

Using Artificial Intelligence to Drive Efficiency, Cost Savings, and Predictive Maintenance for the Wind Industry

Shweta Khushu
Senior Computer Vision and Machine Learning Engineer, SkySpecs



Table of Conents

01

Introduction

P. 4

02

Machine Learning

P. 7

03

Neural Networks

P. 9

04

Artificial Intelligence —
Real World Applications

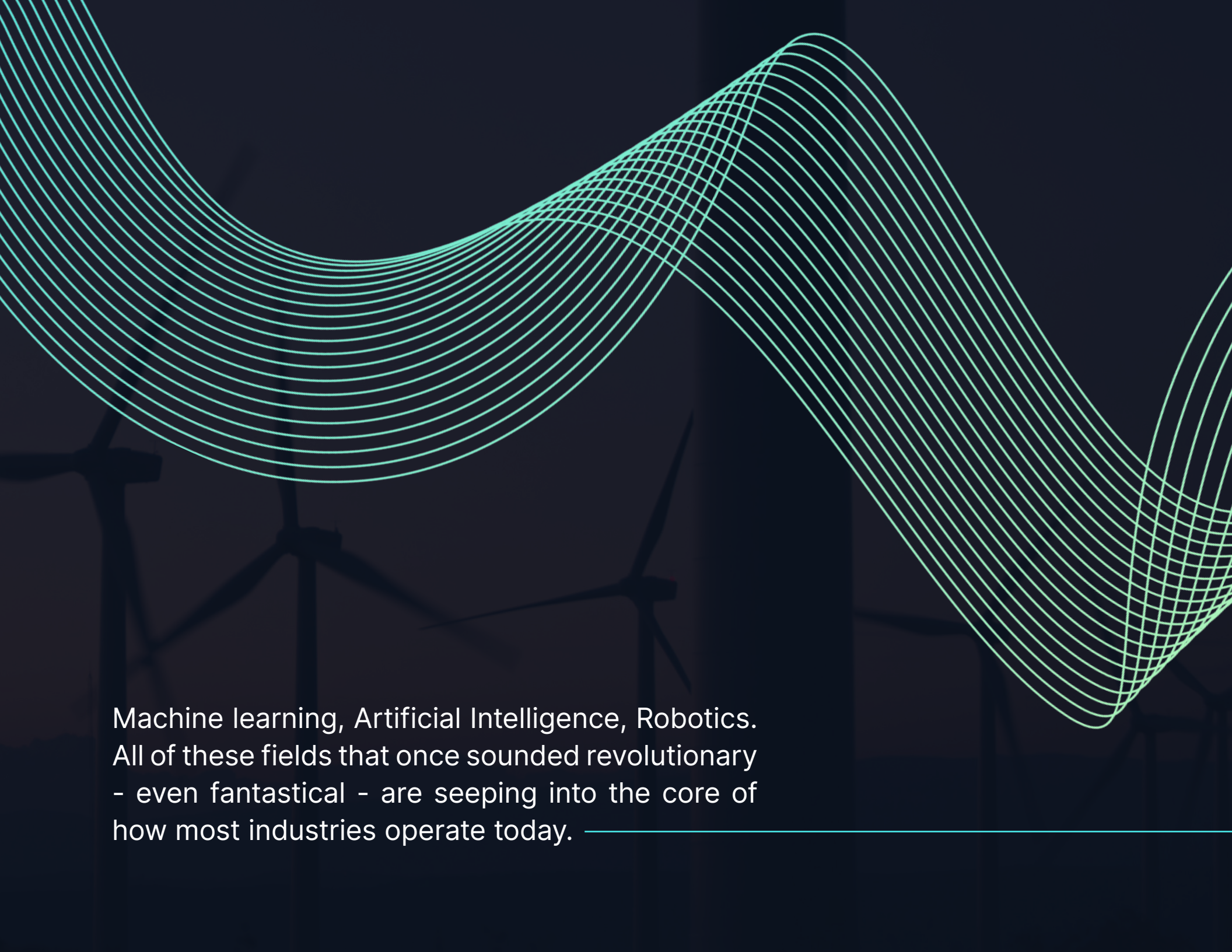
P. 15

05

Artificial Intelligence —
Wind Energy Industry

P. 18



The background features a series of teal-colored wavy lines that create a sense of motion and depth. In the lower portion of the image, there are faint, dark silhouettes of wind turbines, suggesting a connection to renewable energy and modern industry.

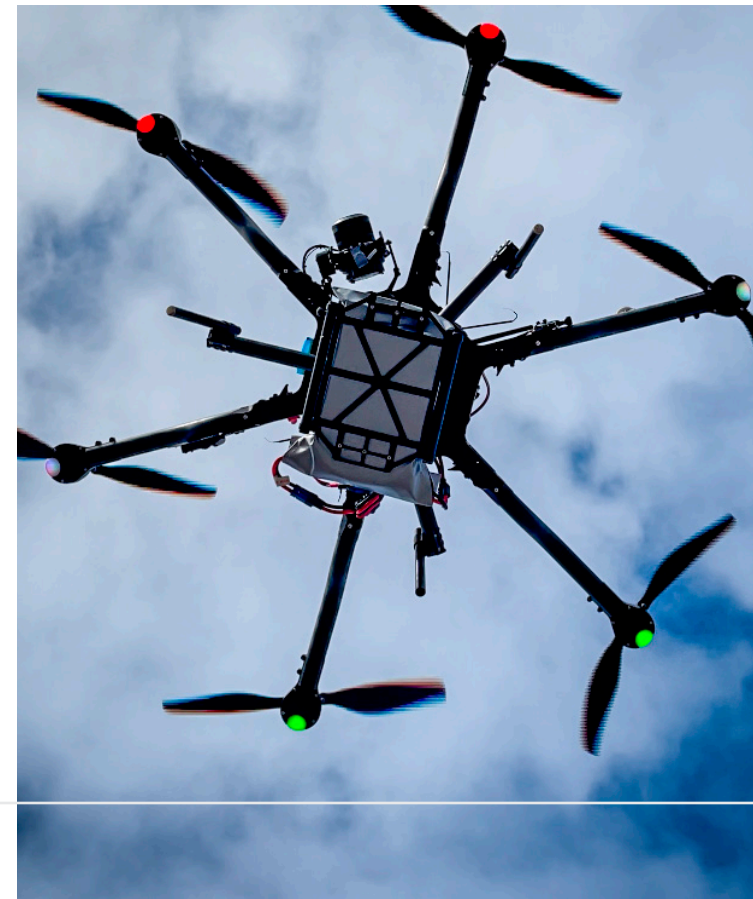
Machine learning, Artificial Intelligence, Robotics.
All of these fields that once sounded revolutionary
- even fantastical - are seeping into the core of
how most industries operate today.

