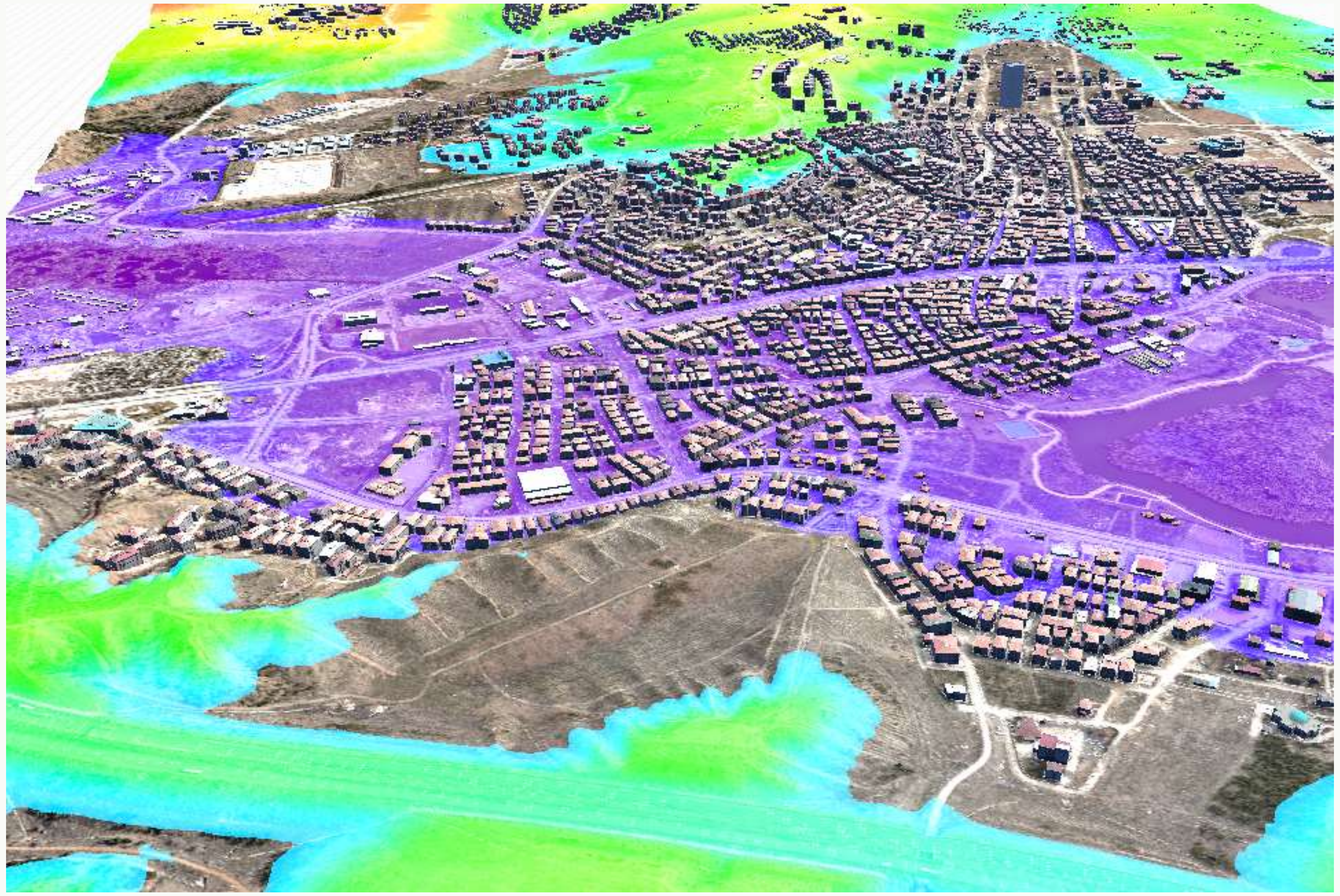
Cut&Fill Analysis





Slope Analysis

Multi-level Elevation Masks



3D Building Modelling Pipeline

- We use building roof prints as first input
  - Existing vector data such as cadastre maps, city plans etc…
  - Manual editing by using true orthoimagery
  - Automatic building extraction (machine learning)
- We generate roof geometry
  - Manual editing by using in-house-built 3D editor
  - Automatic roof geometry extraction (advance computer vision techniques)
- We generate CityGML LOD2 style building Facades and apply automatic texture mapping

Deep Learning Based Building Extraction

(ongoing work)

- We have divided the maps into 640x640 image patches.
- We have respectively trained and tested our deep learning model (implemented in Python-Theano) with 537 (training data) and 37 (test data) patches.
- We have achieved an f-score of .87 on average, i.e, roughly, 87% of the pixels are successfully labeled.
- We achieved very promising results to minimise manual editing and improve automatic extraction.

Semi Automatic Deep Learning Based Object Extraction

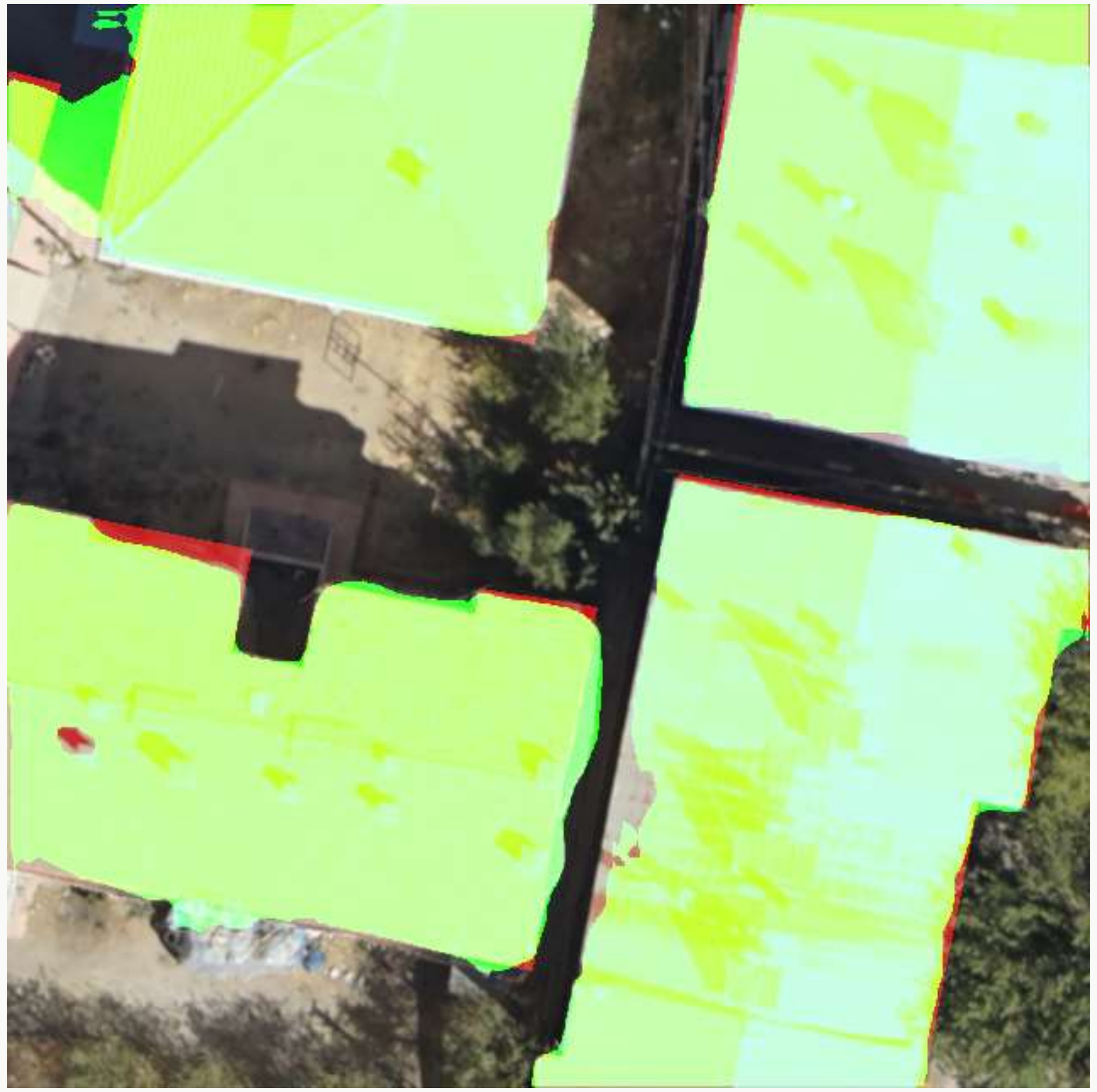
(ongoing work)

Original image **Output image**

(green pixels indicate building labels)

Semi Automatic Deep Learning Based Object Extraction

(ongoing work)

