REPUBLIKA HRVATSKA
DRŽAVNA GEODETSKA UPRAVA

State Geodetic Administration and LIFE CROLIS project:

Development of nDSM for Croatia

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LIFE19 GIC/HR/001270 - CROLIS - CROatian Land Information System
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INTRODUCTION

For the implementation of the National Land Information System LIFE19 GIC/HR/001270 - CROLIS - CROatian Land Information System (hereinafter referred to as LIFE CROLIS), the State Geodetic Administration has undertaken to create a normalized Digital Surface Model – nDSM.

The normalized Digital Surface Model (nDSM) is calculated as the difference between the Digital Surface Model (DSM) and the Digital Terrain Model (DTM) and highlights objects in relative relation to the ground or objects on the ground (Figure 1).

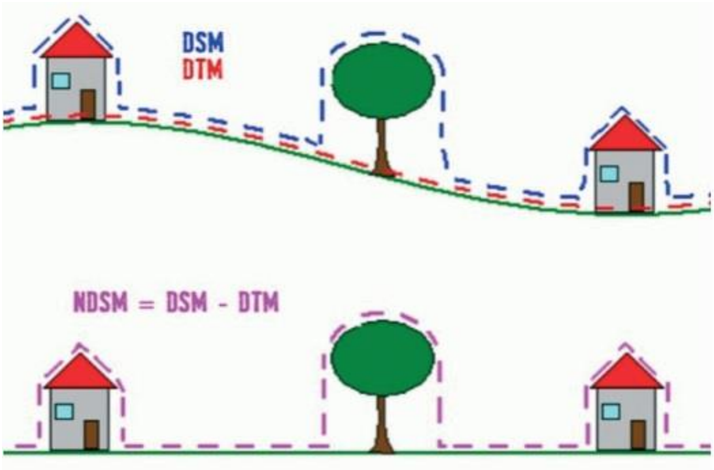

Figure 1: nDSM as the difference between DSM and DTM

As part of the LIFE CROLIS project, the following terminology is used for the development of a normalized Digital Surface Model (nDSM):

NORMALIZED DIGITAL SURFACE MODEL - nDSM - represents the relative height of natural (vegetation) and built (buildings, bridges...) objects on the Earth's surface in relation to the Earth's surface itself.

DIGITAL SURFACE MODEL – DSM - is a digital elevation model of the Earth or a part of the Earth that shows the Earth's surface including all natural and built objects on the Earth's surface.

DIGITAL TERRAIN MODEL – DTM - is a digital elevation model of the Earth or a part of the Earth that depicts the Earth's surface excluding natural and built objects from the surface. It represents a series of spatially defined points and geometric elements (break lines, form line and exclusion area).

LIDAR - Light Detection and Ranging is an optical instrument that emits laser beams that bounce off very small particles scattered in the atmosphere (aerosols, cloud droplets, etc.) and are then registered in an optical receiver (usually a telescope).

The input data required to calculate the nDSM (DSM and DTM) can be collected using various methods and technologies, on which the quality of the nDSM depends.

One of the possibilities was to calculate nDSM from input data obtained by a combination of radar method (DSM collecting) and photogrammetric restitution (DTM collecting), but the mentioned method does not provide satisfactory results. In the meantime, the LIDAR data collection project was completed and it was decided to use the mentioned data, because of higher accuracy and resolution of input data.

COLLECTING OF DSM AND DTM WITH A COMBINATION OF RADAR METHOD AND PHOTOGRAMMETRIC RESTITUTION

For the pilot areas, 12 locations on the territory of the Republic of Croatia were selected on the official base maps of the State Geodetic Administration (DOF5) (Figure 3). Location that are completely or predominantly covered vegetation were selected and they were distributed across different regions of the Republic of Croatia in order to obtain the most relevant results of the pilot project, taking into account the diversity of relief and cover. The areas are defined by squares 2500x2500 meters (Figure 2).

Figure 2: Pilot areas locations

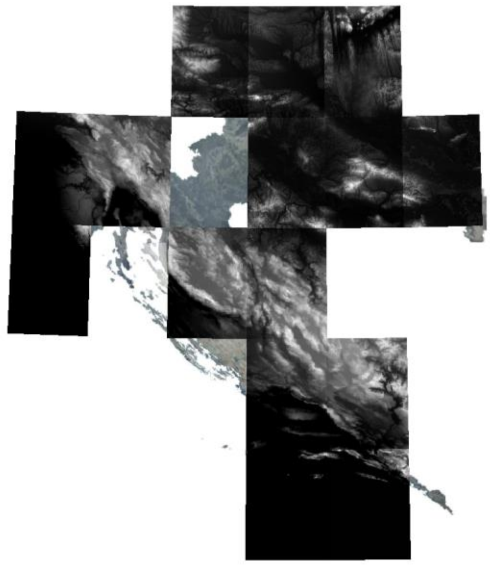

Figure 3: Overlay of DSM with DOF5

The DSM data was collected as part of the TanDEM-X, an interferometric SAR (Synthetic Aperture Radar) mission. The synchronous operation of two radars (satellites) collected high-resolution images for monitoring land areas and coastal processes, particularly for agricultural, geological and hydrological applications. The radar is able to collecting data relatively quickly even in unfavorable weather conditions (cloud cover) and penetrate vegetation down to ground level.

