

# Mathematical Functions Power Artificial Intelligence

Major advances in artificial intelligence (AI) have brought benefits and new challenges to society. A key breakthrough in AI is machine learning (ML), which helps computers learn from examples. This kind of learning works well for tasks that cannot be defined by explicit rules, like identifying an object in a photograph, recommending music, flagging fraudulent credit card activities, creating adaptive video games, or transforming speech into text.

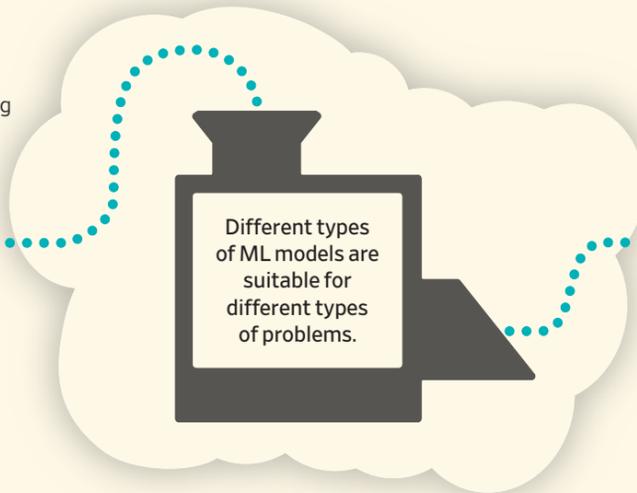
These technologies and their evolution have created significant new mathematical challenges including the analysis of “models” that underlie machine learning.

## What does machine learning do?

Machine learning models process raw data to produce meaningful information, such as converting raw audio input into text in this example.



Machine learning models may accept input data from speech, images, text, sensor readings, time series data, and so on. They are “trained” using up to billions of examples in order to learn how to process the data.



Both the training and the use of machine learning models require extensive computer processing to evaluate and are therefore typically run on the cloud.

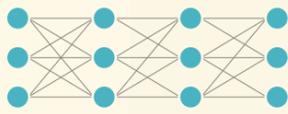
## Outputs

“How are you?”

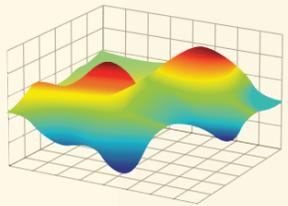
Outputs of machine learning models include evaluations (text-to-speech), commands (playing a song), predictions (labeling a person in a photo), translations (English-to-French), and forecasts (your next purchase).

## Designing a Machine Learning Model

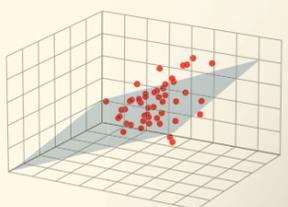
A machine learning model can be understood as a mathematical “function” that depends on “parameters” learned from training data. Data scientists must choose the appropriate mathematical function, often trying many different possibilities. Typical choices include neural networks, Gaussian processes, and multivariate linear regression. Mathematical and statistical analysis helps to understand the properties of these functions, guiding the design.