01 - Introduction

One of the challenges when attempting to convey something of a futuristic or cutting-edge nature, is that it can be easy to claim it is a part of a solution or offering without customers or partners really understanding its benefit to them - or lack thereof. And as Google Glass taught us, just because it sounds or looks cool doesn't mean it's going to do much of anything to move your business ahead. It would take someone who hasn't read the news in a few years not to have an idea of what Artificial Intelligence is (or AI as it's commonly referred to). So when technology companies claim they "use AI" or that AI is a "core part of our powerful solution," it sounds like a

prudent investment! But it's important to communicate how the technology works and how it directly impacts day-to-day operations and the bottom line.

SkySpecs develops technology for the wind energy industry. We use Artificial Intelligence, Machine Learning and Robotics to create a faster, more precise, sustainable solution for our customers around the world. But how we use it and why requires a bit of background. This whitepaper will seek to educate as well as to delineate between the three aforementioned fields in order to better understand the respective value and application(s) of each.



To get started, let's take a high-level look at each of the three concepts:



Robotics

Robotics deals with design, construction, operation and the use of robots. A robot is a physical machine that carries out tasks either autonomously (without human intervention) or manually (operated by a human).



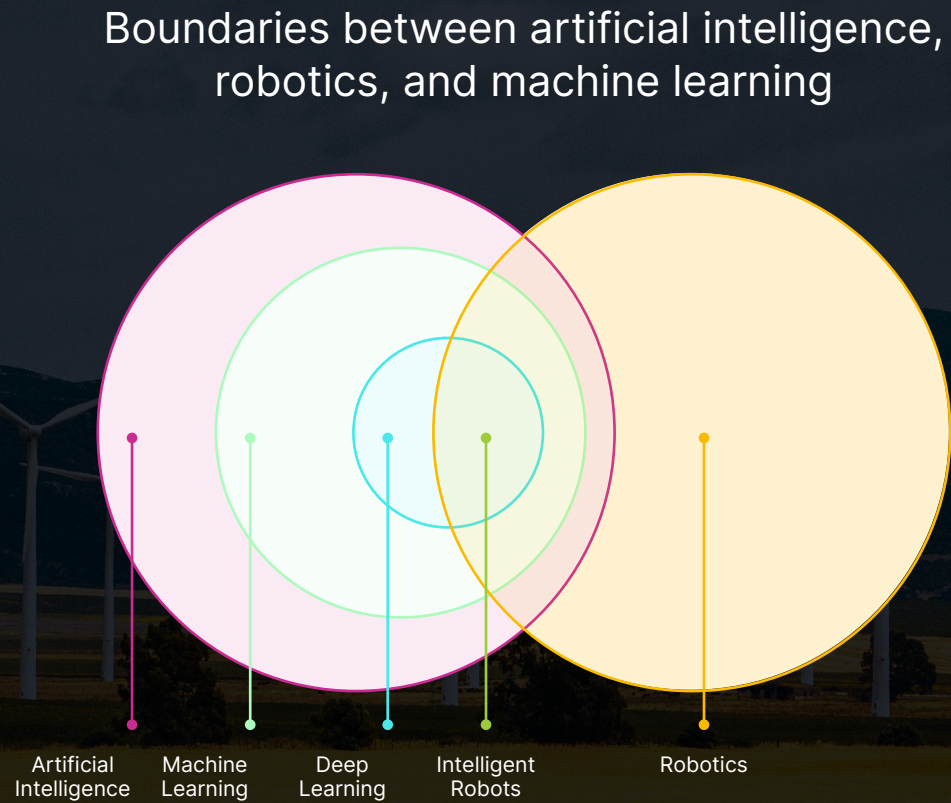
Artificial Intelligence

A broad concept, artificial intelligence denotes machines that carry out "intelligent" tasks. In other words, the intersection of robotics and AI might be a drone that can fly autonomously in unknown terrain.



Machine Learning

Machine learning is a field that focuses on computer algorithms that 'learn' or infer from data. Hence, it falls under the umbrella of Artificial Intelligence. For example, the traditional AI computer chess game worked on defined rule-sets, it did not learn actively from data. On the other hand, modern machine learning-enabled computer games like AlphaGo learn from extensive training on both human and computer play.



02 - Introduction

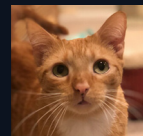
Machine Learning solves problems that cannot be solved by numerical means alone. At its simplest, machines copy and adapt certain human behaviors in order to achieve a higher level of speed, accuracy and efficiency. The benefits of those advancements are fairly simple to calculate. It's important to understand that machine learning is one very large field of study, and within it, there are categories - or techniques - that apply to different intended outcomes. Broadly, machine learning algorithms can be classified into two categories: supervised learning and unsupervised learning.

Let's take a look at each more closely.

In Supervised Learning, the machine learning model learns the relationship between input data and its output by training on a dataset of input-output samples called training data. The training process continues until the model achieves a desired level of accuracy on the training data.

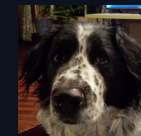
For example, in a classification algorithm like a cat classifier, the input would be images of cats and the output would be the label "Cat". The machine learning model would train on many cat and non-cat images with the corresponding output label of "cat" and "not cat". Thus, on a given image of a dog, it should be able to output the label "not cat".

Classification Example



Cat Classifier

"Cat"



Cat Classifier

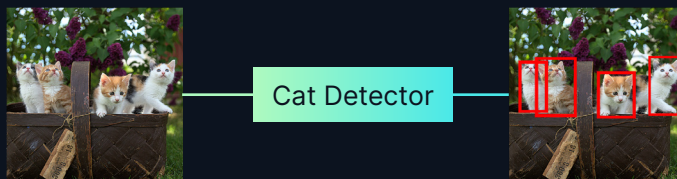
"Not Cat"

Regression Algorithms

Another example is a regression algorithm, which can predict the location of cat in an image. The input would be any image, and the output would have pixel locations of all the cats identified in that image. Yes, finding Waldo could be made much easier with a regression algorithm!