The collected DSM has the following characteristics:

- Output format: GeoTIFF (32-bit) divided into regular sheets (1°x1°)
- Resolution: 12 x 12 meters
- Elevation accuracy: relative < 2 m, absolute < 10 m
- Horizontal reference system: WGS84
- Vertical reference system: EMG2008

The DTM data were collected by photogrammetric restitution from aerial photogrammetric scanning of different years, whereby the images had a resolution of at least 30 cm (GSD < 30). The accuracy of the photogrammetric restitution depends on the resolution of the aerial photogrammetric images. Furthermore, in photogrammetric surveying it is difficult and sometimes even impossible to capture terrain data below areas with dense vegetation. Such areas are referred to as "unreliable DTM areas" and are filled in from other sources (usually by vectorising isohypses from "older" source (HOK5 or TK25)).

The collected DTM has the following characteristic:

- Output format: DGN/ DWG
- Position accuracy: 50 cm
- Elevation accuracy: 75 cm
- Horizontal reference system: HTRS96/TM
- Vertical reference system: HVRS71

The created nDSM has the following characteristics:

- Output format: GeoTIFF (32-bit)
- Resolution: 10 x 10 meters
- Horizontal reference system: HTRS96/TM
- Vertical reference system: HVRS71

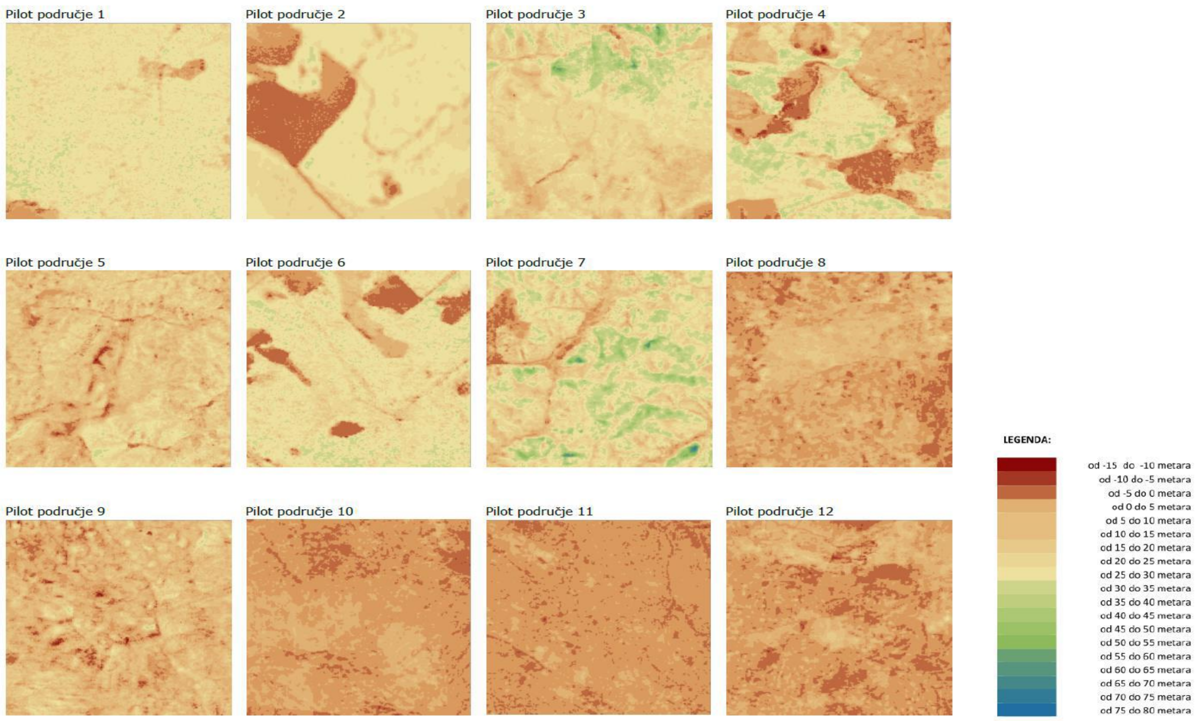

Figure 4. Created nDSM in the selected areas

The definition of the pilot area, collecting the nDSM in the selected areas and the results indicate this combination of radar method and photogrammetric restitution does not provide satisfactory results (obtained negative nDSM values up to -15 meters) (Figure 4).

