

Previsualization of Wind Turbines in the Web Browser as Augmented Reality

Axel Durdel, Jörn Loviscach*
TU München, München, Germany
*FH Bielefeld, Bielefeld, Germany

Summary

Many projects for constructing wind energy plants fail due to a lack of acceptance by local communities. Members of the population fear various disadvantages, which leads to opposition to the construction of wind turbines. To convey a very realistic idea of the size of a wind turbine, we have developed a mobile augmented reality application that visualizes wind turbines in real time in the actual environment. The application runs on many current smartphones and tablets through the internet browser; thus, an installation is not necessary and the user only needs to visit the appropriate website (currently https://www.i3L7h2.de/wind_ar/).

1. Introduction

Augmented Reality (AR) is well known from games in which a device, for instance a smartphone, is applied as a see-through frame that displays both the real environment and virtual objects. Those objects seem to be embedded in the real environment and appear to be fixed in space. Augmented reality is currently booming. Apple and Google each recently released software development kits (SDK) to develop AR applications [1, 2]. Microsoft has been working on its device called HoloLens since 2015, a stand-alone headset that is worn as a pair of see-through spectacles, exclusively to be used for augmented reality [3]. This means that augmented reality will be much more accessible in the future and will possibly enter everyday life soon.

While the mentioned AR technologies depend on the operating system (iOS, Android, Windows), we have brought augmented reality to the web browser, which can be invoked from any modern computing device. The program enables users to gain a realistic, true-to-scale impression of a wind turbine before it is built.

This article describes the application programming interfaces (API) used for this application, explains how to handle it and points out ways on how to employ the application to raise acceptance to wind turbines.

2. Related work

We are not the first ones to develop an augmented reality application. In fact, there are many examples of AR apps on the market already:

The iOS application Raumbild views furniture in augmented reality to allow the users to see possible new furniture in their homes using an iPhone only. Similar to our application, Raumbild makes use of AR technology to support the forming of an opinion concerning aesthetics and appearance. [4]

In terms of content, the Swiss project VisAsim is stronger related to our application than Raumbild. Its

aim is to support planning and building new wind turbines with the help of virtual reality (VR). Unlike augmented reality, virtual reality does not blend digital and physical content but immerses the user into an entirely virtual world. VisAsim simulates actual Swiss energy turbines in typical environments in both a visual and acoustical way. This technology enables the user to experience wind turbines and their effect on the environment in a realistic way. Note that the usage is limited since specific hardware is necessary to generate visuals and sound in a proper way. [5]

3. Implementation

3.1 Technical background

The application makes use of several data sources and amalgamates them using HTML and JavaScript: Google Maps for positioning the wind turbines; GPS to get the user's position; the device's orientation sensor (synthesized by the operating system from accelerometer, gyroscope, magnetometer) to determine the camera's viewing direction; the camera to provide real-world image information, onto which the 3D model rendered on the device's graphics chip using WebGL is superimposed. The 3D model is also illuminated according to the astronomical position of the sun in the sky. This can be seen in Figure 3 when comparing the light on a tree and on the tower. Optionally, the wind turbine can cast a shadow onto itself; by default, this feature is switched off to ensure a smooth performance on all devices. The rotor of the wind turbine turns; at night, warning lights are added to the nacelle.

3.2 User interaction

Launching the application proceeds as invoking any other website. To get started, the user has to take four simple steps, guided by an on-screen explanation: The first step is to start the camera (which for security reasons always requires a user action in the web browser). The second step consists in calibrating the camera to determine the camera's field of view, which is necessary to adjust the size of the 3D model to that of actual objects captured by the camera. For calibration, the user has to match the picture of an A4-sized sheet of paper with marks on the

screen by finding the appropriate distance of the camera to the sheet of paper. The user has to enter this distance into the application. The third step is to determine the user's location, either through GPS or by tapping onto the appropriate spot on the map. In the fourth and last step, the user places wind turbines on the map near his or her position. After switching to the camera view, the user can see the wind turbines in the environment when holding the smartphone or tablet like a see-through frame.

Figures 1 to 3 illustrate this procedure: Figure 1 shows a user in the English Garden in Munich holding his smartphone. There are no actual wind turbines in the vicinity. Figure 2 shows the map view with a wind turbine placed about 500 meters south of the user. Figure 3 depicts the result: a virtual wind turbine about 500 meters away as it can be seen using the application.



Fig. 1 A user in the English Garden in Munich holding his smartphone



Fig. 2 A wind turbine approx. 500 m away; map view corresponding to Fig. 1



Fig. 3 A wind turbine approx. 500 m away; camera view corresponding to Fig. 2

The menu button provides access to additional features. The user can open three different submenus: Picking "Viewing direction" displays the current viewing direction. "Rotational speed" shows the currently set wind speed at hub height as well the rotational speed. Wind speed and thus the rotational speed can be altered. "Wind direction" shows the currently set wind direction which can be altered too. Furthermore, the menu gives access to the calibration submenu and the GPS location as set in the second and third step when launching the application. The last two buttons in the menu quit the application and give access to the imprint and data privacy statement, respectively.