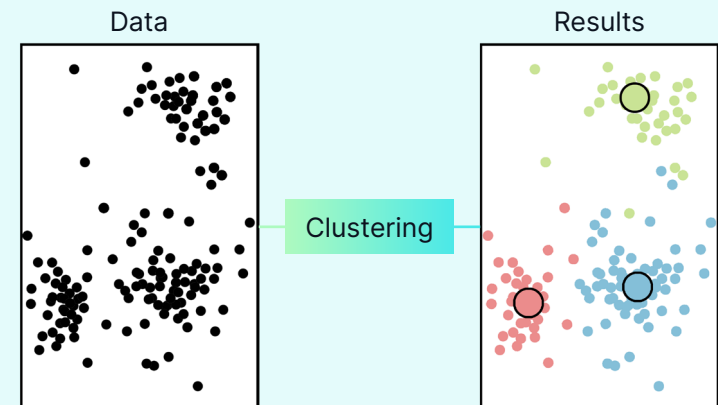
Regression Example



In Unsupervised Learning, the output of the training data samples is not provided. Usually the goal is to learn the structure of the input data; that is, what 'features' best represent the data, or to extract some information based on the data's distribution.

For example, a clustering algorithm may be designed to help a supermarket chain identify prospective locations for opening a new branch. In this case, the population density data of a geographical region would probably be the input for the algorithm along with existing branch locations. The output of the algorithm would be geographical locations that benefit most from having a new branch supermarket.

Clustering Example



03 - Neural Networks

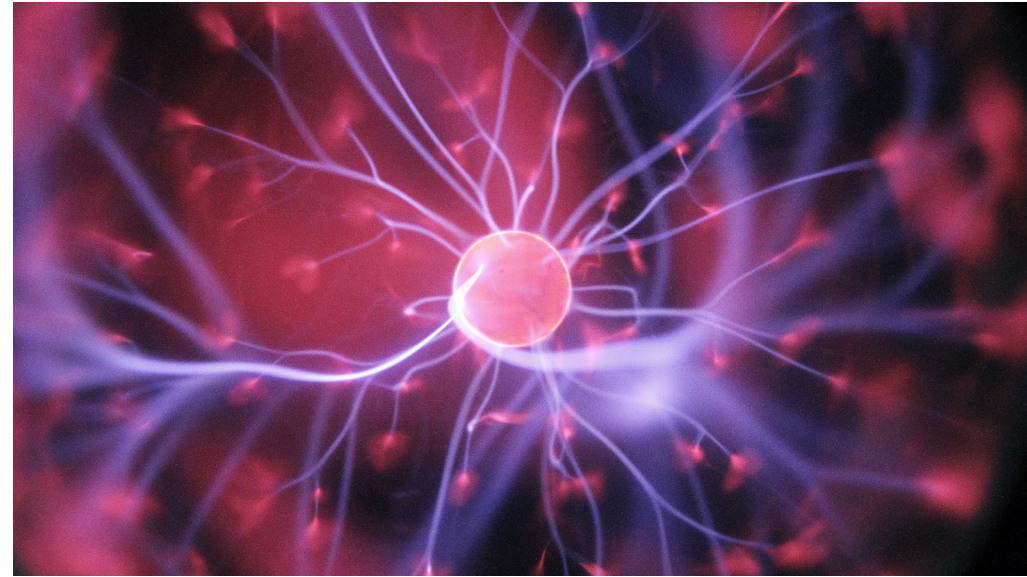
A machine learning segment that has especially gained popularity today is artificial neural networks or simply, neural networks. While the original idea was derived from the neural connections in a living being, in reality the workings of the neurons in the brain are far more complicated and still not well understood.

What Are They?

The building block of a neural network is a neuron. A neuron is simply a node that holds information. Multiple such neurons stacked together and interconnected create a single layer basic neural network. Information is transferred from one neuron to another through branches called weights. The weights of the branches connecting them are trained and represent the features of the data. There are many variations of this basic model and hundreds of different types of neural networks.

When many such layers of neural networks are placed together end-to-end, we have what is called a deep neural network.

Deep neural networks are very powerful because of their ability to learn complex patterns in data. This field of machine learning using deep neural networks is known as Deep Learning.



Why Are They Popular?

Neural networks work by learning the 'features' of the data and do not require human input to decide what 'features' are useful. For example, in the cat classification algorithm, a neural network will learn to look for certain features like whiskers, a tail, and triangular ears, while distinguishing between cat and non-cat images without having been directed explicitly by a human to look for these features. It learns these features when it is being trained with thousands of image samples.

Each layer of a network learns some features and the deeper layers build on simpler features from the previous layers and are thereby able to learn more complicated features. This particular attribute of a neural network allows it to learn complicated shapes and patterns in the data which may even be outside human interpretation. This is why neural networks almost work like 'magic boxes'.

Moreover, due to the AI boom and the advent of many open-source Deep Learning algorithm implementations, it has become easy to use an off-the-shelf algorithm and tune it to work on custom data.

Single-Layer Neural Network (Perceptron)