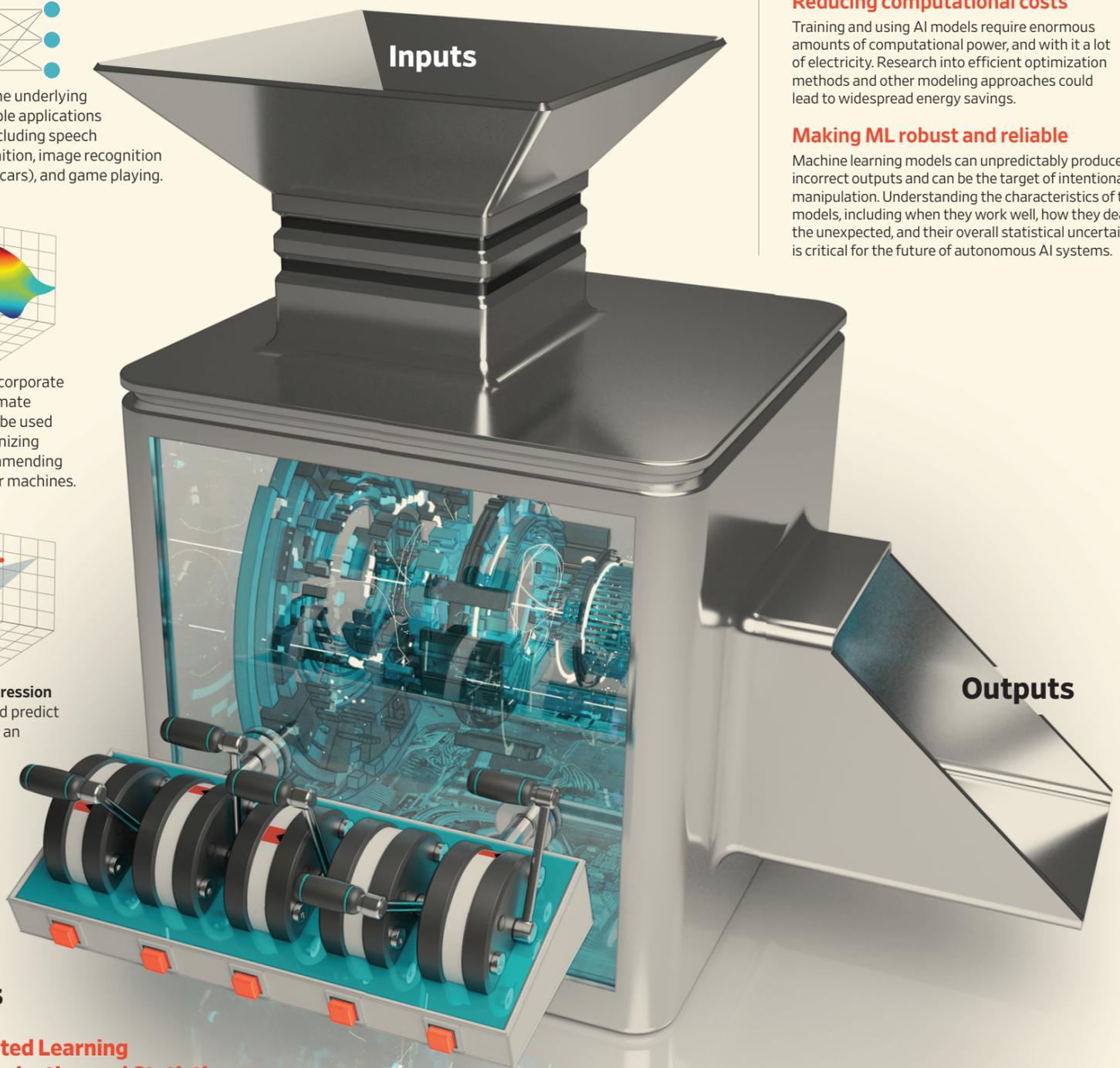
**Neural networks** are the underlying tool behind some notable applications of machine learning, including speech processing, face recognition, image recognition (such as in self-driving cars), and game playing.



**Gaussian processes** incorporate available data and estimate uncertainty. These can be used for tasks such as recognizing handwriting and recommending optimal movements for machines.



**Multivariate linear regression** works well to model and predict variables when there is an understanding of what functions might best serve to model the phenomenon, such as with real estate prices, many examples in the social sciences, and locating astronomical objects from few observations.



## The Challenges Ahead

### Mitigating bias

Machine learning can introduce and amplify biases in contexts such as facial recognition or screening for employment, even when demographic information is not explicitly considered. Research in areas such as statistical bias correction can help avoid this.

### Reducing computational costs

Training and using AI models require enormous amounts of computational power, and with it a lot of electricity. Research into efficient optimization methods and other modeling approaches could lead to widespread energy savings.

### Making ML robust and reliable

Machine learning models can unpredictably produce incorrect outputs and can be the target of intentional manipulation. Understanding the characteristics of the models, including when they work well, how they deal with the unexpected, and their overall statistical uncertainty is critical for the future of autonomous AI systems.

## Parameters



### Automated Learning via Optimization and Statistics

The machine above is analogous to a machine learning model that takes in diverse inputs, evaluates them using mathematical functions (shown as the blue inner workings above), calibrates parameters (as levers would in the machine), and ultimately provides outputs for consideration.

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