Terrestrial laser scanning and 3D modeling of a wind turbine generator

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Introduction

Energy efficiency and environment protection streamline initiated the development of variety of alternative energy resources. Among them significant role has the **wind energy**.

- **Climate**
  Moderately air flow conditions are characteristic of Serbian climate.

- **Region**
  Several **wind farms**: Kula, Vršac-Zagajica, Vršac-“Košava”, Kruščica and Alibunar are installed (or currently under construction) in Serbia

Location

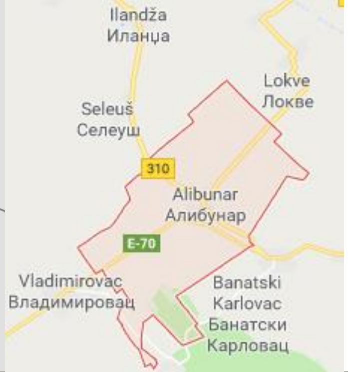
- Wind farm in municipality of Alibunar, opened on September 11th 2018

- Road distance of Alibunar from Belgrade to the North-East is 56km, with aerial distance of 52km

- Built on agricultural soil

- Consisted of 21 wind turbines

- In optimal conditions wind park can generate 42 MW of power



Wind Turbine

Individual power of 2 MW

Height 134m

Parts: Tower, nacelle structure enclosing the power generator, three rotor blades, rotor hub and ground equipment station

The foundation is the only part which has to be built directly on the site

Measuring instrument and equipment

- *Laser scanner FARO® Laser Scanner Focus^{3D}* was used for scanning procedure

- Device uses high technology for terrain data collection with high time efficiency

- Discretization of complex objects and environments with high geometry definition

Characteristics	Values
Wavelength	905 nm
Laser power	20 mW
Measurement speed	976000
Maximal range	120 m
Ranging error (10 m to 25 m distance)	±2 mm
Working temperature	+5°C do +40 °C
Field of view (horizontal/vertical)	360° /305°

Measuring instrument and equipment

- *Digital camera NIKON Coolpix S9300*
- 16 Mpix resolution
- Optical zoom of 18x
- 1/2.3” (6.16 x 4.62mm) CMOS sensor

Characteristics	Values
Maximum resolution	4608 x 3456
Effective pixels	16 megapixels
Sensor size	1/2.3" (6.17 x 4.55 mm)
Focal length (equiv.)	25–450 mm
Max aperture	F3.5–5.9
Dimensions	109 x 62 x 31 mm
GPS	Built-in

Methodology

Process of turning real world model into computational model consists of:

- **Scanning procedure**
  Scanning procedure with FARO Focus 3D scanner
- **Photogrammetry procedure**
  NIKON Coolpix S9300 camera was used for obtaining photos and GPS information
- **Geometry camera matching**
  Automatic perspective matching and camera orientation matching of acquired data

Scanning procedure

• Scanning procedure with FARO Focus 3D scanner .

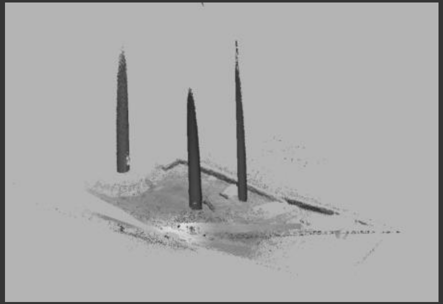
• The instrument is placed at previously 5 planned station positions, in order to capture the shape of the whole object

• 6 markers are placed (the overlap of the two neighboring scenes contained minimum three common markers)

• Scan parameters are adopted: scan resolution was set for 3mm ranging error at the distance of 10m, which required 20-30 min of scan duration

• The field of vision is defined for each particular station and both angles (horizontal and vertical); It varied from 90 to 210 degrees

• Scanning result is set of 3D points, i.e. point cloud, where each point has four attributes: three spatial coordinates and information about intensity of the returned radiation (depending on the reflectivity of the scanned object)



Raw scanned data

Photogrammetry procedure

Photogrammetry method interprets photographic images and patterns to obtain reliable information about physical objects and the environment

Method commonly requires more than 20 photographs from different locations around the object

In order to create a model from images it is preferred to know the information about the position where each image is taken (GPS location)

In our case 28 photo images were taken for two different wind generators. The unstable weather conditions and slight movements of the blades (due to the wind conditions) affected on image quality. NIKON Coolpix S9300 camera was used for obtaining photos. Images were imported into *Autodesk Recap* software, in order to obtain point cloud results.