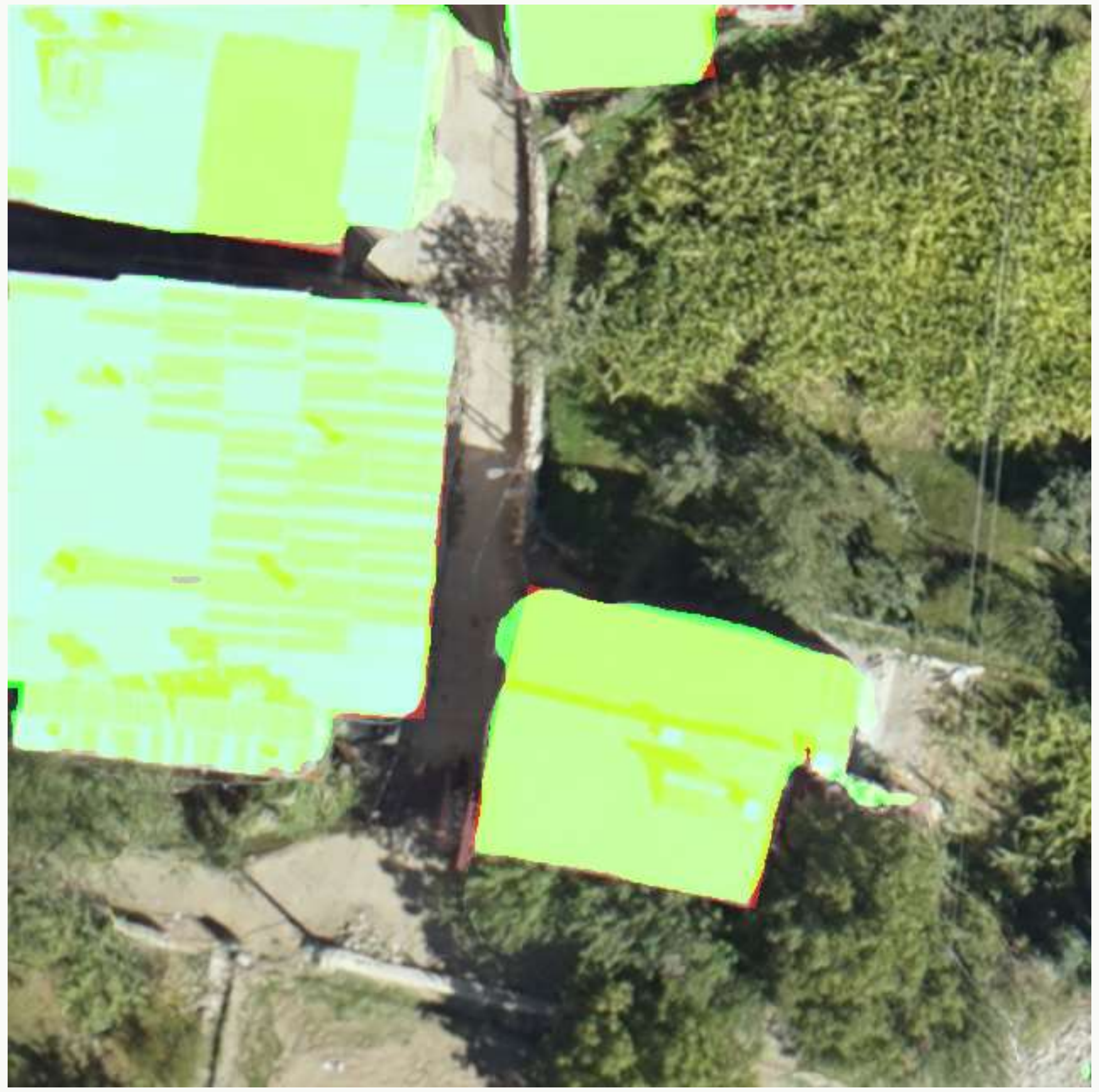


Original image **Output image**

(green pixels indicate building labels)

Semi Automatic Deep Learning Based Object Extraction

(ongoing work)

