Virtual reality modelling of wind farms including the countryside

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Abstract: This paper presents a virtual reality (VR) visualization tool, able of generating a completely artificial landscape with complex artificial objects such as turbines, forests and houses. The VR-method is valuable tool for environmental impact analysis and as a supplementary tool during the visualization analysis. VR-modelling within WindPRO is fast, delivering a draft VR model within a few minutes and a detailed model within a few days. Three cases from European sites – flat terrain, offshore and mountainous are shown and commented.

Keywords: Planning, virtual reality, VR, presentation tools, visualization, visual environmental impact analysis

1. Introduction

When estimating the environmental impact of a wind farm on the surrounding countryside, the visual impact analysis is of outmost concern – especially in dense populated areas and scenic landscapes. This paper presents a virtual reality (VR) visualization tool, able of generating a completely artificial landscape with complex artificial objects such as turbines, forests and houses. Within the VR-modelling area, the user is able to move freely around in real time, enabling views of the site area from an arbitrary point on ground or in the air. The VR-model is completely integrated within the WindPRO software package [1]. This enables re-using data, such as roughness areas and height contours, already prepared for traditional wind energy analysis. The VR-model may be run using these original data only – or supplemented with data intended for use in the VR-model – such as data for rising forests or full 3d-models for sub-areas in the model. The specified data can be used on other WindPRO modules, with purposes like static or animated photomontage or the model for calculating zones of visual influence (ZVI).

Figure 1: Virtual Reality Modelling within WindPRO.

2. The Implemented VR-model

The VR model in WindPRO runs on standard PC's interfacing the DirectX in Microsoft Windows. The actual interfacing is done through a commercial 3D engine – also used for PC-games. In order to run the model, WindPRO extracts geometric information of the included objects (such as the ground or a turbine). Each object is split into a number of polygons, then – if required - added a surface (picture/texture), and finally the geometric information is processed by the 3D-engine. The engine then controls the display of the added objects as well as rendering.

The engine itself does not hold any level of detailing processor (LOD). However LOD control is to some degree implemented within the WindPRO VR-model, as the turbines are shown differently depended on the distance to the turbines. If the distance becomes large – about 10 times the rotor diameters – then the simplified turbine models are used.

The VR-engine is capable of holding a very large amount of polygons, but in reality this depends on computer speed, the graphics card as well as the available memory. Today (summer 2003) models have been run with up to 150000 polygons shown simultaneously. However this amount of polygons cannot – with the current CPU/GPU speeds - be processed in real time. Instead - if this type of detailing level is required – the VR-model allows for generating digital videos following the Windows AVI-format.
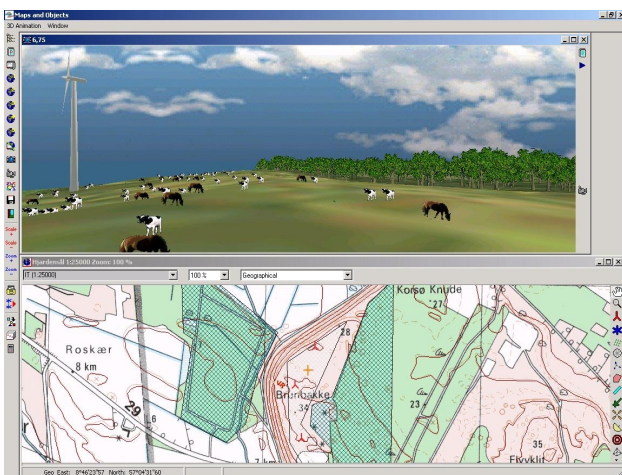
3. Data Setup

A large number of different data types can be added to the VR-model in order to perform a realistic modelling. The Figure 2 shows a map of a VR-modelling area with the included objects shown as symbols: turbines (blue stars), skies (diamonds) and forests (hatched areas).

Figure 2: Map of objects included in a VR-model.

Furthermore, the time of day and the date must be specified as all shading on turbines and ground are generated with the actual sun position corresponding to the entered time.

Also the model has the option of adding fog in an arbitrary colour. The colour is – however – often chosen corresponding to the background (sky) colour. In order to simulate different weather types or possibly a sun set; an option is to add a background picture to the VR-world, see the background in Figure 1.

3a. Data Setup: Elevation Model with Surface Texture

When running the VR-model implemented in WindPRO a minimum requirement of data is to specify the orography (height contours). The generated surface can be filled with any of the maps defined in WindPRO – such as topographical maps, aerial photographs, satellite images or a simple texture stretched over some specified area. Also one has the option of generating a surface with colours based on the height from the TIN height model (triangular irregular network). Other options in the elevation model are using rectangular gridded data instead of the TIN model. This may reduce the number of polygons used for the surface. Furthermore it is possible to exaggerate the z-coordinate. The purpose of the exaggeration may be to scan any errors in the digital elevation model or simply to analyse the surface more closely.