Input

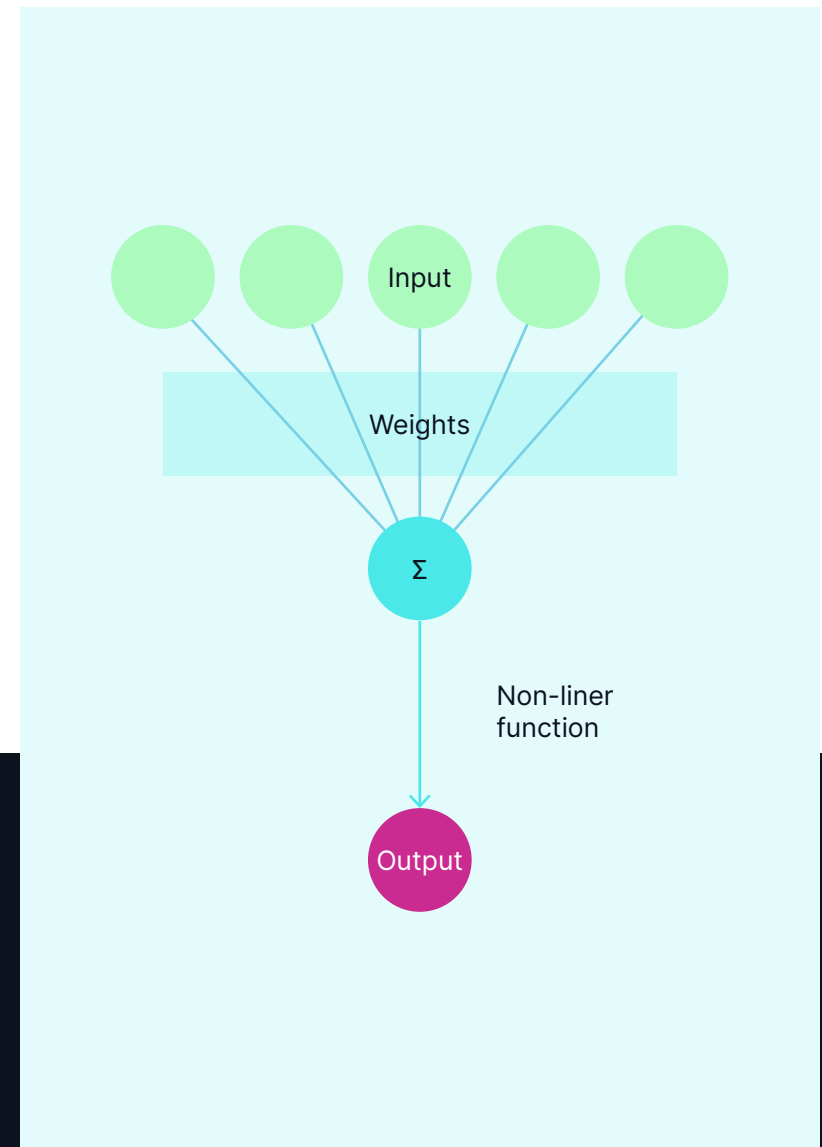
Digital data samples of like images, sensor outputs etc.

Weights

Branches between input & output that are learned during training. They represent the features of the data.

Output

The desired label or characteristic of the input data that needs to be learned



Why Did They Just Become Popular?

The first idea of neural networks started floating around as early as the 1940s when neurophysiologist Warren McCulloch and mathematician Walter Pitts wrote a paper on how neurons might work using electrical circuits. Over the years, there were many scientific papers that expanded the idea into the more complex modern neural networks and how to train them.

However, the biggest challenge in successfully training such a network is the amount of data it needs. The larger the network, the more weights that need to be trained and the more data required to train them. In

modern deep networks, there are easily over a million weights that need training. Therefore, neural networks only received widespread attention and application in the more recent years due to developments in big data and higher-end computing. Thanks to Moore's law and the onset of cloud computing, it is possible to train very deep networks (100s of layers) in a matter of hours as opposed to months and running these networks is possible in real time even on mobile devices. Thanks to readily accessible terrabytes of cloud storage and quick databases, it is possible to store and query for enough data to train on 100s of layers of neural networks.