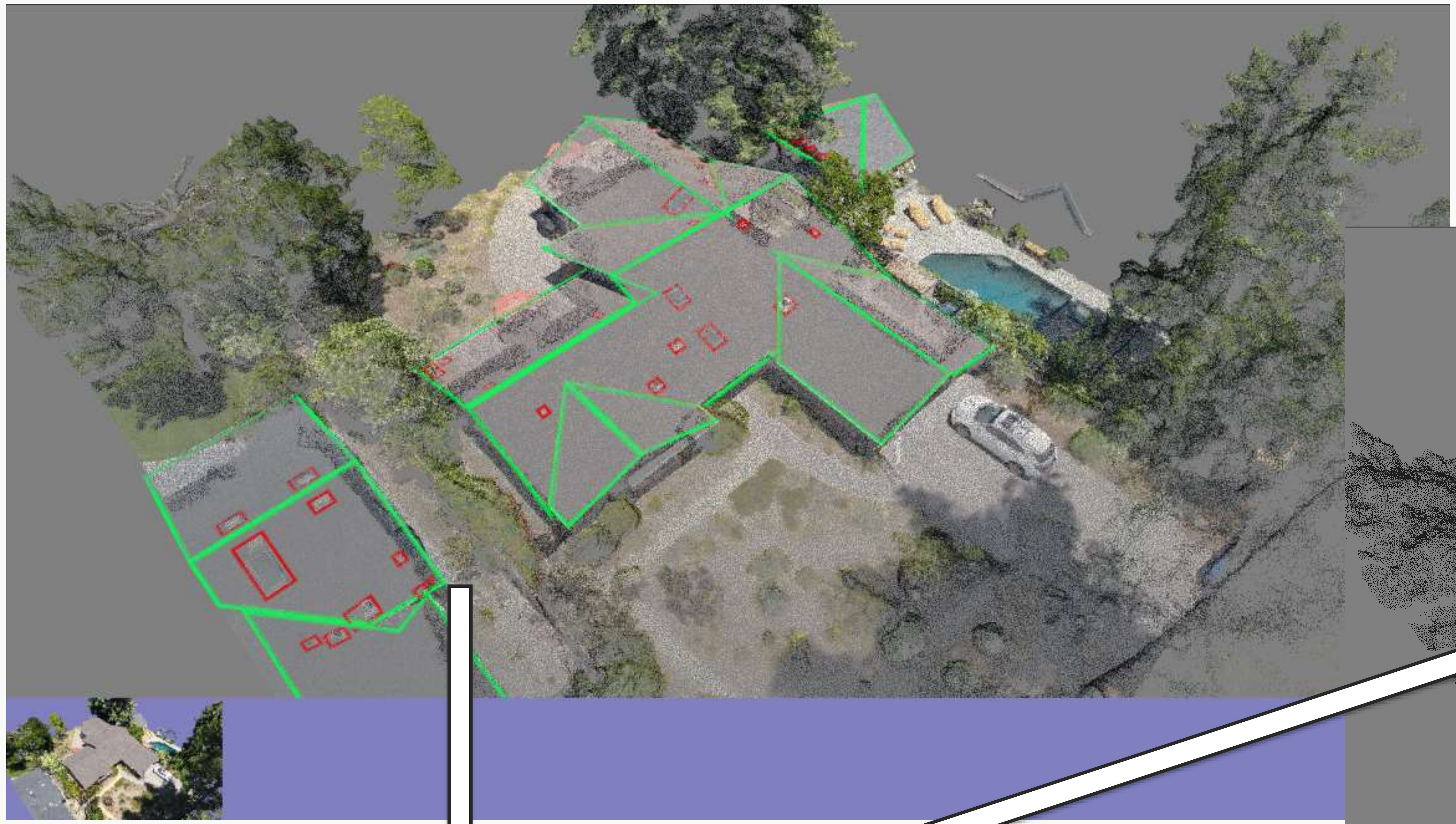


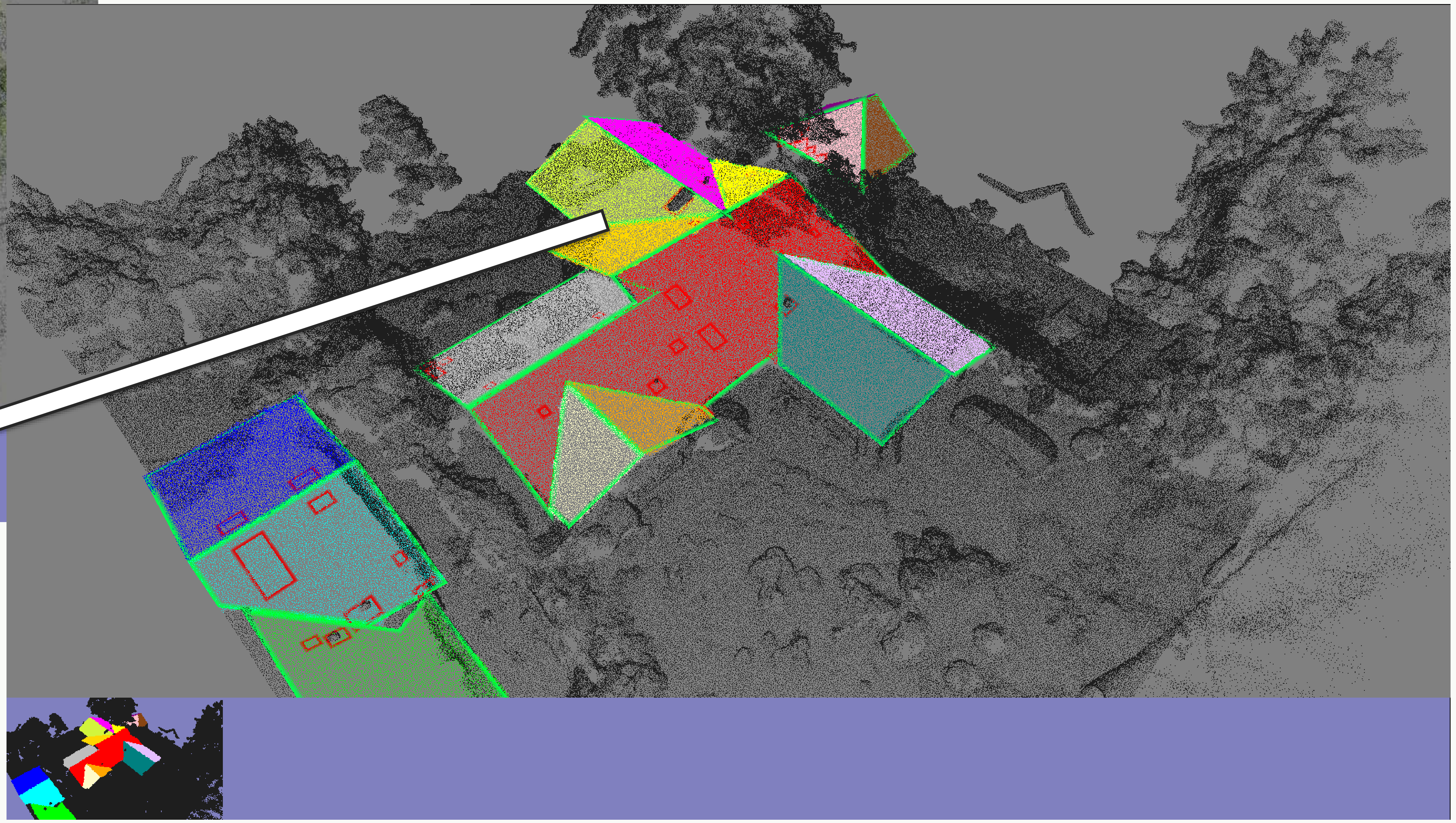
Original image **Output image**

(green pixels indicate building labels)

Automatic Roof Extraction

(ongoing work with AURVIS research team by using advanced computer vision algorithms)

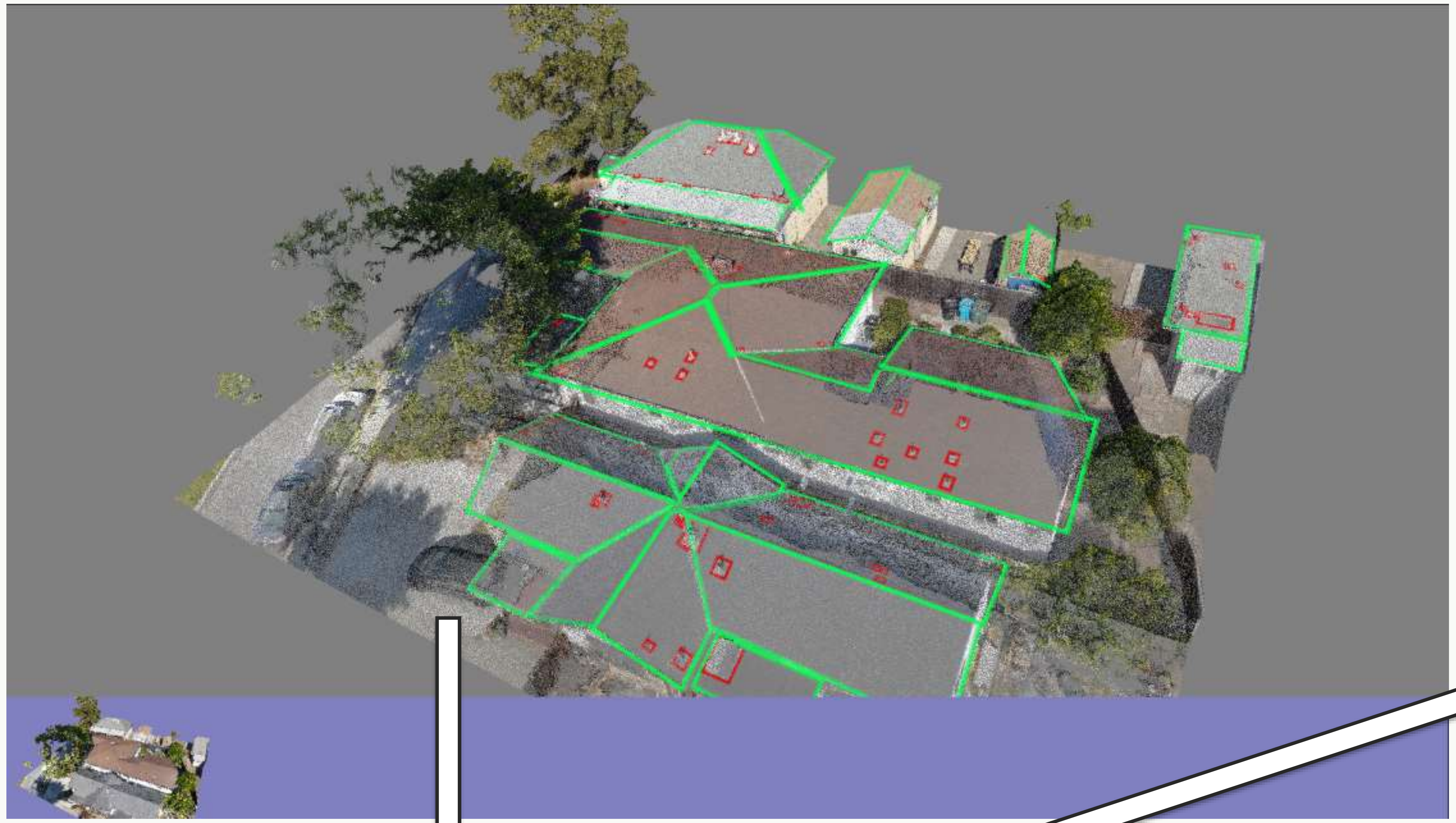


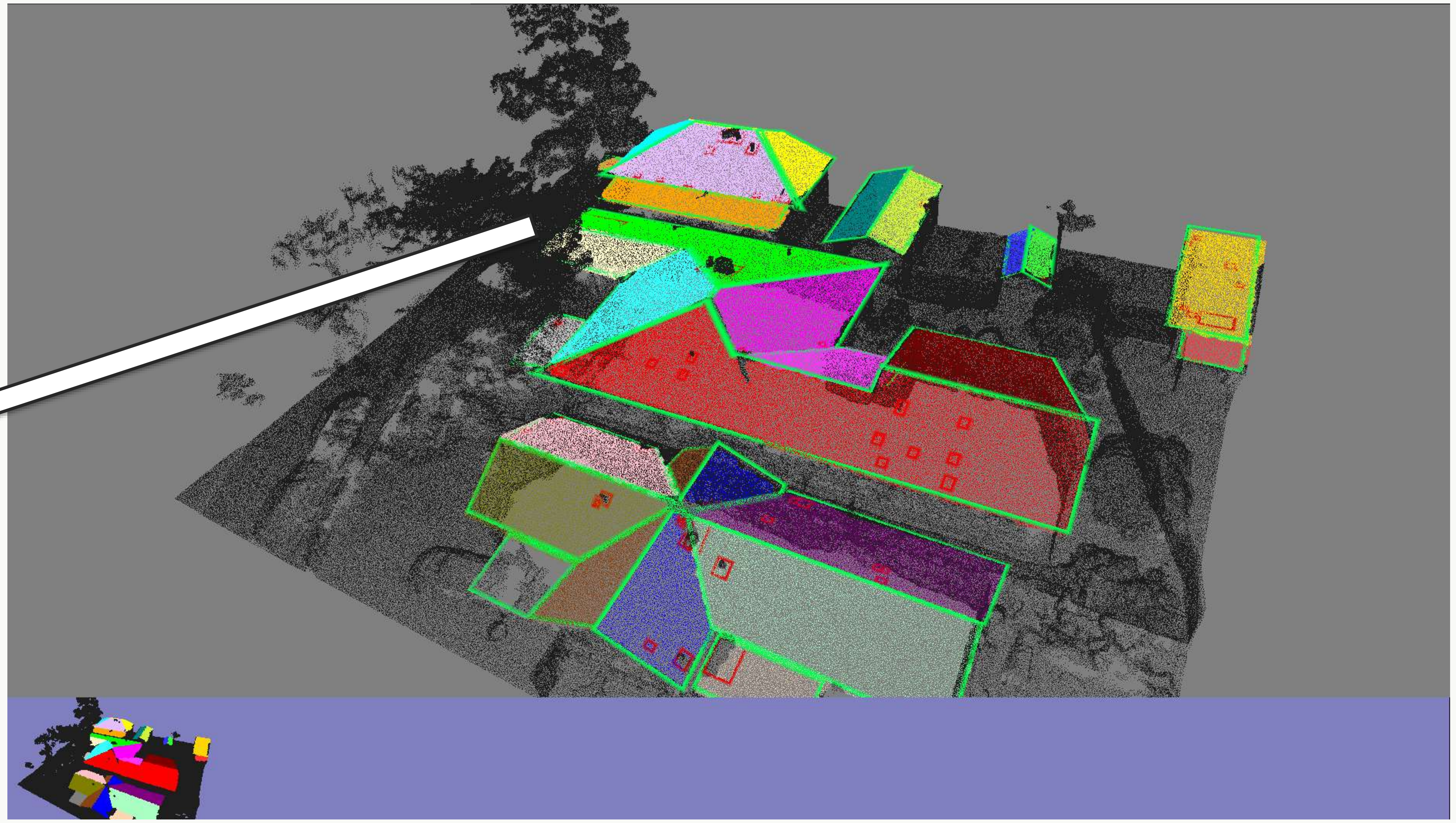


Building Roof and major decoration (automatic process)

