Machine Learning Concepts and Applications

Yusifov Mahammad[1], Lala Bakirova [2]

[1,2] *Azerbaijan State Oil and Industry University 1, 34 Azadliq Avenue, Baku, AZ1000, Azerbaijan*

Abstract

The thesis includes the main basic concepts of machine learning and its applications. For simplest possible explanation of machine learning concepts, handwritten number recognition software has been represented and on this application, concepts like artificial neurons, weights, edges, connections and others has been explained. Layered structure of artificial network, artificial neuron activation value. What is edges shapes? How the recognition process happening, what is neural network and neurons? What is weight and activation value, Sigmoid and ReLU function? What is the parameter of connections between neurons? These questions and others has been covered in this article.

Keywords

Neural network, artificial intelligence, neurons, auto recognition, activation, weight

1. Introduction

Machine learning is a field of science that covers mathematical complex calculations and equations in order to make computers imitate the "learning" process of humans. This process involves a computer algorithm that builds models based on given training data to make proper decisions without being manually programmed by a developer [2]. Machine learning is considered as an important functionality and branch of Artificial Intelligence and the applications of this interesting technology are very wide: Speech recognition and other image recognition techniques, computer vision, email spam, and malware filtering, virtual personal assistant, online fraud detection, self-driving cars, stock market trading, and medicine. And this list can be expandable. In this thesis, main concepts and applications of machine learning will be covered.

2. Neural network

The artificial neural network is a set of connected units that each represents a neuron, like in the human brain. Every neuron can be considered as a function that takes input as a number and passes as output to the next so-called artificial neuron [1]. Figure 1 is an example of artificial neural network that consists of input, output and some additional hidden layers that can be considered as black box for now.

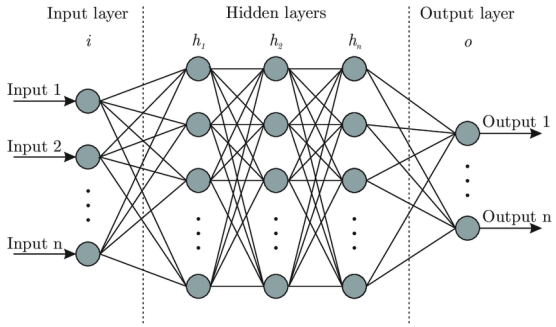

Figure 1: Artificial neural network

In every layer, neurons are connected to each other via weights that can be modified with result of learning or training process. Next, we can take simple example application handwritten number recognition and go through these concepts of neurons.

ISIT 2021: II International Scientific and Practical Conference «Intellectual Systems and Information Technologies», September 13–19, 2021, Odesa, Ukraine EMAIL: yusifov.19@mail.ru (A. 1); lala_bekirova@mail.ru (A. 2)
ORCID: 0000-0002-4295-8642 (A. 1); 0000-0003-0584-7916 (A. 2)

2.1. Handwritten number recognition

Although it is not so challenging to humans to understand the number on the left which is sloppy written by me, for computers it is not an easy task.

Figure 2 shows an example for number recognition which has been taken from this site: https://www.i-am.ai/neural-numbers.html.

Figure 2: Screenshot of number recognition AI

How this software converts or translates the analog number given on the left to the digital mathematical number that has been given on the right by the machine? Let's start with conceptualizing the term "neuron".

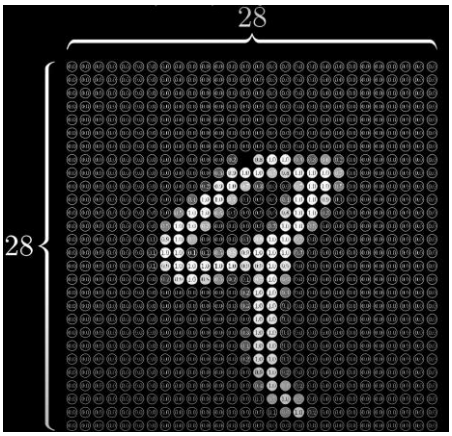

Figure 3: Number on pixels or on "neurons"

We can consider a neuron as a unit that holds a number between 0 and 1. In figure 3 we have 28 x 28 = 784 neurons and each one of these neurons holds a value that represents the greyscale value of the corresponding pixel. For example, the neuron that value is 0 means it is black and the one with value 1 means it is white. This number is called "activation" [3].

All of these 784 neurons represent the input layer of our artificial network and the output layer consists of 10 neurons that each represents a number as a result. The activation of neurons in the output layer also represents grayscale value, the neuron with the highest activation number is the "choice" of the machine. For example in our case, the number is 9 and the neural network of the decision process has been shown in Figure 4.