COLLECTING OF DSM AND DTM FROM LIDAR

LIDAR is based on the principle that a device emits directional pulses of light towards an object or the ground and measures the time it takes for the signal to bounce back and return. How detailed the specified area is recorded with the LIDAR system depends on the density of the points, which is expressed by the number of points recorded per unit area (n points/m^2).

After the image is taken, the data is processed on the computer. The result of laser scanning the terrain is a large amount of raw data in the form of a group of „point cloud“.

Each point in the point cloud has its XYZ coordinates in the HTRS96 system (official coordinate system of the Republic of Croatia). Based on the density of the points, we can deduce how detailed a particular area has been mapped.

The LIDAR scans of the Republic of Croatia achieved a minimum point density of 4 points per square meter in non-urban areas (uninhabited and sparsely populated places) and a minimum point density of 8 points per square meter in urban areas (cities and settlements with higher density).

LIDAR data are classified into 10 classes, of which classes 2 and 9 contain DTM data, and classes 2, 3, 4, 5, 6 and 7 contain DSM data (Table 1).

LAS class	Description	Required class	Grid models (used classes)	
			DTM	**DSM**
0	Unclassified (unprocessed data)	x		
1	Unclassified (processed data, not assigned to any class)	x		
2	Soil/terrain (points under bridges, overpasses and similar)	x	x	x
3	Low vegetation	x		x
4	Medium vegetation	x		x
5	High vegetation	x		x
6	Buildings (roofs and facades)	x		x
7	Noise	x		
9	Water (također točke voda ispod mostova)	x	x	
17	Bridges, Viaducts	x		x
	Total	**10 classes**		

Table 1. Classification of laser points

The collected DMS and DTM have the following characteristics:

- Output format: TIFF/TFW
- Resolution: 1 x 1 meters
- Projection coordinate system: Projection coordinate reference system RH - HTRS96/TM
- Height system: Height reference system RH - HVRS71

The created nDSM has the following characteristics:

- Output format: GeoTIFF (32-bit), table list of coordinates (*.xlsx)
- Resolution: 1 x 1 m
- Projection coordinate system: Projection coordinate reference system RH - HTRS96/TM
- Height system: Height reference system RH - HVRS71

Analyzing the results, we conclude that the input data of DSM and DTM obtained by a combination of radar and photogrammetric restitution do not provide satisfactory results (negative values of nDSM). In order to obtain satisfactory results, it is necessary to use the input data collected by the same method (LIDAR), which would fulfil with its accuracy the required demands of the LIFE CROLIS project.

DEVELOPMENT AND DELIVERY REPORT OF NORMALIZED DIGITAL SURFACE MODEL – nDSM, CREATED BY CADCOM d.o.o.

Geospatial data Abstraction Library – GDAL, an open-source library under the MIT licence, was used to prepare input data and calculate nDSM. GDAL is a collection of functions used to convert between different GIS formats (vector and raster), data types and coordinate systems. Using the GDAL library, it is possible to perform manipulations on raster data, such as changing the projection, NO DATA value change, metadata change and similar.

Deduction of the DMR pixel value from the DSM pixel value at the same location the nDSM pixel value for that location is obtained.

Quality assurance after conducting quality controls, the nDSM data is subjected to a control process to ensure compliance with the technical specification of the project assignment. The created nDSM has characteristics which include the projection coordinate system HTRS96/TM, the height system HVRS71 and a resolution of 1 x1 m. The data are also available in table format where the coordinates and values of nDSM are show. The results of the control confirm that the data are reliable, precise and useful for further analysis and use.

The data of the nDSM is delivered according to defined blocks according to the following schedule:

BLOCK	DELIVERY DATE	NUMBER OF DELIVERED SHEETS
Eastern parth of Croatia	18.03.2024.	21656
Western parth of Croatia	22.03.2024.	30775
Southern part of Croatia	29.03.2024.	7667
Easter – Western – Southern parth of Croatia – Corrected sheets	29.03.2024.	2242

TOTAL: 62340

Delivery raster and table data are named according to the official division into 1:2000 scale sheets, according to *Technical specifications for calculation procedures and division into sheets of official maps and detailed sheets of the cadastral plan in the cartographic projection of the Republic of Croatia – HTRS96/TM*, with retention of the prefix mark on the LIDAR scans group of the Republic of Croatia as in the input data. The data were delivered in the projection coordinate system HTRS96/TM and the height reference system HVRS71.