Automatic Roof Extraction

(ongoing work with AURVIS research team by using advanced computer vision algorithms)





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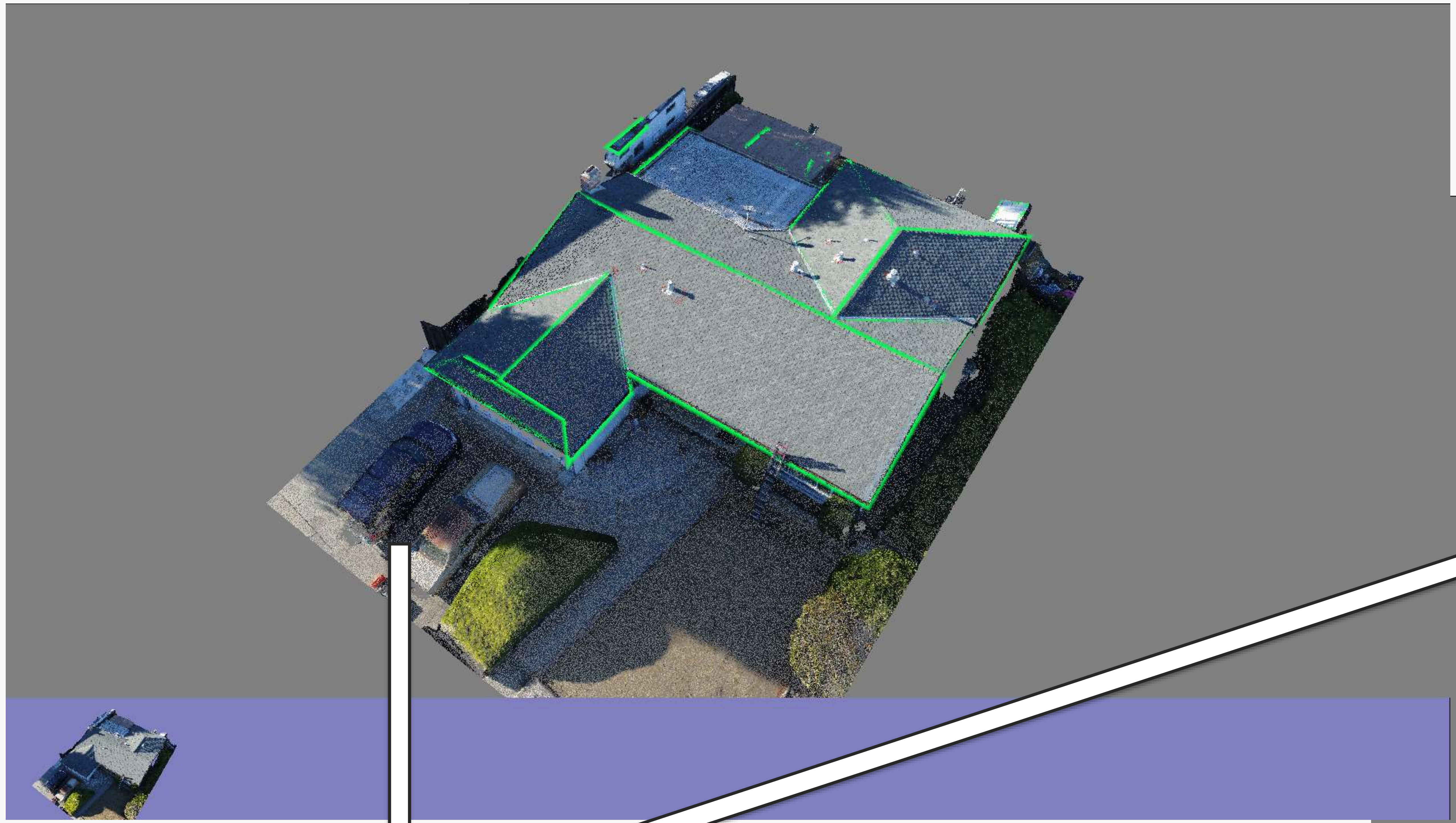

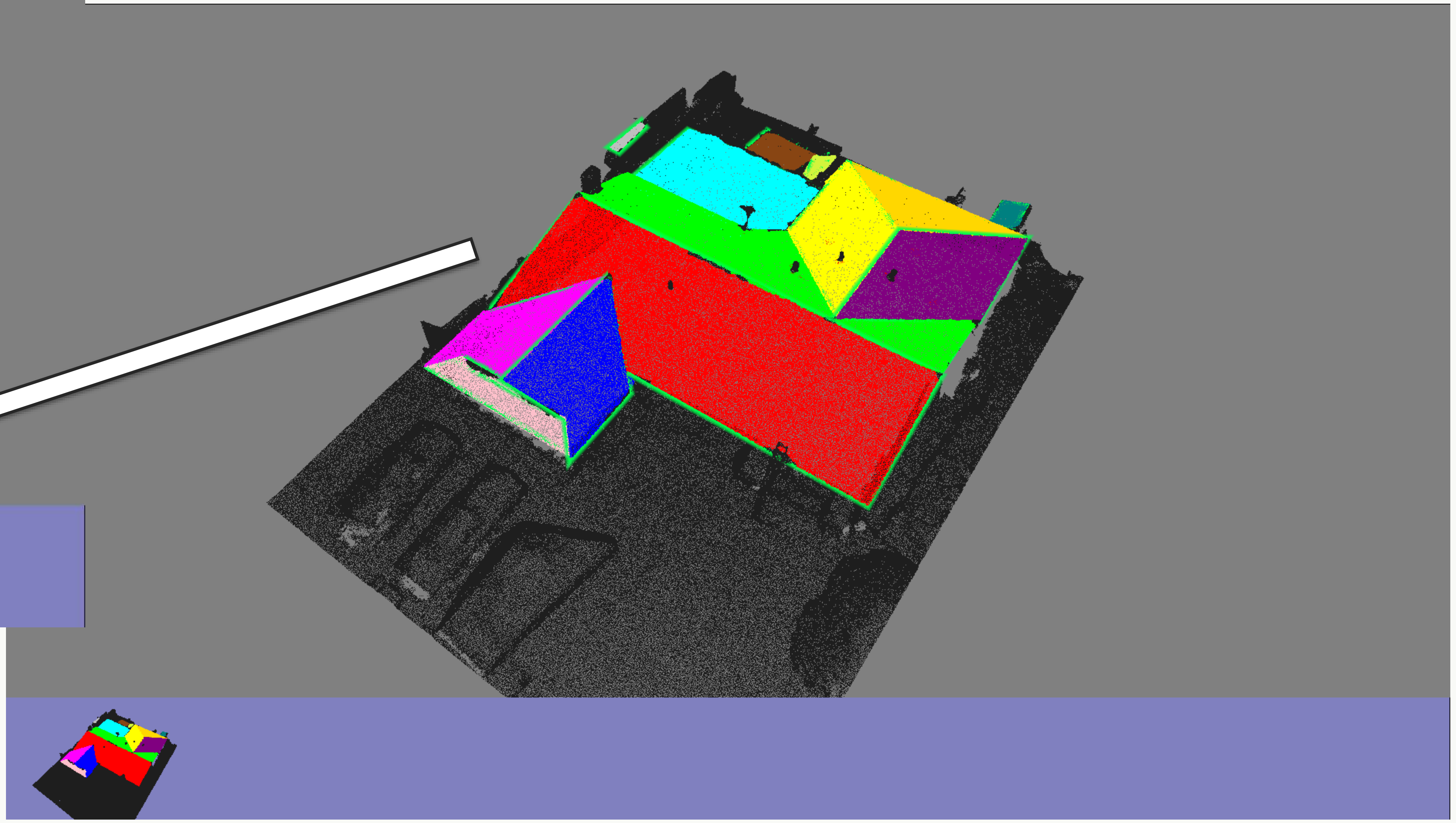

Building Roof and major decoration (automatic process)

Texturing 3D Objects From Aerial Images

Texture of a 3D plane positioned on earth can be calculated via aerial images gathered from cameras mounted on a aircraft. To do so, 2D image coordinates are transformed (projected) to the 3D coordinates on a 3D objects surface coordinates. Projection algorithm use intrinsic and extrinsic camera values:

-Intrinsic: intrinsic *camera matrix* and *distortion parameters*

-Extrinsic: *3d geographic camera position* and *orientation*

Texturing 3D Objects From Aerial Images

Figure (a) displays a 3D camera image plane in a 3d geographic environment. Green lines represents projection rays which are originated from camera center and finalized at 3D wall plane corners displayed in Figure (b).