Raw point cloud data

Geometry camera matching

- This method uses still images
- GPS location is extracted from EXIF data from the photographs, establishing geographical coordinates of shooting positions, focal length and camera's sensor size. Using intrinsic parameters, manual and automatic perspective matching and camera orientation matching is performed resulting in extrinsic parameters within newly generated reference system

Intrinsic parameters

- geographical coordinates of shooting positions
- focal length
- camera's sensor size

Extrinsic parameters

- Orientation of the cameras
- Position of the cameras.
- Reference system

Modeling procedure

Process of turning raw data into computational 3D model consists of:

- → **Point cloud from FARO Focus 3D scanner to the mesh**
- → **Point cloud from potogrammetry procedure to the mesh**
- → **Geometry camera matching to the mesh**

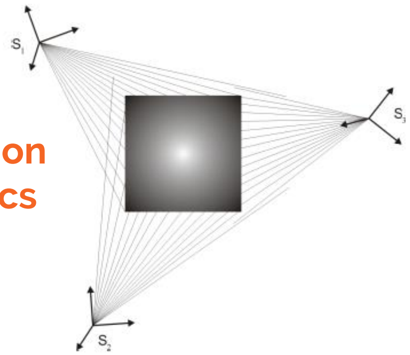
Point cloud from FARO Focus 3D scanner to the mesh

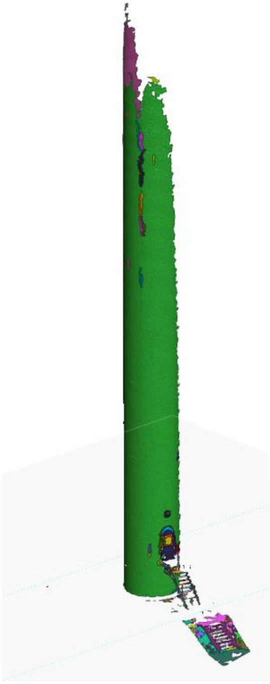
Using FARO Focus 3D laser scanner obtained 3D point cloud data of a maximum distance scanner can reach, which is 120m from the position of the measuring instrument, but only 40m from ground level of wind turbine tower

Data that were taken from wind-turbine environment, such as ground, grass and other plants were manually cleaned

In order to obtain the scan results, registration of the point clouds was required. Registration involved 3D transformation of 5 point clouds into one (based on markers-spheres), within single coordinate system

Registration Schematics





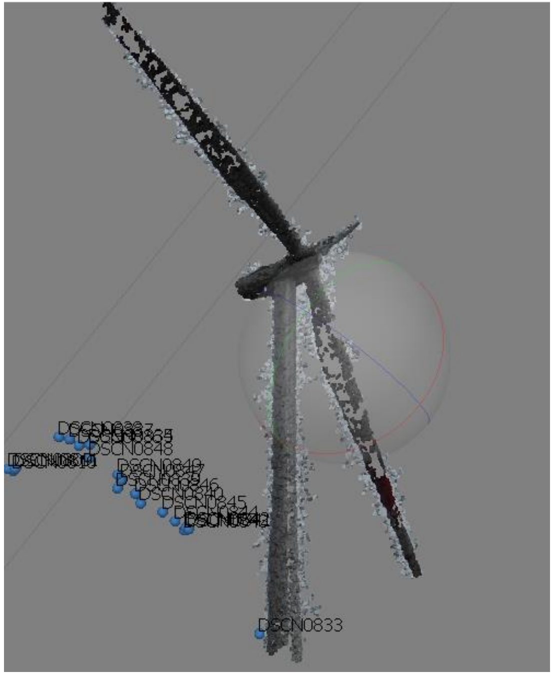
Cleaned and combined point cloud data

Solid model created

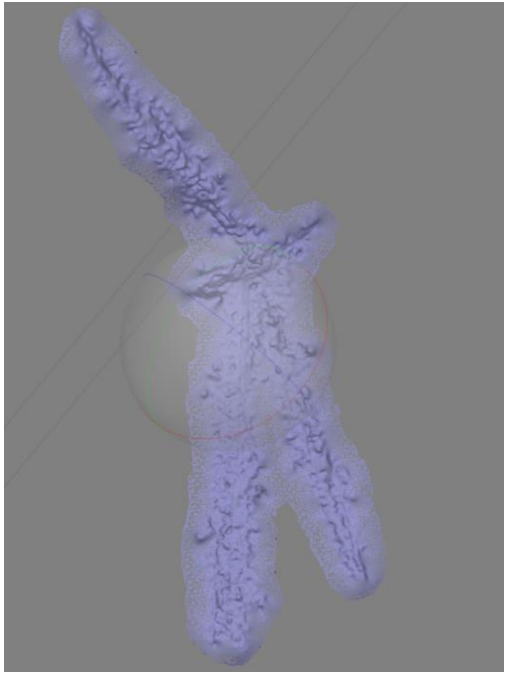
After the completion of sphere registration all point clouds are combined into one, which is then converted into mesh