Deep Neural Networks Learn Hierarchical Feature Representations

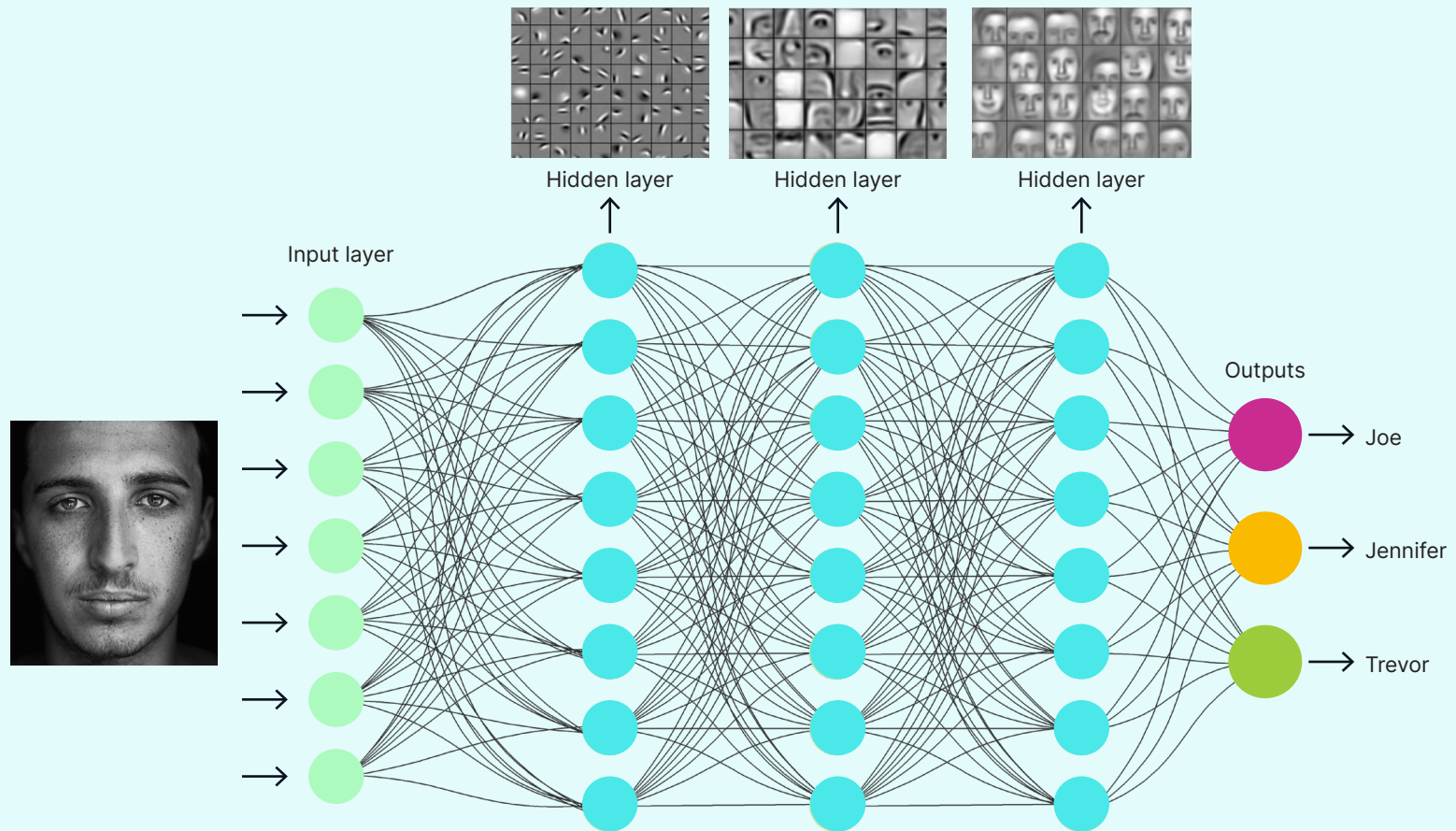


Image source: Honglak Lee, Roger Grosse, Rajesh Ranganath, Andrew Y. Ng, Unsupervised learning of hierarchical representations with convolutional deep belief networks, Communications of the ACM, v.54 n.10, October 2011

What Contributes to a Successful and Effective Machine Learning Solution?

The most important factor influencing the success of a machine learning algorithm is the quality and quantity of the dataset that is used to train the system - perhaps even more than the algorithm employed. A good dataset contains:

1

Many data samples. The more the better. Deep learning algorithms require tens of thousands of training samples to learn complex patterns.

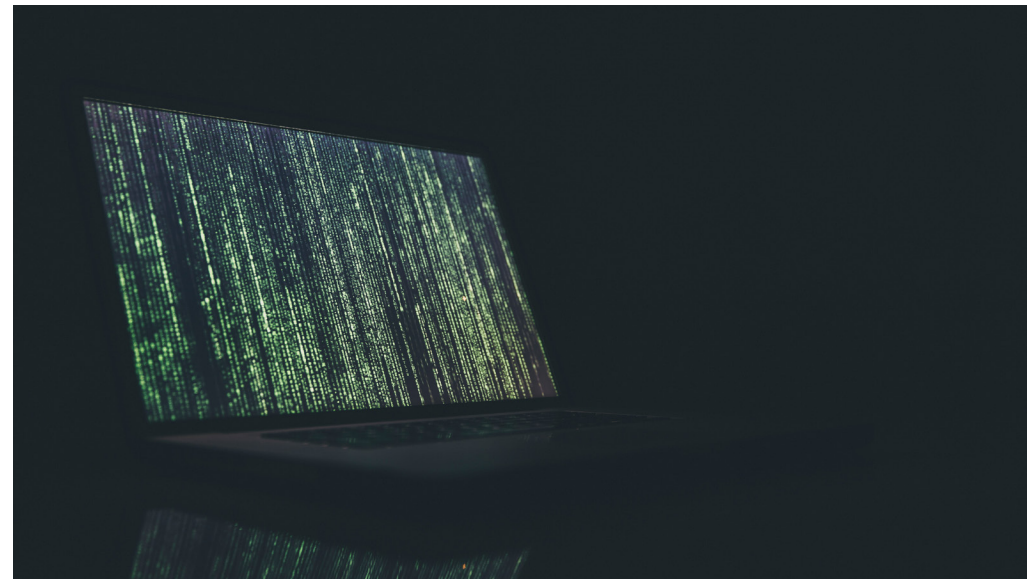
2

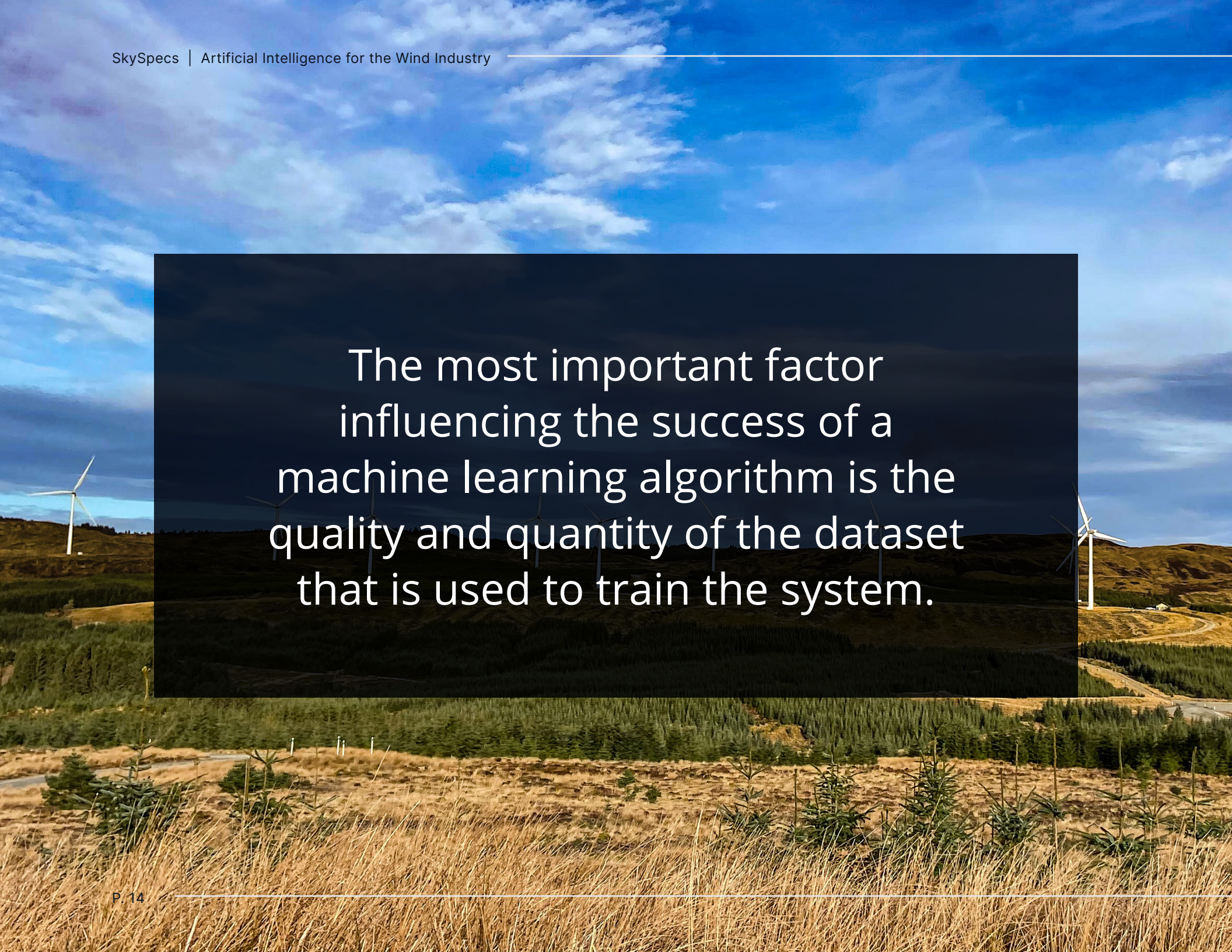
A Comprehensive set of samples. For example, let's say a car detection system running on an autonomous car was trained with thousands of samples of mostly red cars and very few other colors. Such a system may perform exceptionally when tested on another picture of a red car, but may fail on another color like a blue car image. And we well know that not all the cars in the world are red, so time was wasted gathering a dataset that only ended up producing a bias.