So far, textures are generated via the outputs of the softwares.

Similarly texturing can be achieved via mobile mapping images

Figure a

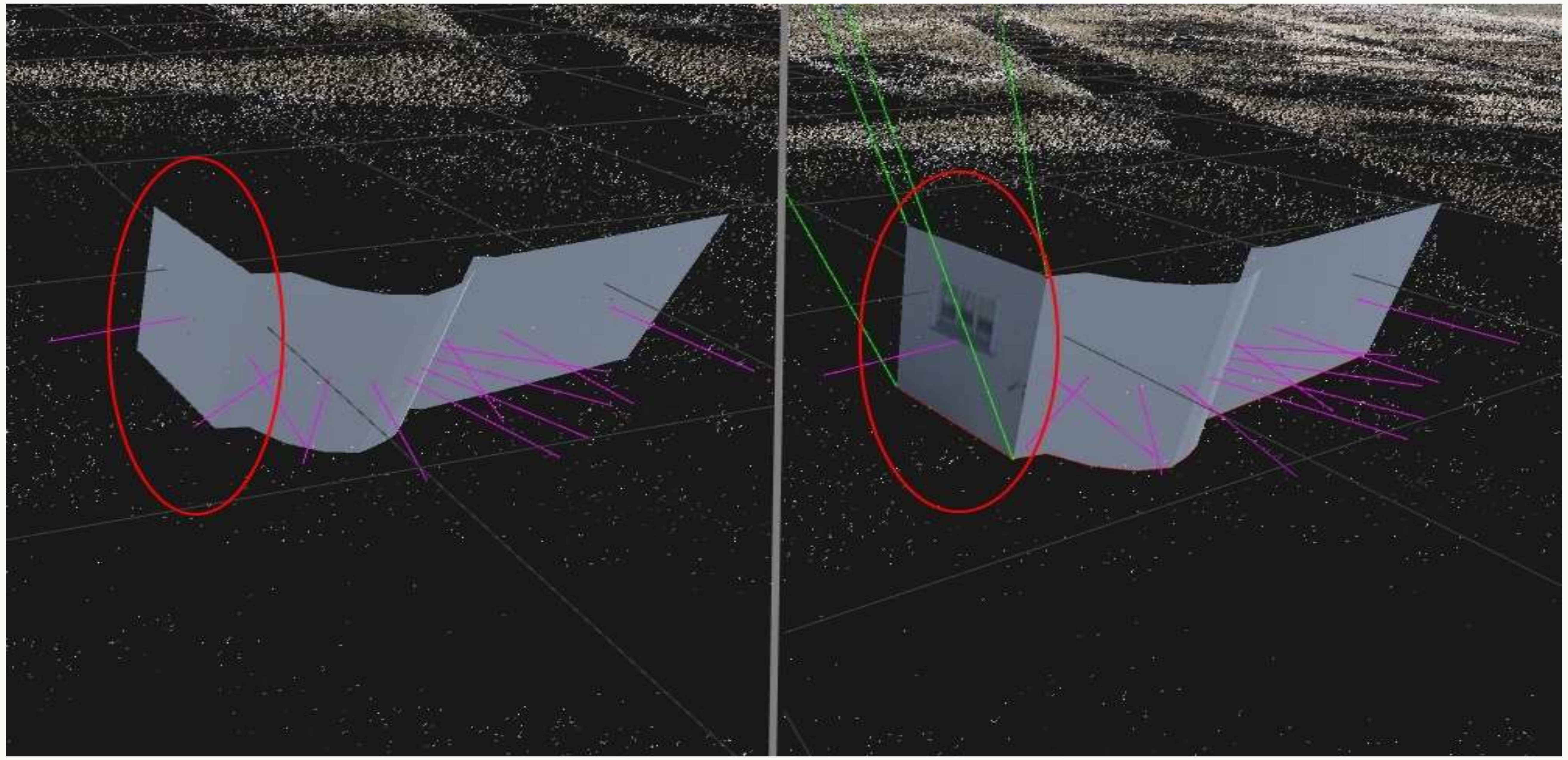

Figure b

Fixing The Tilted Textures

03

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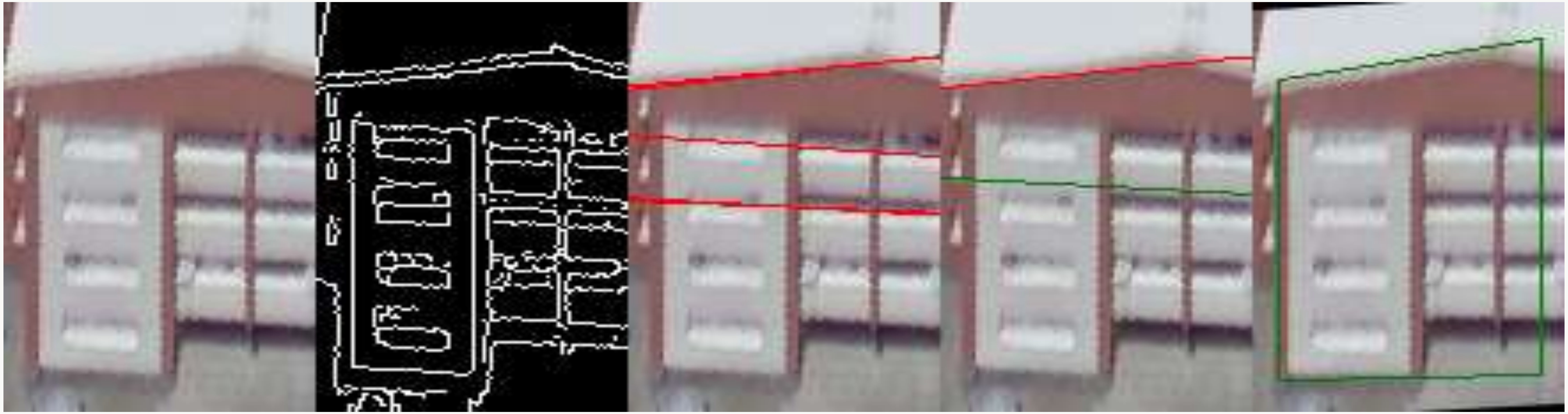


a b c d e

In some cases, inconsistencies of input data my cause tilted textures

(a) Desired fixed texture

(e) is obtained through below steps

(b) Canny edge detection

(c) Finding Hough Line transforms

(d) Eliminating insignificant duplicate lines through clustering and selecting best slope line from eliminated results

Composing Texture From Multiple Cameras

a b c d

In some cases, one building wall face may not be wholly covered by any camera image or maybe occluded by some obstacle. Different cameras may contain different parts of the wall face. So whole texture of the wall can be obtained by composing those different parts from different camera images.

Figures (a), (b), (c), (d); represents how partial images (a) and (b) generated from different cameras are combined into final image (d) via using the mask (c)

Texturing 3D Objects From Aerial Images

Texture of a 3D plane positioned on earth can be calculated via aerial images gathered from cameras mounted on a aircraft. To do so, 2D image coordinates are transformed (projected) to the 3D coordinates on a 3D objects surface coordinates. Projection algorithm use intrinsic and extrinsic camera values:

-Intrinsic: intrinsic *camera matrix* and *distortion parameters*

-Extrinsic: *3d geographic camera position* and *orientation*

Image Enhancement

(AI based image processing - noise removal - multiple image combination, integration and balancing)

Original Image

Improved Resolution and Enhanced Quality

Original Image

Improved Resolution and Enhanced Quality

Facede Enhancement procedures implemented to the every buildings' facade images:

1. **Contrast/Color Enhancement & Gamma Correction**
2. **Resolution Improvement (Super Resolution; Resolution is being increased x2)**