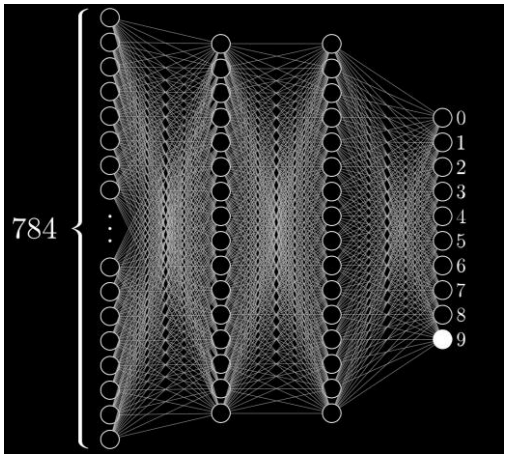

Figure 4: Artificial network with result "9"

When we try to recognize a number, our brain looks for certain patterns like loops or shapes. For example, in our example, the number 9 has circle up top and a line on the right. The number 8 has 2 circles or loops one on top and the other at the bottom. So our next inner layer can be responsible for holding each one of these patterns shapes in a neuron. If the activation of the specific neuron is close to 1, the possibility of that corresponding pattern is high. For example, suppose there is one certain neuron that represents a circle pattern, and the activation is 0.9. That means the resulting number can be: 0, 6, 8, 9.

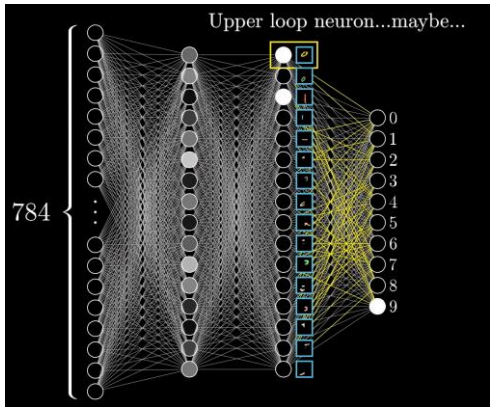

Figure 5: Second last layer holding patterns

So we can suppose, our second last layer is responsible for recognizing patterns as shown in Figure 5.

But, these patterns themselves also consist of little shapes, which we can call edges. For example circle can consists of a bunch of edges.

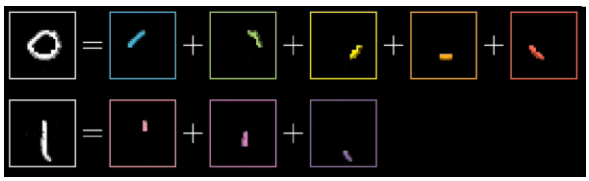

Figure 6: Little edges of patterns

So we also need to have a layer that is responsible for recognizing these little edges. The layer that comes after the input layer can be responsible for that operation. So with 2 layered 16 neurons structure, we can suppose the working principle of our little AI is in this way: In the first layer we get input as a handwritten number with 784 neurons, and then it sends a signal to the next layer in order to detect edges and then comes third layer to detect bigger shapes as patterns and at the output we have our result as a number.

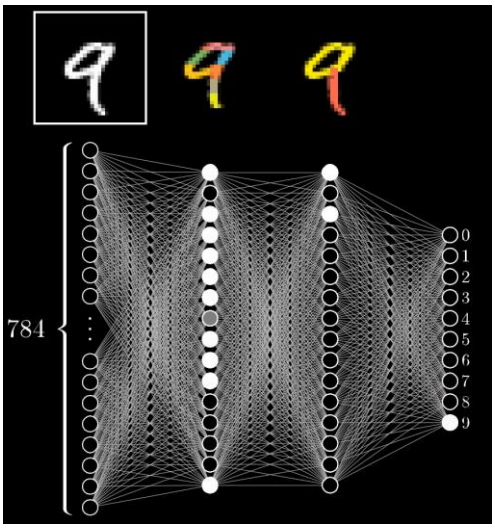

Figure 7: Overall of 2 layered neural network structure.

This structure can be also applicable for other recognition tasks like image and voice recognition. For example, detecting shapes in the pictures, or identifying syllables in human voice can be our "patterns" or "edges" in this structure.

To be able to detect that edges, we need to assign new parameter to the connections between neurons: weight which is also number. And from mathematical approach:

$$a1w1 + a2w2 + \ldots + anwn\,, \qquad (1)$$

This equation is weighted sum [4].