3.2 Technical challenges

Different devices and operating systems pose different challenges that need to be overcome. A major challenge when developing browser applications is security, or rather: dealing with the built-in security mechanisms. While native applications are downloaded and the user accepts terms and conditions once upon installation, a browser application has no terms of use that need to be accepted when invoking the website. Instead, the user has to grant the browser access to specific hardware (for instance to the camera) every time when invoking the website. But the use of such hardware components differs from OS to OS. iOS-based devices, that is iPhones and iPads, for example, cannot create live video streams in the browser, because iOS does not support this feature, while Android and Windows generally do. But this does not mean that every Android-based device can access the camera without any problems, because not only the OS but also the browser and the device itself affect the way how the device's hardware components can be accessed.

In summary, there are several components in our application that are browser-, device- or OS-dependent, which makes it impossible to handle all issues in every circumstance. The most severe issues on some devices are:

1. Some browsers, including Firefox, cannot read the absolute orientation; no compass data are available using Firefox on the devices that we tested. Hence, we have implemented a workaround to change the user's viewing direction manually.
2. In some combinations of device and browser, the user cannot switch between front and rear camera.
3. iOS does not support the camera API, which makes iOS-based devices unsuitable.

Despite these problems we are confident that most features will be available on all devices in near future, for example when the camera API will be obligated and standardized, so that every browser handles the camera the same way. Another important aspect is that issues with the orientation sensor and the camera mostly seem to appear on older devices. In our tests, up-to-date devices have been unlikely to cause issues regarding this.

4. Ways to raise acceptance

Replacing fossil energy sources with renewable energies is indispensable to reduce carbon emission. In 2016, Germany's gross electricity generation consists to 29 % of renewable energies, of which almost 40 % are made up of wind energy [6]. At the same time about 92 % of all wind turbines are onshore plants [7]. Onshore wind energy is therefore of significant importance for the German Energiewende. But for the Energiewende to be successful, it must be accepted by the population, especially by local communities affected by wind turbines. As a German survey on wind energy acceptance on land from 2016 [8] revealed, 31 % of respondents said that a wind turbine's impact on the landscape was stronger than they previously thought. This could lead to a social opposition to wind turbines, which could complicate the further expansion of wind power in Germany. Hence, esthetics ranges among the important aspects for the acceptance of wind turbines.

Our application can be used to give the population a better idea of how a wind turbine would look like in the environment. An intuitive and interactive operation encourages the user to discover locations where wind turbines in fact do (or do not) impair the landscape, giving the user a more lifelike experience of wind turbines. To educate about wind turbines concerning their esthetics in the environment, our application could be employed as a tool in a survey. In the first step, participants would be asked for their opinion on how large a wind turbine would appear next to a common object, a tree for instance, and whether they think the wind turbine would impair the landscape's appearance or not. To check their guesses, the participants would go on to use the application and view a wind turbine next to such an object. Finally, the participants give feedback and can correct their initial guesses. By doing so the application supports an independent yet well-informed opinion but does not push into acceptance.

As Schmid and Zimmer [9] showed in their study on the acceptance of wind power plants in Baden-Württemberg, Germany, one of the vital aspects for successfully building new wind power plants is to integrate local communities into the planning process. The earlier the population is informed and involved, the more likely it is to accept and support the construction. A survey on wind energy acceptance on land from 2015 [10] confirms this, since more than 80 % of the respondents think that a strong public participation in the planning progress is important to raise the local acceptance for wind turbines. The survey also reveals that an early integration of the public even before the formal planning process could improve room for maneuver. A specific example for no or little exchange of information and integration into the planning process can be found in Hasselbach where the residents complained about the noise and periodic shadows as well as the size of the new wind turbines in the wind park nearby. They claim to not have been informed about the consequences [11]. To achieve such early communication with the help of our application, the user could mark locations on

the map, for example spots where wind turbines are not desired. These locations could be shared with the planning office. Future versions of our application could include such features.

5. Future work

In 2015, Microsoft released the HoloLens, a device developed solely for AR apps [3]. Apple introduced ARKit, a software development kit for augmented reality applications in June 2017 [1]. Google published its similar ARCore in September 2017 [2]. Thus, native AR applications will be available on the HoloLens as well as on iOS- and Android-based devices soon.

In contrast to our browser application, these SDKs enable developers to create native applications. Generally, native apps run smoother and faster, but must be developed individually for each operating system. Nevertheless, the activity of the manufacturers demonstrates that AR is an important topic and will be developed further, which will probably lead to native AR apps related to ours.

But not only AR is being developed further, also its simpler sibling VR is subject to current research and development, for instance, Windows Mixed Reality, which is, despite its name, Microsoft's platform for virtual reality. The first immersive headsets will be available in October 2017 [12]. Like AR, also VR can be employed as a tool in the planning progress of new wind turbines. Using portable VR technology such as headsets, the Swiss project VisAsim could become accessible to many more users.

As far as the future of our application is concerned, we are looking for interested parties and volunteers (e.g., wind turbine manufacturers and citizen energy associations) to test the application and give feedback. Further extensions such as the integration of additional 3D models from a manufacturer's product range or a comparison between the wind turbines' sound level at a given distance and ordinary noise sources (e.g., lawn mower, truck) are conceivable.

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