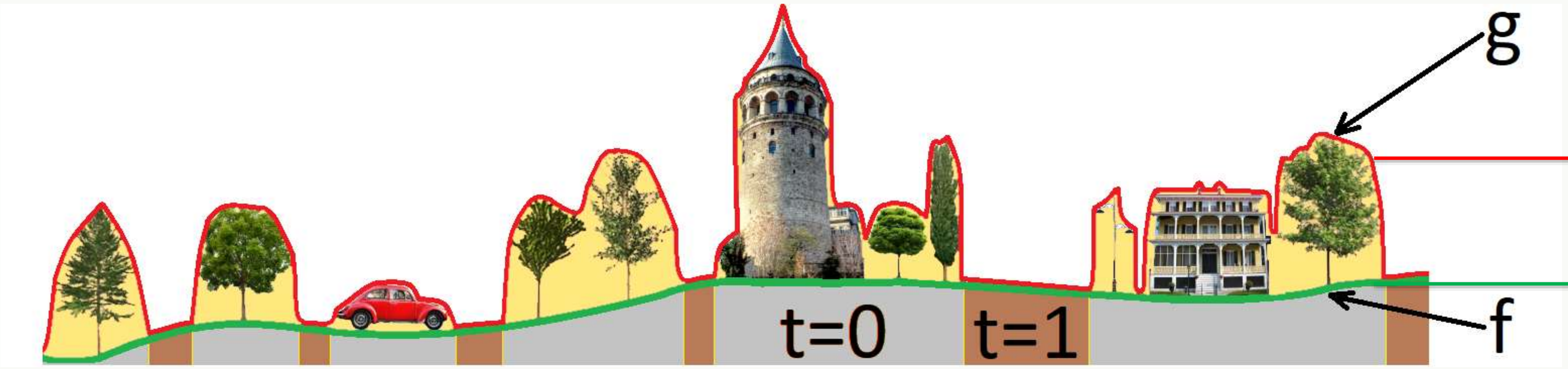
   a. Image Repairing (Sharpening the edges especially the windows)

   b. Deblurring (Reducing the blurring on the facades)

SPARSITY-DRIVEN DIGITAL TERRAIN MODEL EXTRACTION

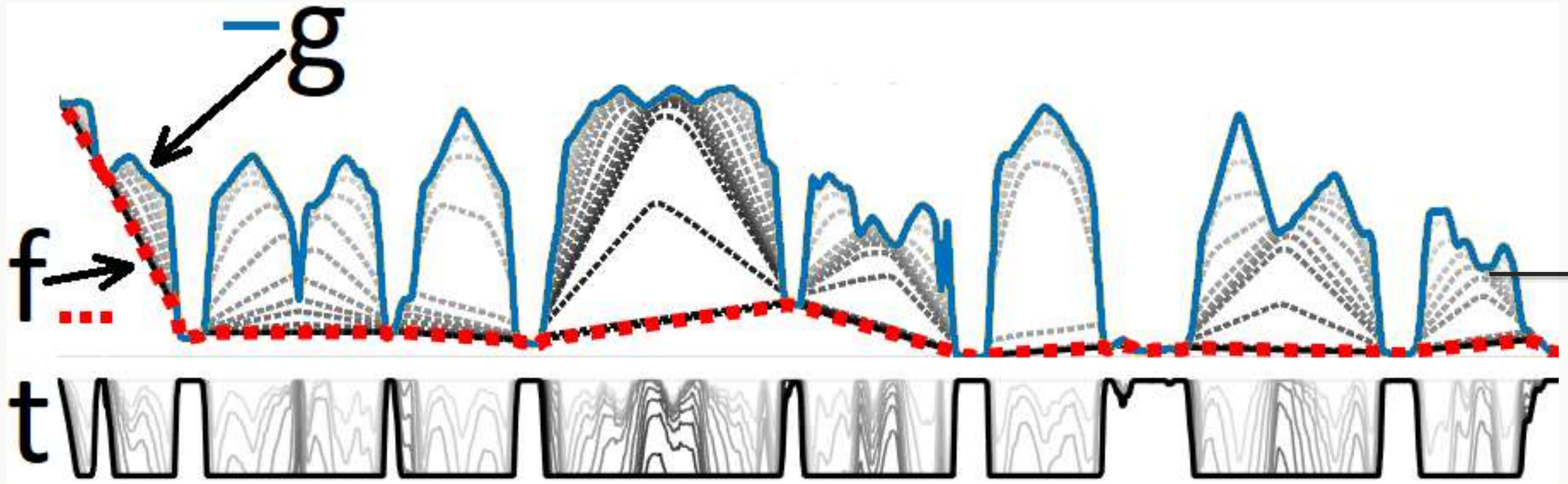
(Detailed paper will be presented at IGARSS 2018, Valencia, SPAIN)

We introduced an automatic Digital Terrain Model (DTM) extraction method. The proposed sparsity-driven DTM extractor (SD-DTM) takes a high-resolution Digital Surface Model (DSM) as an input and constructs a high-resolution DTM using the variational framework. To obtain an accurate DTM, an iterative approach is proposed for the minimization of the target variational cost function. Accuracy of the SDDTM is shown in a real-world DSM data set. Experiments show that proposed method can produce an accurate DTM for the given high-resolution DSM where wide variety of non-terrain objects exists on the terrain with various slopes



Red surface represents DSM

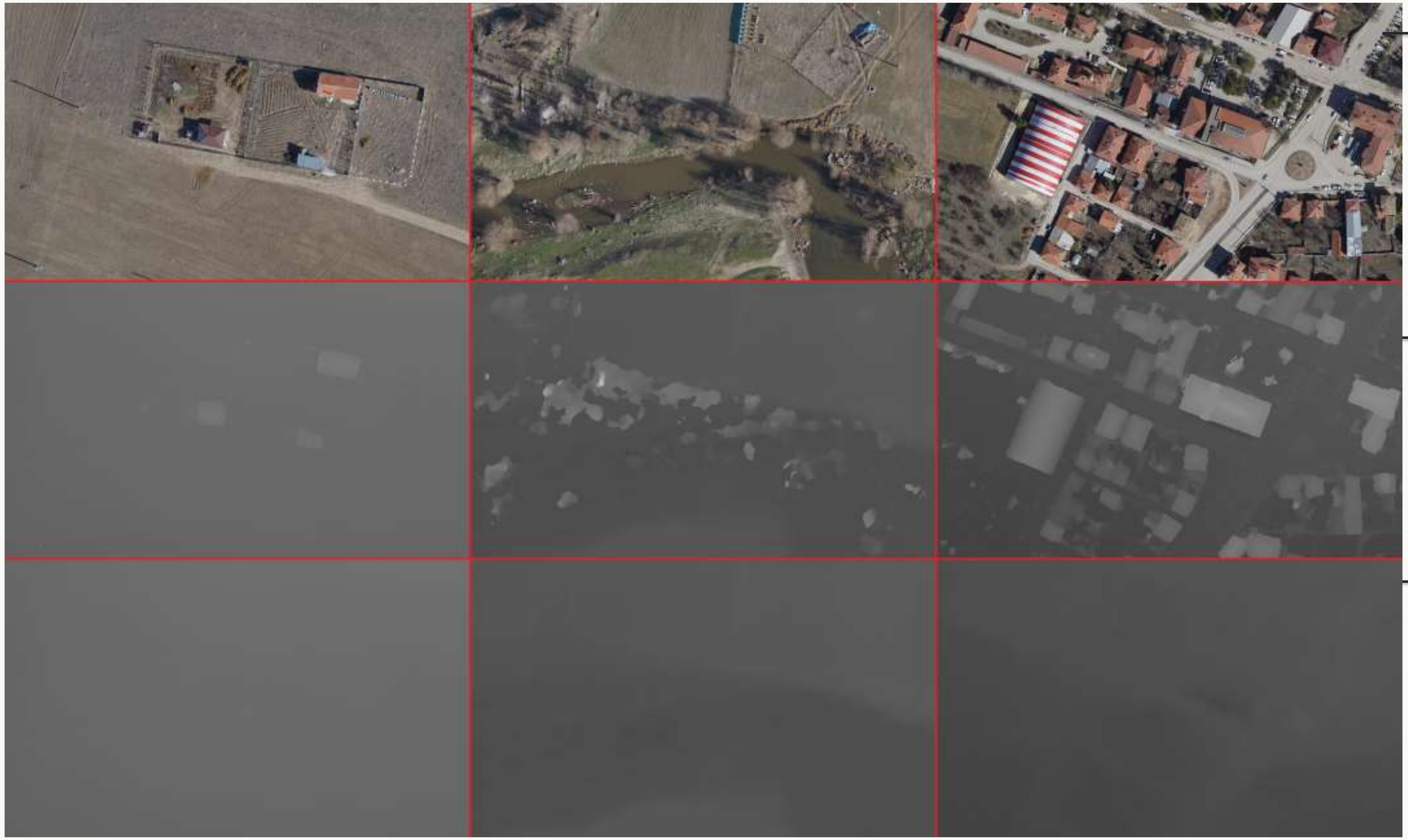
Green surface represents automatically extracted high-resolution DTM



Iterative approach to extract DTM

SPARSITY-DRIVEN DIGITAL TERRAIN MODEL EXTRACTION

(Detailed paper will be presented at IGARSS 2018, Valencia, SPAIN)



Orthoimagery

DSM

DTM
Algorithm preserves natural features and removes man made features

Case Studies - Cerkes 3D Smart Project

04

- **Cerkes 3D Smart Project – 3D City model was created in 10 days' time consisting of:**
  - **5cm GSD orthophoto,**
  - **3D buildings (a total of 5,916 buildings),**
  - **3D Trees (about 6,000), fences, power lines, and other planimetric features**
  - **DSM / DTM / Contours all to the precision of ~10 cm.**

This solution displays the entire city intelligently to users. The system also allows for powerful analyses such as contour maps, noise maps, flooding and so forth. It is a good example of rich and intelligent geospatial data compiled in a short duration.