3

Similar Data Source. The training data should not originate from a different distribution/source than the production data on which the algorithm is actually going to be used. For example, training extensively on images taken by ground-based camera and then validating on that dataset, only to finally use the software on drone images may not yield reliable results.

When it comes to the algorithm, it is common to iterate over various methods that have proved successful on problems of a similar nature in the past. That said, one must beware of the mathematical theory called 'No Free Lunch', which essentially means that because an algorithm works well for one problem, it doesn't mean that it would perform optimally for another. So it may be prudent to try multiple approaches before settling on one. The iterative process of finalizing a machine learning solution involves research, and a cyclic process of data preprocessing, tuning a model, running validation, gaining feedback and re-tuning the model.





The most important factor influencing the success of a machine learning algorithm is the quality and quantity of the dataset that is used to train the system.

04 - Artificial Intelligence — Real World Applications

Artificial intelligence finds application in many industries and the number continues to grow as more data is collected.

The average person doesn't realize how many ways s/he is touched by artificial intelligence, especially machine learning, in the course of a day - or how much easier, faster, more efficient and more fun it makes interacting with technology and other people!

Here are a few familiar data sources and their applications that touch many people's experiences:



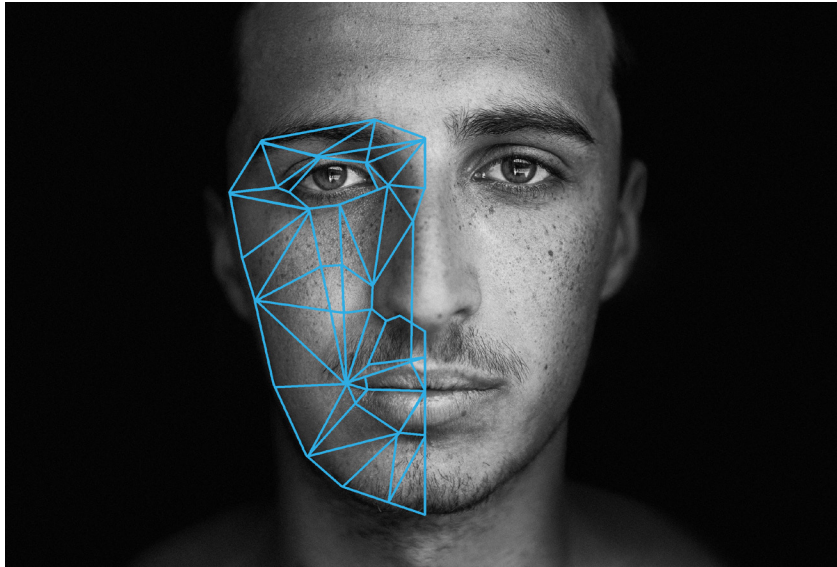
Computer
Vision



Natural Language
Processing



Recommendation
Systems



Computer Vision

Have you ever logged on to Facebook, uploaded an image of your friends, and realized each friend was correctly - and automatically - tagged without you having to do a thing? Spooky? Coincidence? Nope! Artificial intelligence. When AI is applied to digital images or video feeds to infer meaningful information, it is called computer vision.

Tracking facial features for the filters many kids use on Instagram is another example as is license plate detection in traffic cameras. Still another way, that greatly benefits the future of healthcare, is clustering and detection of tumors in medical images like MRI scans.



Natural Language Processing

Artificial intelligence extends beyond just images to things like speech and language-driven data. Google Translate is probably a familiar (and potentially annoying!) example for many. In fact, there are now websites dedicated to hilarious auto-completion examples that happened as a result of incorrect assumptions on the part of Google or like-providers. Over time, these services will become better and more accurate as more data is collected. This applies to Amazon Echo and Google Home as well.



Recommendation Systems

When we log into our Netflix account and wish we had something good to watch, we are often treated to a handful of possibilities labeled, “We think you might like....” These recommendations are based on our past viewing histories and trends. The more we watch, the more fine-tuned the recommendations become. The same is true of YouTube and product recommendations while shopping online.

Artificial intelligence has revolutionized Industries far and wide. Any industry that deals with data is beginning to grasp the value machine learning algorithms provide by helping gain insights. Here are a couple of examples of industries leveraging AI technology:



Autonomous Cars

We’re still waiting, but the autonomous car industry is a great example of a vertical market that benefits hugely from artificial intelligence. Industry giants like Google, Tesla and Baidu are invested in manufacturing fully autonomous cars. Ride-share services like Lyft and Uber are working toward a self-driving taxi service. Major car manufacturers have been actively shifting resources towards the driverless industry as illustrated by the investment of GM in Cruise Automation, Ford in Argo AI, etc. And to add to the list are hundreds of startups, all competing in the race to reach autonomy. Eventually, more and more machines will use autonomy to do what humans did before. Eating breakfast and sipping your latte while commuting to work? Yes, please!



Healthcare

The healthcare industry is another important industry benefitting from machine learning. Robotic surgery, predictive health trackers, drug discovery and medical record digitization using natural language processing are all examples of the transformative and important work that is being done in this field.

05 - Artificial Intelligence — Wind Energy Industry

Now that we've seen how artificial intelligence is benefitting many industries in today's world, let's look closer at the ways in which it can benefit the wind energy industry.