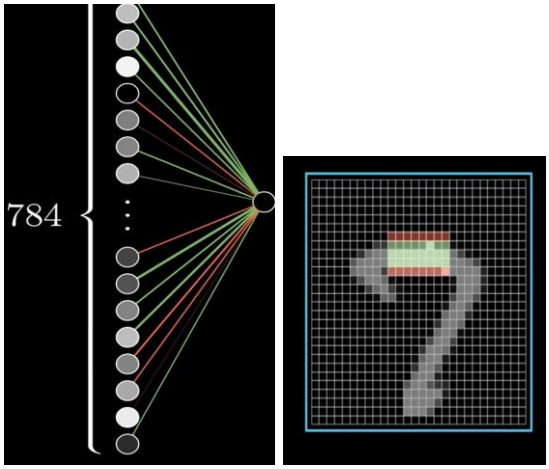

Figure 8: Edge recognition with weights

Weight with the color green means positive vale and with the red color means negative so weights with the pixel color red means darker are and it distinguishes darker and lighter areas on pixels so that it can detect edges.

When we compute weighted sum in equation 1, we can come up with any number, but for our network, we need activation values to be in the range of 0 and 1 and here we need to use the specific function that minimizes real number to the range between 0 and 1. A common function is the sigmoid function.

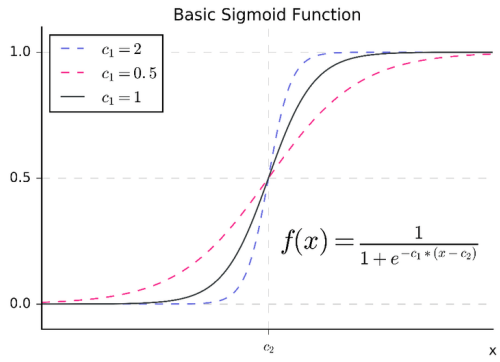

Figure 9: Sigmoid function

Negative inputs end up close to 0 and positive inputs end up close to 1 [5]. So the activation of a neuron in our network is a measure of how positive the corresponding weighted sum is. But also we need bias for inactivity. We just need to

extract that value from the weighted sum before processing the sigmoid function [1].

$$\sigma(a1w1 + a2w2 + \ldots + anwn - bias), \quad (2)$$

So, the weights indicate what pattern, edges this specific neuron in the second layer is picking up on and the bias indicates how high the weighted sum needs to be before the neuron starts getting active.

But there is another better function called ReLU – REctified Linear Unit.

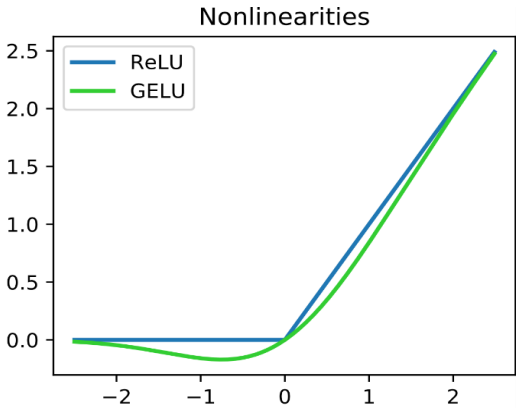

Figure 10: ReLU function

Using sigmoid function, was very difficult to train at some point, but ReLU solved this problem [10].

Every neuron in the first layer is connected to the 784 neurons. And each one of these 784 connections has weight and bias. So we have 784 x 16 weights with 16 biases and the connection between other layers also has weights and biases according to them. Our network has 13002 weights and biases in total.

Learning in here is, getting the machine to find a true setting for all of these many numbers so that it can solve the problem at a time [7].

The training process of the network can be done with the help of certain special databases that store collections of images of numbers handwritten. So the machine can train itself to become a better "predictor" with both having input and output from the database [8].

MNIST database is well-known example of these databases which stores 70000 images of digits handwritten by people like high school students and employees of the American Census Bureau that are published to help AI researchers.

Figure 11: Some numbers from MNIST database.

The more training data we give to the machine, the more it evolves itself by doing feedback: taking input from the picture does its operation and match the result with the real idealistic value behind the number and correct itself [6].

3. Applications

Very popular example of how powerful artificial intelligence can be is GPT-3 (Generative Pre-trained Transformer 3) launched by OpenAI company. This model uses deep learning to produce texts that are very similar to human words [9]. GPT-3 can even code by its own, you just have to give input commands like create a button that looks like rectangular and when it is pressed increase certain value or do some other operations. For example debuild.co is interesting website that uses GPT-3 to write code. User gives orders as input and it generates JavaScript code according to orders and visually shows the result at a time [10].