Case Studies - Hannover Project

04

▪ **Hannover Test Area**

- **10cm GSD orthophoto**
- **3D buildings**
- **DSM / DTM / Contours all to the precision of ~10 cm.**

This solution shows how we created a 3D City model by using low overlapped imagery (70% forward, 30% side). The result proves that it is even possible to generate nice city models by using low overlapped data.

Case Studies – Frederick USA Project

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▪ **Frederick Test Project**

- **7cm GSD oblique imagery**
- **3D buildings**
- **DSM / DTM / Contours all to the precision of ~10 cm**
- **Super-resolution implemented to improve image quality**

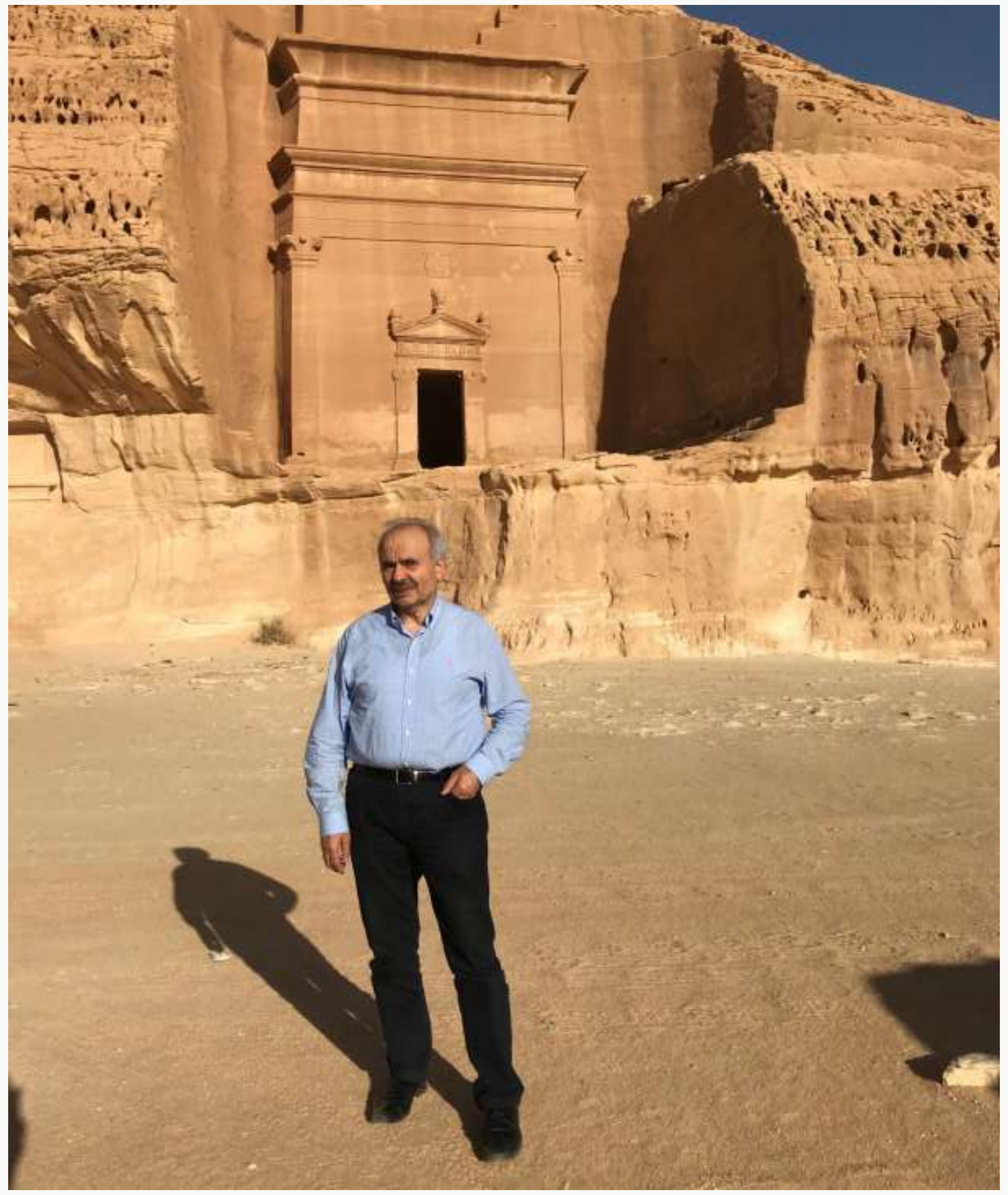
This solution shows an example of oblique imagery. Please note the quality improvement in the facades.

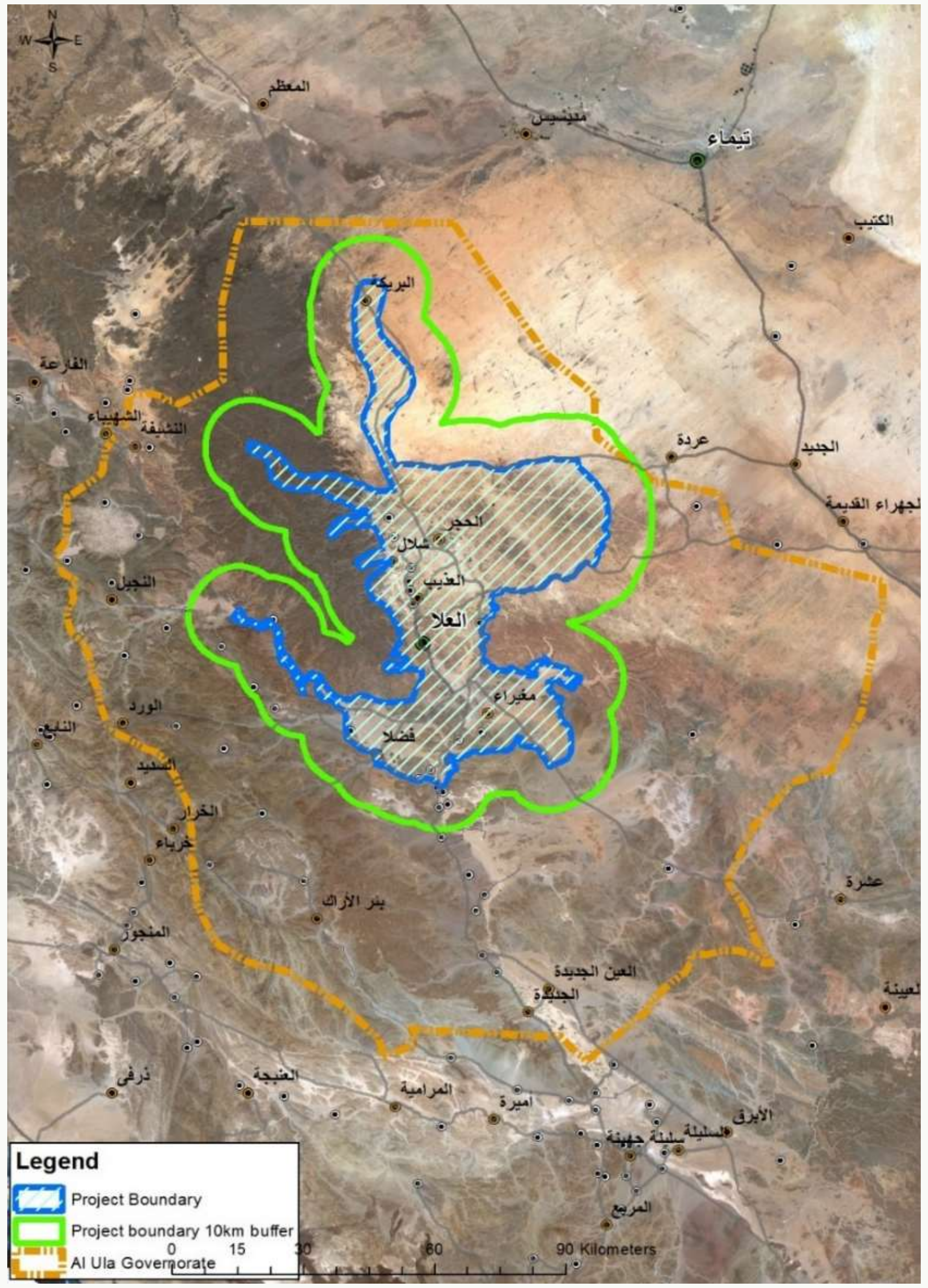
The facade texture maps are improved by using our super resolution solution.