AI can touch nearly every stage in the life cycle of a wind turbine. While SkySpecs is currently focused on using AI for blade inspections, there is room for application across all areas of manufacturing, quality assurance and optimal location selection for wind farm installations. But perhaps the greatest potential lies in the repairs and maintenance sector.

A Closer Look at Wind Turbine Inspections

Before we jump into how AI and machine learning work in this industry, let's consider the way in which inspections have been historically conducted.

Until recently, wind turbine inspections were mostly carried out manually in the form of rope inspections. There are many reasons why this is a less-than-ideal method for initial inspections including:

- 1 Excessive turbine downtime is required
- 2 Inspections by rope are costly
- 3 Safety is a major factor

Manual vs. Automated Drone Inspections

There are also manual drone inspections, different from SkySpecs' fully autonomous inspections in which the drone is programmed to complete a wind turbine inspection without human intervention. A manual inspection requires a pilot to navigate the drone around the turbine by eyeballing it or through FPV monitor on the ground, while trying to get complete turbine coverage. Considering that the structure is 100+ feet tall, it leads to reduced perspective and increased risk - particularly when the pilot is manually inspecting several towers in a day.

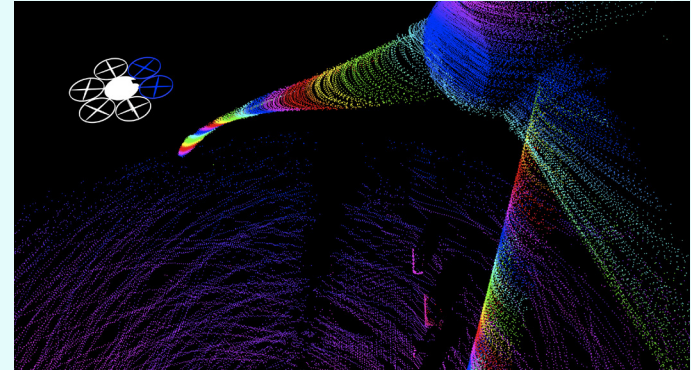
An improvement on the manual drone inspection, a ground-based camera can be semi-automated and safer.

The challenge here is the lack of precision and repeatability that automated drone inspections provide.

Autonomous drone inspections help overcome all of the above-mentioned challenges by applying artificial intelligence on sensor data to map, localize and plan the optimal path around the wind turbine. With this added ability, intelligent autonomous software can capture all segments of the blade in the least amount of time.



Additionally, they do not require the tower to be halted three times for every blade, or pitched to capture all sides of the blade. Faster inspections enable faster damage reporting and decision making.



Visualization of laser scans mapped by Skyspecs drone during inspection



Manual drone inspection

Data Analysis

The next step in an inspection is the data analysis. The analysis involves marking damages and categorizing them into one of several damage categories. Based on the size, type, and severity, the blade can either be deemed healthy, or in need of repair. A category 5 damage identification may necessitate a total shutdown. The process of manually analyzing these images is quite cumbersome, and time consuming.

Humans are adept at inventing new, creative ideas, and discovering clever means of exhibiting analytical reasoning. Humans are less adept at laborious, repetitive tasks that require long periods of focused attention.

Human error can take the form of missing damages, inconsistent labeling of damage due to the subjective nature of human analysis, inaccurately drawn contours around the damage etc.

Machines, on the other hand, are ideal for performing repetitive tasks for indefinite periods of time. This is where machine learning

comes in. Given enough training, machine learning algorithms can detect and accurately classify images. Moreover, image data

- when fused with data from other sensors like GPS and/or LiDar
- provides a precise estimate of the real-world measure of the damages seen in it. Categorizing severity of the damage is possible when these measurements are known.

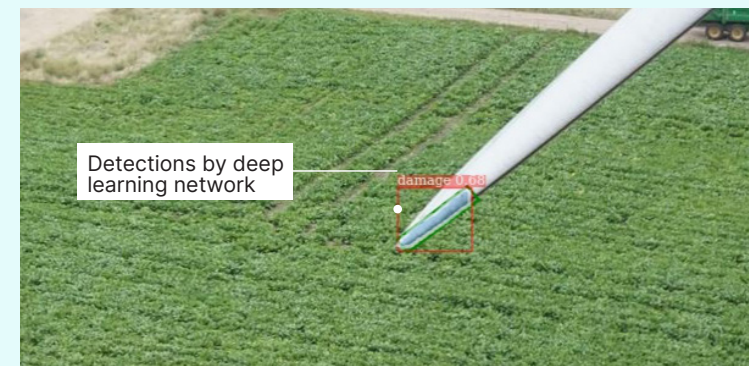
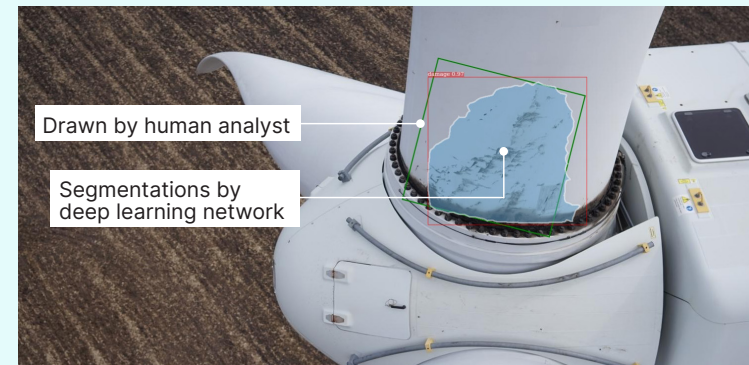
SkySpecs' Software Can Run Detection and Segmentation on an Image at Less Than 200 Milliseconds.

Object detection deep learning algorithms, like the cat detector, can also be extended to detect damage. With enough training on human-analyzed blade images, the model should be able to learn to detect as well as classify damages in blade images efficiently. Further, there is a good amount of research on segmentation learning, which will enable not only detecting the damage but also drawing of a tight segmentation over the exact damage region. This feature can help extract very accurate measurements of damages from the image.

Along with reliability and accuracy, machine learning can also considerably reduce the analysis time. The time taken by a software to run inference on one image is on the order of magnitude of milliseconds. SkySpecs' software can run detection and segmentation on an image at less than 200 milliseconds. Moreover, the software will only improve over time as it constantly learns from analyst feedback.