Examples of different surface texture types are found in figures included below, e.g. Figure 5 (a stretched texture showing the sea surface) and Figure 6 (aerial image).

3b. Data Setup: Turbine Data

Data for the rendering of the wind turbine is found in visual definition part of the wind turbine catalogue in WindPRO. The complete catalogue contains data on approximately 500 different commercial turbines – ready to use in the VR-modelling. Furthermore, the software allows definition of user defined turbines, allowing the user to add different colours, logos on nacelles, different tower types & blades. The modelling approach is to use simple 3d-geometries (box or cylinder) and then put these together into a realistic turbine, see Figure 3. This modelling approach is justified, because the distance from the turbines to the observer is quite large in most visual impact analysis. Entering data for visual modelling a new
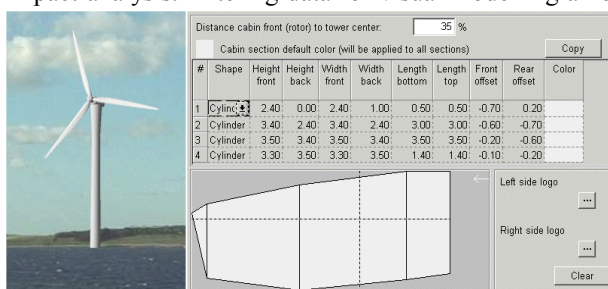
turbine may be completed within less than one hour.

3c. Data Setup: General 3d objects.

Two different types of 3d objects are used within the model: Mapping of pictures onto single polygons - see Figure 4 - and adding complete 3d models – see Figure 5.

The image mapping procedure is very easy to use giving quite realistic impressions. This procedure enables the user to take a digital photo of an object, remove the background from the picture and then add the picture onto a polygon by specifying the width and height of the object. A modelling of an object using this method is completed with some 30-60 minutes. WindPRO holds a large collection of different pre-defined and ready to use 3d-objects, including animals, houses, trees etc. Within the model, the polygon is specified either always to face the viewer (used in most cases), to have a fixed direction in space (used when adding signs along roads) or to consist of two crossed polygons (used when modelling trees). This method gives a high level of detail with using a minimum of CPU-resources (polygons).

Figure 4: Modelling a cow and a field with cows.

Adding complete 3d-models from specialised 3d modelling software tool is possible - but may be quite time consuming. The model must be converted into a format that the VR-model is able to read; using one of the several available software tools for this conversion, like the Milkshape shareware software [2]. The ship in Figure 5 consists of approximately 1200 triangular polygons, thus using much more resources than a single bitmap or a modelled turbine – which uses some hundreds of polygons. The small yachts in Figure 5 are modelled using the image mapping procedure and uses one polygon only. A number of Internet sites offer free 3d models in various formats, but conversion of the models may take several hours.
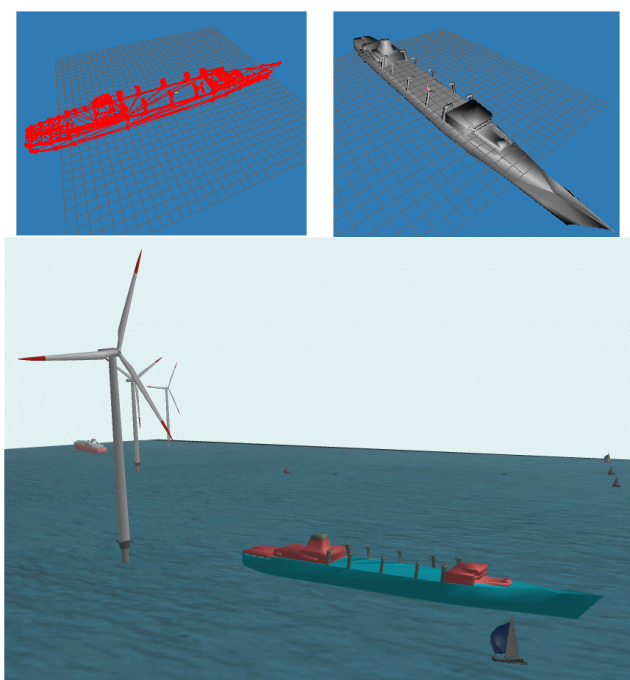

Figure 3: Render of a 1.5 MW Turbine using WindPRO.

Figure 5: A ship in 3d loaded into the VR-model.

A convenient way of realistic modelling of large areas with distributed 3d objects is to specify the amount of objects per unit area. Each object – such as a tree – is then distributed around the area. It is possible to use a collection of objects within the area, such that forests are modelled with different types of trees. The difficulty using this method is that the number of included objects easily explodes, such that the model is not able to run in real time. This problem occurs when adding large forest areas with tens of thousands of individual trees. In this case, the user could choose a 'box modelling' of the forest instead – simply modelling the forest as a box with tree textures on the sides and on the top of the box. However this modelling does not give as nice view of the forest as when using individual trees, but may be applied with success especially for objects located in some distance from the expected flyby tracks.

