How can artificial intelligence be used to find areas for wind turbines and solve other challenges associated with wind energy?

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Abstract

This article discusses the use of artificial intelligence in the wind energy industry, particularly in addressing challenges and optimizing the expansion of renewable energies in Germany. It highlights the application of artificial intelligence in wind forecasts and yield predictions, bird detection, wind turbine and farm design, condition monitoring, and predictive maintenance. Additionally, it introduces the "WindGISKI" research project, which aims to use artificial intelligence to identify new areas for wind turbines. The project utilizes a neural network to analyze and predict flight routes, potentially reducing bird mortality. The document also emphasizes the potential broader applications of "WindGISKI" in other fields of activity, such as land use planning and city development. Overall, it underscores the significant role of artificial intelligence in addressing challenges in wind energy and outlines the potential for artificial intelligence to drive the expansion of renewable energies while addressing key obstacles.

Keywords: wind turbine, WindGISKI, artificial intelligence

1 Introduction

1.1 Structure

The article begins by explaining the relevance of the topic. This is followed by an explanation of how the results were obtained and the research methodology. This is followed by a description of the four main areas in which artificial intelligence (AI) is already being used successfully in connection with wind turbines. The "WindGISKI" project is then explained. The article ends with a conclusion and outlook.

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1.2 Relevance

The coalition agreement of the current German government stipulates: "To drastically accelerate the expansion of renewable energies". However, this is not proving to be easy. The expansion of onshore wind energy is being halted primarily by complaints from the public. [1]

Currently, around 0.8 % of the land area is designated for wind energy; the German government wants this figure to rise to 2 % by 2032. A solution must therefore be found to develop new potential areas and assess their quality in advance. [2]

Furthermore, the coal phase-out requires secure and stable electricity generation, which is currently not provided by solar and wind energy, as most of the energy generation is lost when there is no wind and clouds in the sky. A lot of research is currently being carried out and studies published in this area. Furthermore, AI is on the rise and has long since arrived in our everyday lives, at the latest with the release of ChatGPT and other chatbots. The use of AI can simplify many things and provide a solution to complicated problems. Problems with wind turbines can also be partially solved or simplified by AI. This article reflects the current state of research and describes the areas in which AI helps to use wind as a sustainable energy source. [3]

2 Methods of literature research

At the beginning, the methods of the literature research are described to make the procedure reproducible. Google Scholar and FH Münster's Findex were used to provide a good overview. The main search queries used were "artificial intelligence wind energy". Without the addition of "wind energy", the spectrum is not differentiated enough. To date, only the participating institutions have published an article on the topic of "GISKI"; even a complex search did not produce any further literature. Furthermore, several AI tools were used to organize this work logically, but also to gain an initial overview of the literature.

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"Perplexity" and "Chat GPT 3.5" were used for this purpose. "Litmaps" was as well used for a visual overview of the literature. The article by Màrquez and Gonzalo was used as the source literature [4]. The articles on "GISKI" are too few for a literature map.

3 AI in the wind energy industry

3.1 Wind forecasts and yield predictions

AI is already being used in many areas of energy generation by wind turbines. Four examples are described below. The first is the calculation of wind speeds and the energy output of wind turbines. Before wind turbines can be integrated into the power grid on a large scale, the uncertainty must be reduced and the continuity of the power supply ensured. To this end, AI has long been used to predict wind speeds. Many studies are currently being published that use AI to provide forecasts for wind speeds. The forecasts are becoming more and more accurate and can look further into the future. It would make no sense to show the latest study here, as this article could no longer be up to date tomorrow. [5]

Nevertheless, an example of artificial intelligence in wind forecasting is given here. Currently, NASA uses the Global Forecast System (GFS) to make predictions with the help of advanced numerical models. However, they are researching machine learning models to make more accurate predictions with larger amounts of data in the future. They are also trying to increase the resolution of the predictions using AI. Given the amount of data generated, numerical algorithms would use too much computing space, which is why they are to be replaced by AI in the future. [6]

3.2 Bird detection

Another example of the use of AI in energy generation with wind turbines is bird detection. Wind turbines are currently a major threat to birds. Studies generally find that onshore and offshore pose a direct and or indirect danger.The Brandenburg State Office for the Environment has published the numbers of reported bird corpses that have died as a result of being hit by wind turbines. A total of 4990 corpses were reported. This figure is of course much lower than the actual number of birds killed by wind turbines because not all birds are found or reported. [7]

NABU estimates the number at over 100,000 per year [8]. To ward off these dangers, images are analyzed by machine learning to detect birds at an early stage. In the 2021 study, for example, Google AutoML Vision was used [9]. This service uses recurrent neural networks to find the best possible neural network. This allows flight routes to be analyzed and predicted, which could reduce bird mortality in the future. [10, 11]

3.3 Wind turbine and farm design

The previous examples were applications for AI in the operation of wind turbines. However, AI is already being used in the development of wind turbines. The design process is characterized by many variables. The complex calculations for the design of wind turbines and entire wind farms are carried out by artificial neutral networks. In the article by Marugán et al. various studies are listed which are used in the calculation of individual variables such as the correction of the lift coefficient for the design of the angle of attack of airfoils. For the design of wind farms, even more variables must be considered. Here, too, artificial neutral grids are often used. [12]

3.4 Condition monitoring for predictive maintenance

AI can help with the condition monitoring of wind turbines in a variety of ways. It enables predictive maintenance, in which sensors continuously record data that is analyzed by AI systems. This allows potential defects to be detected at an early stage and maintenance work to be planned before failures occur. AI-based condition monitoring and predictive maintenance aim to maximize the uptime of wind turbines, prevent costly major damage and extend the service life of individual components through early action. They also enable better monitoring and evaluation of repair measures. AI models can detect anomalies - discrepancies between actual measured and simulated behavior - at an early stage. This enables rapid action and prevents major damage to the main components. [13]

AI can also help to reduce the number of sensors required. For example, AI models can analyze vibration patterns to identify operating speed, eliminating the need for a cumbersome speed reference sensor. [14]

In summary, AI plays a crucial role in the condition monitoring of wind turbines by enabling early detection of faults, optimizing maintenance and ultimately helping to increase turbine efficiency and profitability.