Case Studies - Al Ula Historical Project

04

- **AL ULA Project of Royal Commission of Al Ula (RCU) (Saudi Arabia) –** Historical, archeological and touristic Mapping: Geospatial Data and GIS Project of Royal Commission for Al Ula (RCU); Satellite imagery, orthophoto, cadastral registration, geodatabase and Geoportal in Al Ula Area (3,300 km^2)

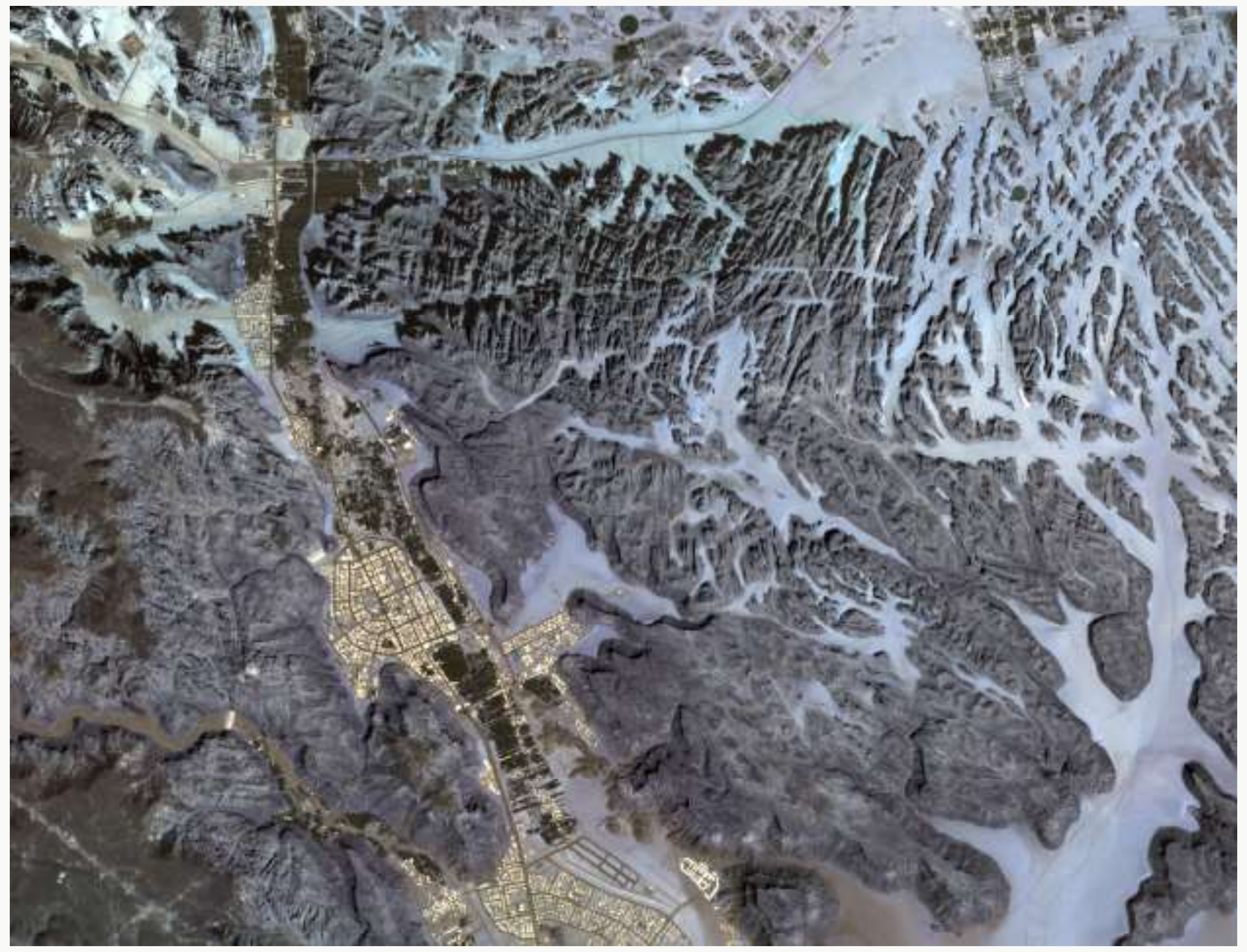




Case Studies - Al Ula Historical Project

04

- 3m Resolution Planet Imagery (23,000 km^2)
- Land Use / Land Cover (28 classes) .. 9,000 km^2
- 10cm Resolution Aerial Imagery (9,000 km^2)
- 5cm Resolution Drone Imagery (600 km^2)







Concluding Remarks

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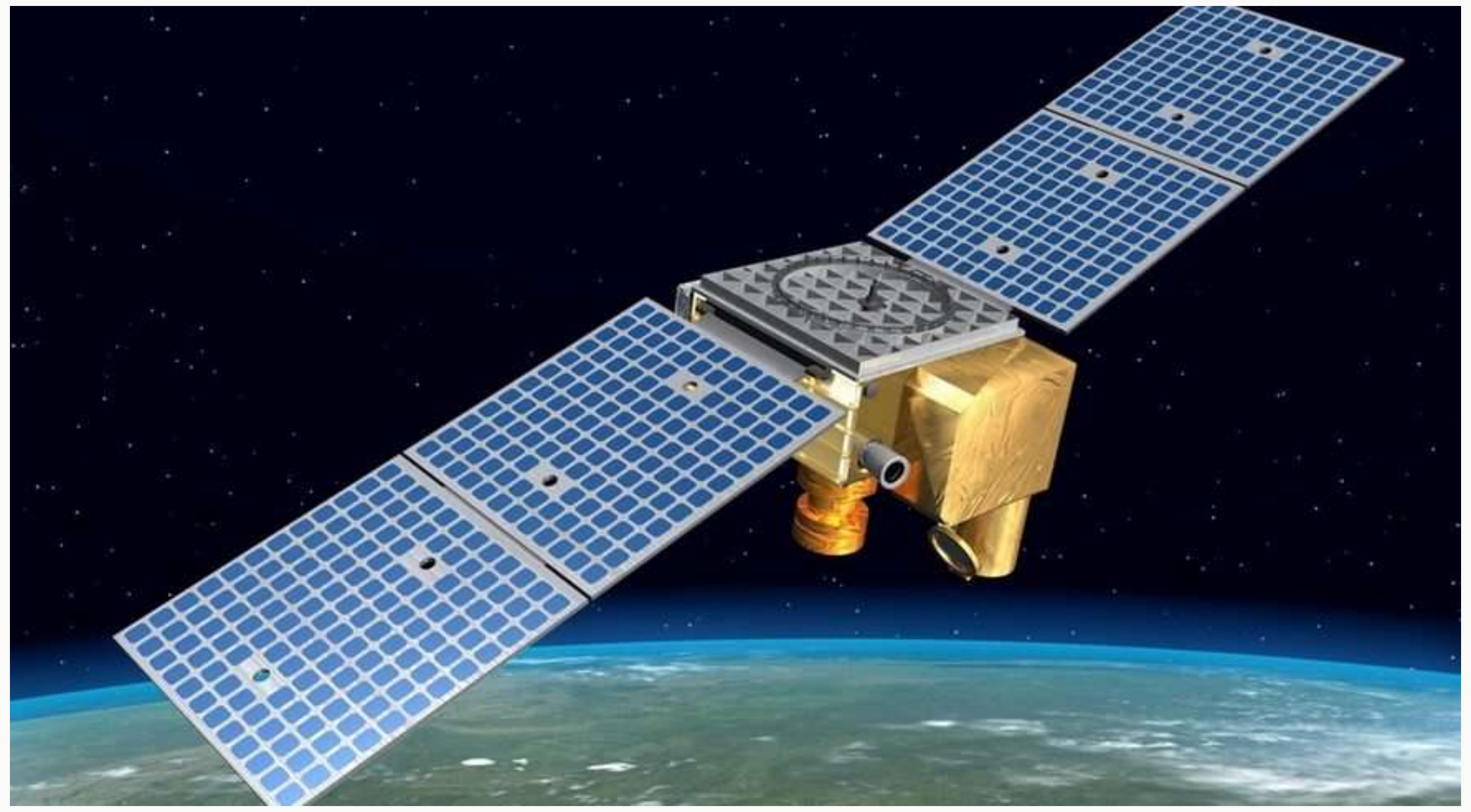
This cutting edge solution combined with aerial imagery using aircrafts, UAVs and so forth, makes it possible to develop smart geospatial data for smart cities in a nearly automated fashion. Thus, a smart geospatial base can be established in **weeks rather than the years** that would be required using traditional approaches and techniques.

- **Object based 3D GIS Establishment**
- **Cadastral registration and Real Estate Value Assessment**
- **Environmental Management**
- **Spatial Planning and Landscape Planning**
- **Urban Transformation and Traffic Planning**
- **Energy Efficiency**
- **Disaster Prevention and Disaster Management**
- **Improving the Quality of Life (noise, air pollution, air flow, etc.).**
- **Urban Life Mobility Analysis (Business centers, streets, underground transportation)**
- **Infrastructure Construction and others.**



Questions & Answers

05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شكرا لحضوركم
THANK YOU