3d-data established in previous projects are easily loaded into the VR-world. Furthermore, the data is easily shared with the other visualization tools like the photomontage and animation models in WindPRO.

4. Case Studies

Three cases have been prepared in order to demonstrate the capabilities and limitations of the model. The terrain types differ immensely, ranging from an offshore site, a flat terrain site and a mountainous site.

4a. Case: Flat Terrain (Denmark)

A flat terrain case was tested using a site 'Gammel Vrå Enge' in the Northern Part of Jutland, Denmark. A total of 15 NEG Micon 750 kW turbines were included in the modelling as well as vegetation, people (attending an

open air concert) and their cars. The model is 3.7 km x 2.5 km in size. When the forests were added as individual trees, the number of simultaneous polygons within the model reached 150000, causing the model not to be able to run in real time (without reducing the number of polygons). Instead, the VR-model allows for creating a digital video, from which pictures are shown in Figure 6. The surface shown is an aerial image with a pixel resolution of a few meters, added as a background map in WindPRO. The aerial image gives a very nice and apparent detailed looking terrain surface. The modelling of the site was created from scratch, lasting about one full day of work.

Figure 6: Flat terrain: Gammel Vrå Enge in Denmark.

4b. Case: Offshore (Spain)

The offshore site is situated off the coast of the Ebro delta, approximately 125 km southwest of Barcelona, Spain. Included in the model is 60 large 3.0 MW generic turbines placed in four arcs with 15 turbines in each arc. Also included in the model are two full 3d-modelled ships (Figure 5) and some simple yachts. The surface texture was initially modelled using a Landsat satellite image with a pixel resolution of 30 meters. Even if such a texture looks nice at a distance, then the resolution is too coarse for modelling when individual fields, houses and

roads should be visible. Instead it was chosen to model the water surface using a stretched picture looking like nice waves. The colour of the sea surface was edited using a picture editor. Some mist/fog was added to the model, which covers an area 12 km x 17 km in size. The wind farm itself covers an area about 7 km x 8 km. Screen shots from the model are shown in Figure 5 and Figure 7. The screen shot is taken from within the wind farm, it is possible to see three rows of turbines. The distance to the turbines farthest away (found near the ship) are approximately 4.5 km. These turbines are hardly visible – not only due to the added mist – but also because the screen resolution is too poor to show details that far away. It is possible to increase the visibility of the turbines by assigning a darker colour. The time for adding VR-information to this project have lasted one day of work, mainly due conversion and import of the 3d-ship model.

Figure 7: Offshore wind farm with turbines and ships.

4c. Case: Mountains (Greece)

The third case includes a mountainous terrain in Greece. Three individual wind farms on the mountain ridges are modelled. A total of 50 turbines are with a rated power equal to 800 kW is included. The surface is an image of a mountainside stretched onto the surface. Total modelling time is approximately half an hour to add the VR-data to the model.

Figure 8: Mountainous site seen from 1.5 km distance.

The Figure 8 shows the site from a distance of 1.5 km to the nearest turbines. The turbines at the left side of the picture are 3 km away and hardly visible due to the low resolution of the picture (approximately 800 pixels wide). However, when moving up the mountain, as shown in Figure 9, the turbines on the nearby ridge become visible.

Figure 9: Mountainous site: On the mountain ridge.

5. Postprocessing the VR-results

Presenting the results of the modelling it is possible trough generated digital videos (.AVI files) for e.g. for easy presentation on the Internet.

6 Conclusions

A virtual reality model within the WindPRO software tool – named the 3d-animator – is now commercially available, increasing the applicability of virtual reality modelling for all potential wind farm sites. The involved working time for adding VR-data to a wind farm project is from less than an hour for a draft presentation to a few days for a nice detailed presentation.

The main limitations with the VR-model are currently that large models cannot be run in real time. However large models can be presented in real time by recording a track and let the PC produce an AVI file over night. Also, a current limitation that will be included in a upcoming release is dynamic wave and cloud modelling. Furthermore the light marking of WTG will also be modelled. Modelling of turbines far away is limited by screen resolution, as they become very difficult to see. If this issue become important, other tools may be applied; namely the photomontage and the animated visualization – both models are available in the WindPRO software.

The main advantage is that the tool can be used by the project developer himself, no expensive specialists to involve – and that the 3D modelling becomes an integrated part of the work preparing the documentation of a wind farm project, including efficient validation of the data used for e.g. energy calculation.

References

[1] Nielsen, Per et al: *WindPRO: Software and Manual*, Energi- og Miljødata (EMD), june 2003, http://www.windpro.com.
[2] *Milkshape: Software for 3d.modelling and conversion*: http://www.milkshape3d.com.