4 Area development through AI

4.1 Research project

As the previous chapter shows, AI is already being used in many areas relating to wind turbines. One of the biggest hurdles in the expansion of renewable energies in Germany is currently the development of

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new areas for wind turbines or wind farms. With the *wind-on-land act*, the German government has decided to expand the amount of land available. By 2032, 2 % of the current 0.8 % of the land area is to be made available. Furthermore, this is to be divided fairly among the federal states and wind conditions as well as nature and species protection are to be considered equally. To this end, the new "WindGISKI" research project was approved by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection and supported with two million euros. The eight participating research institutes will develop an AI-based geoinformation system over three years. [2]

4.2 Use of the neural network

The biggest hurdle is to be removed with the help of AI. Currently, many areas are designated as unsuitable because incorrect minimum distances are set. In many places, however, these minimum distances exceed the necessary distances that would prevent a visually intrusive effect and ensure a reasonable level of shadow impact and noise pollution. These small areas are often excluded for wind turbines due to nature and species protection, which is why the areas are not sufficient for the area targets. To avoid these problems, the program starts with an empty map on which, at least theoretically, anywhere would be possible. An artificial neural network is used to solve this problem. [2]

Artificial neural networks solve problems that cannot be defined analytically, based on biological neurons. Simple processing units and weighted connections between them form a neural network, as shown in 1. The neural network is trained with data sets and the connections are reweighted. The network then predicts outputs and can identify fields for potential wind turbines. [15]

The neural network is fed with information on where the construction of wind turbines was possible and where it was prevented by legal action, for example (training). The AI then uses the information to identify areas on the German map. This is divided into 50x50m tiles and each of these tiles is evaluated independently. Where clusters of positively rated tiles are located, potential areas can later be identified (output). [2]

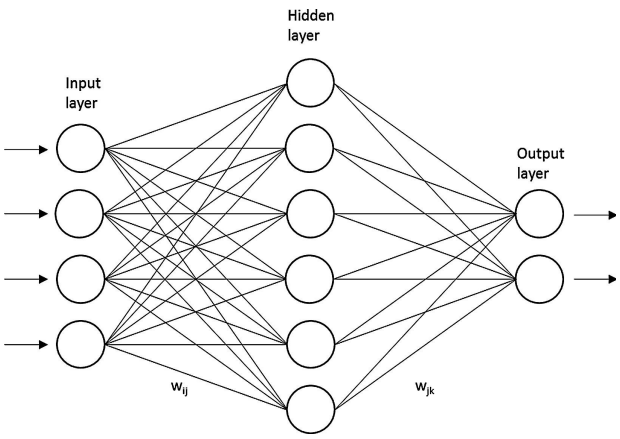

Fig. 1: Structure of an artificial neural network [12]

5 Conclusion and outlook

5.1 What opportunities arise from the use of AI in wind turbines?

Renewable energies are set to replace fossil fuels in Germany. Independence from raw materials and the reduction of air pollution are the main reasons for the energy transition. However, the energy transition in Germany has not yet progressed as far as politicians had planned. There are various obstacles to the expansion of renewable energies. However, the expansion can be driven forward with new technologies. In wind energy, there are many opportunities to use technologies to drive expansion forward. Many problems that repeatedly arise in Germany in connection with wind power are primarily the fluctuation in electricity production, the dangers for birds and the design of the turbines.

AI is being used to find a solution to all these issues. This offers a good opportunity to simplify complicated algorithms and problems and solve them using computers. Progress is constantly being made and new technologies developed. Many studies have been published in this area in recent years and research is continuing. It will be some time before a real solution is found. Nevertheless, it can be said that the solution to these problems lies in AI.

Another problem is currently being researched. The development of land for wind turbines. Currently, 0.8 % of the land area has been designated for wind turbines. Another 1.2 % is to be added by 2032. To achieve this, new methods must be found to develop land. One suitable option could be AI. "WindGISKI" could provide a remedy, as the map of Germany is viewed neutrally and old minimum distances to residential buildings are no longer considered. Only current minimum distances and previous lawsuits against wind turbines are fed into the neural network. However, the project is currently still being researched and is by no means ready for use.

All in all, it can be said that AI offers good opportunities to expand the use of wind energy and prevent its current problems.

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5.2 How can GISKI be used in other fields of activity?

It is quite conceivable that AI will soon be used in almost all areas. The combination of geoinformation systems and AI is another example of this. In the future, all land use plans could be optimized in the same way, making it easier to plan cities. Furthermore, the areas examined could be analyzed for the possibility of solar installations. The field of application is very broad and offers many possibilities. If "WindGISKI" produces a functioning program, it could also be used for all other countries that have a similar problem. The possibilities that this project could provide are huge and could mean a big step for the energy transition in Germany and around the world.

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