Automated Analysis using machine learning can be a good first pass at identifying damages before being subjected to human review. It will help reduce human errors and bias while increasing speed of analysis.

Skyspecs Automated Damage Detection and Segmentation Samples



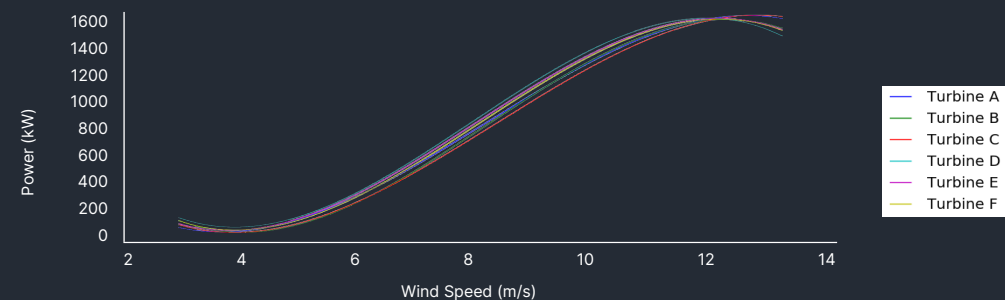


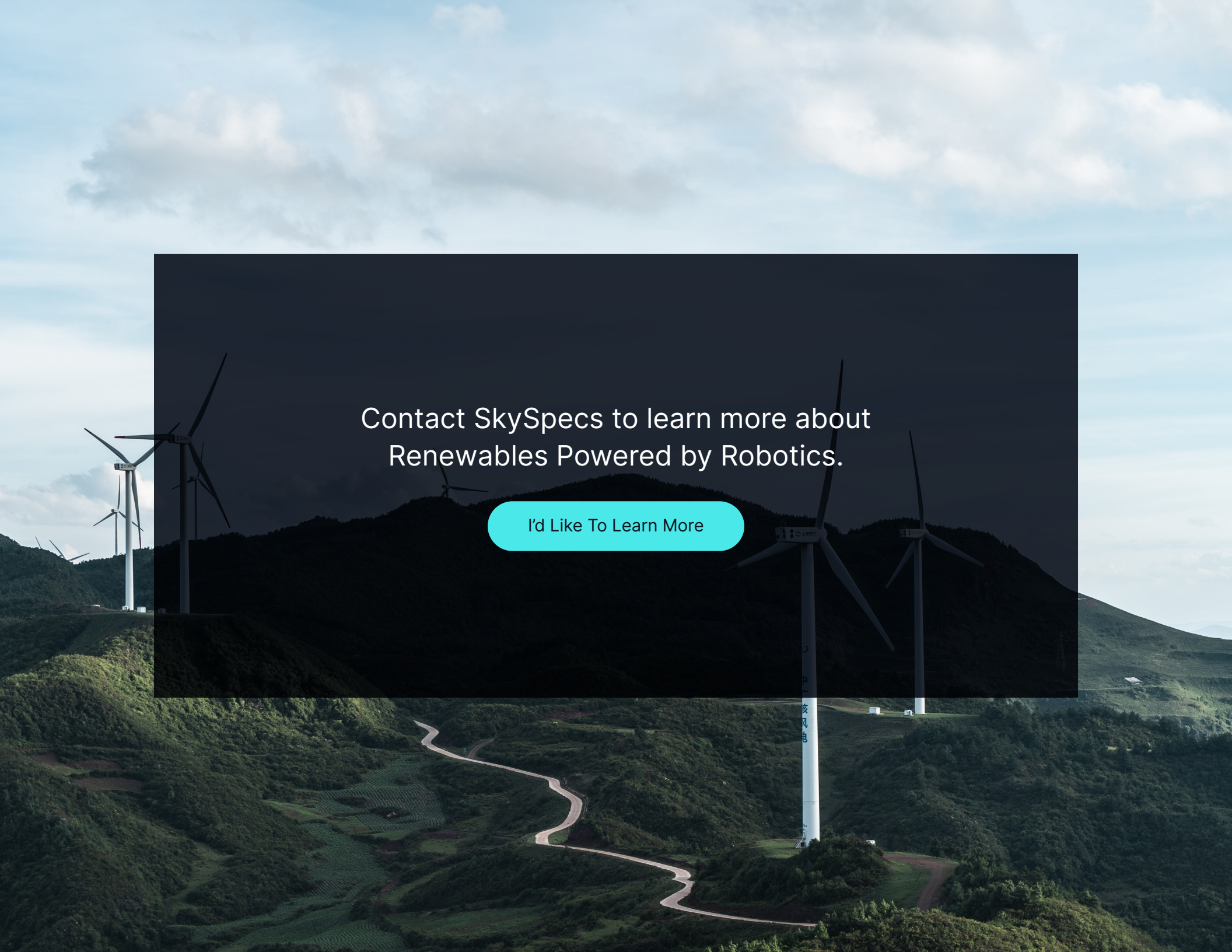
Preventive Maintenance

There is a wealth of data associated with the functioning of a turbine that can potentially be utilized to learn and predict performance, raise alarms and also predict failures. This data exists in the form of SCADA, CMS and digitized maintenance reports. The one major difference in the case of wind energy data is that one can utilize more than just the data to make predictions. Combining the machine learning magic box's learning with that of domain understanding can help make better informed decisions. For example, combining a machine learning model learned on historic SCADA data with a physics-based models can help enable highly informed decision making about the health of the turbine.

Being able to estimate a performance timeline allows advance maintenance and repair planning. Optimizing preventive maintenance such that the downtime loss is minimal, will prove very valuable to the wind energy industry.

By using AI, we are offered a look at the damage information, propagation rate, the history of repair costs, and the production loss based on the health of the turbine from the SCADA data. This results in a powerful arsenal of data that enables decision making that can affect the bottom line and the future.



A scenic landscape featuring several large white wind turbines with three blades each, situated on a lush green hillside. A winding dirt road snakes through the lower part of the image. The sky is filled with soft, white clouds. A dark, semi-transparent rectangular box is overlaid in the center of the image, containing white text and a cyan button.

Contact SkySpecs to learn more about
Renewables Powered by Robotics.

I'd Like To Learn More



info@skyspecs.com | www.skyspecs.com