Point cloud from photogrammetry procedure to the mesh

Bad weather conditions resulted in slightly blurred photographs due to the long exposure times and slight rotation of the blades, which disrupted requirements of photogrammetry method to utilize images with still elements in the frame. This approach did not provide sufficient data



Point Cloud



Mesh

Geometry camera matching procedure to the mesh

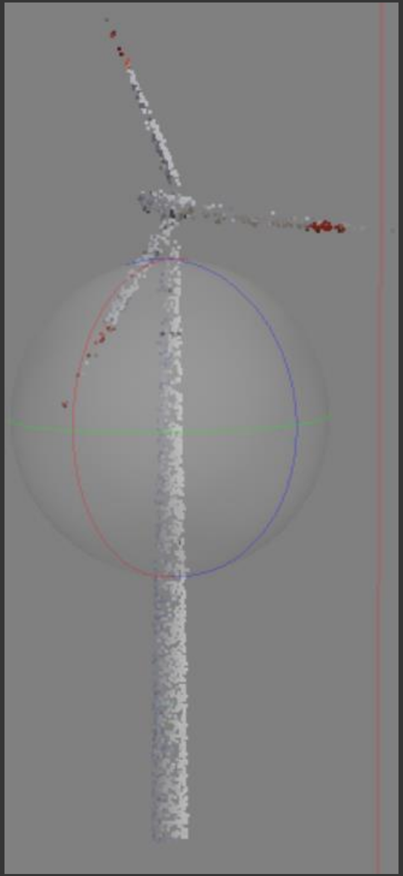
Supplementary method of geometry camera matching was applied as a final stage

Outlines of the subject from the photos are protruded trough recovered views back to the reference coordinate system and using multiple views and 3d shape is reconstructed in Blender, 3D open-source software

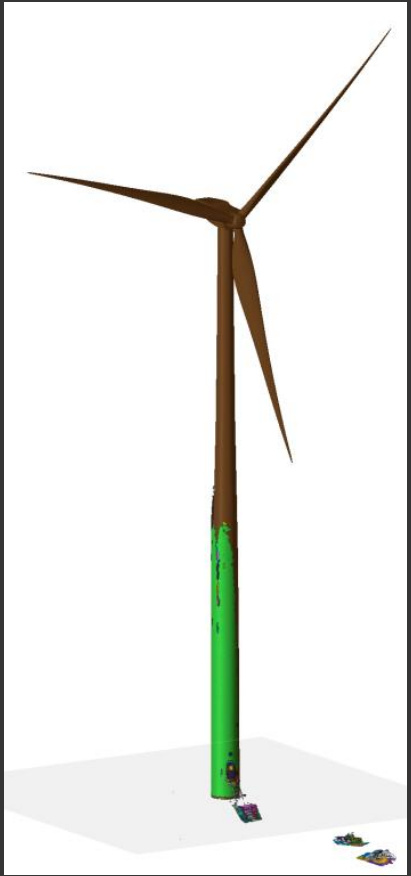
Reconstructed polygonal mesh

Final result

- Final result is translated back from the polygonal mesh to the point cloud, in order to combine it with the point cloud from first two steps ensuring this reconstruction method is used only where the first two methods failed to provide satisfactory result



Point cloud data



Final result

Conclusion

This paper presents two models obtained by using the 3D scanning and Geometry camera matching:

- The 3D solid model of a lower part of a the turbine's tower (from ground level up to 40m) was created in SolidWorks 3D environment, based on the data collected by Faro 3D scene scanner .

- Using the geometry camera matching geometric shape of the upper structural parts of the wind turbine was obtained

Conclusion

Some of the model uses:

- Shadow analysis
- Assess the impact on the environment
- Urban planning
- Cartography
- Numeric simulations
- Visualization for advertisement purposes