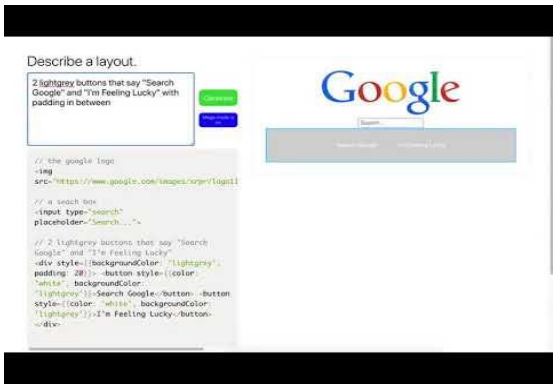

Figure 12: Describing google UI to GPT-3

GPT-3 functionalities are very wide and that shows how amazing works can be done using Machine Learning and Artificial Intelligence.

In medical field, machine learning has so many applications and they are currently being developed. One of the proper examples is Microsoft's InnerEye Project that identifies

differences between healthy cells and tumor cells by using 3D radiological images as shown in Figure 13.

Figure 13: Screenshot from Inner Eye

Pfizer uses machine learning to research about how the immune system of human body can fight cancer. Insitro is a startup uses data science and machine learning to develop drugs that cures people much faster and with high level of success [11].

Besides medical field, there are many interesting fields that use machine learning. Navigation programs like google maps analyzes all roads and transportation ways and brings most relevant choice of travel from location to another. Social media programs has many features that use machine learning to process its functionality like bringing "people you may know", face detection, image recognition and others. Self-driving cars like Tesla works on deep learning and also includes IoT because of intelligent sensors. Language translation apps, online video streaming apps and many others have a touch on machine learning and expands quickly.

Another additional machine learning application can be in psychology field. Model can be established in order to read and store different parameters of humans in a database. Database structure is shown in a following figure.

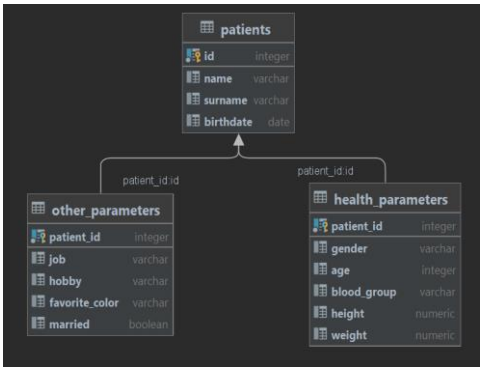

Figure 14: Simple database for model to learn

This database can be input for model and it can use machine learning to improve more correct analyses of human and better treatment for each specific patient. There are 3 tables in this simple represented database:

1. patients: stores basic information for other relations
2. health_parameters: stores vital information about a human this data is essential for identifying potential diseases
3. other_parameters: stores information about daily activites, and possible decisions that the human can make.

The second and third tables are connected to first table via foreign key on id of patient. With only this small data a well-structured AI can predict the cause of psychological disease and develop more relevant therapy for patient. For example: a married man with weight of 120kg who is accountant may have heart disease and with having no hobbies is additional risk parameter that causes psychological disease on him. That one example can be extended widely with the growth of the database. More data provided to model, more it will be decisive and correct. If there are 2 persons that have relation they can also have same problem. For instance, a partner of current patient had this certain disease 4 months ago as she registered in this database. So this AI can read all relations of humans even if they are not bound together but have same workplace that other patient had, this can be important information for model to decide. This complex relation may be difficult for us to see and decide but it is not the same for a machine. It can perform big analysis and diagnostic on a human and identify multiple treatment or therapy methods. And a doctor who is psychologist can choose one or more of those method even modify them. This kind of machine learning application is not only about psychology field, it also can be about other specific fields of medical applications.

4. Conclusions

In the new era of technology, Artificial Intelligence will help humans to solve so many problems in a short time without errors. It can affect the human life as given example about identifying the disease on human by giving database as a training data for machine to learn. In medicine, special surgeries, in oil manufacturing, or in some dangerous places that humans should not be operate, machines will replace and make appropriate decisions like, or better than humans. And that complex operations is starting with

handwritten number recognition task. It is considered as “Hello-World” of Machine Learning. But as we know every big roads starts with first little steps.

5. Acknowledgements

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6. References

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