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Свёрточные нейронные сети

В данной статье освещены свёрточные нейронные сети: определение нейронных сетей, их устройство, определение свёрточной нейронной сети и её вариант с архитектурой Яна Лекуна. Также рассматривается вопрос применения свёрточных нейронных сетей в разных областях.

Convolutional neural networks

Our age is known as the “digital age”. New technologies are being developed almost every day. There is no field of study in which someone has not tried to understand the laws of nature or improve something. Of course, one of the most interesting things to understand and copy is the human mind. The artificial neural network is a mathematical model of the human mind. Now, this field is growing fast, and many models and algorithms have been created. The convolutional neural network is one of these models.

What is the convolutional neural network? To understand this, you should know what the artificial neural network (ANN) is.

An artificial neural network is a large collection of very simple, massively interconnected cells, also known as neurons.

Most ANN-architectures are grouped by the term multi-layer feed-forward ANNs. This means that data goes in one direction, from input to output, and neurons are grouped into layers. Then, we must consider their structure.

The first layer is usually the input layer, and the last layer is the output one. All layers are called hidden layers. Every cell performs a very simple calculation: it calculates the sum of all of its inputs, multiplied by their respective weights (the weight is a characteristic of the connection between two cells), after which a squashing function is applied to the result. The squashing function is usually called the transfer or activation function. Often researchers use the function, called a sigmoid: $g(x) = \frac{1}{1 + e^{-x}}$, or a double sigmoid .

After that, cells transfer data to the next layer. The output of the network is the output of the last layer (output layer).

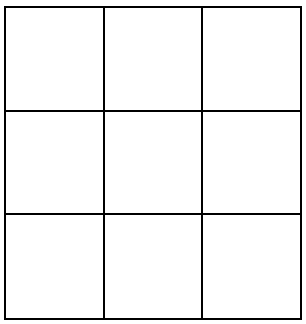
The weights of the connection can be preset by an operator, or trained by presenting the ANN with the examples of the input (possibly together with the desired output). There are many training methods; one of the most popular is the back-propagation method.

This method is based on the following idea: neurons can send error signals in reverse direction – from output to input. In the event of an error, we firstly correct weights on the last layer, then, based on these results, calculate new weights for the previous layer. We will repeat this as long as the current layer is not the input.

Now, we can move on to convolutional networks. But before that, we must define what is convolution.

Convolution is a mathematical operator (denoted by "*") on two functions, defined as the sum of the products of the function values, with the one function mirrored in an origin. Given this, we will use the following interpretation of this definition.

Imagine a square window with mesh, which contains the function value – filter.



Example

Onto this window, the image has to be processed. This window then calculates the sum of the pixel values as well as the respective coefficient. Now, we can store the result in the middle pixel.

One of the most famous scientists, who works with convolutional neural networks, is Yann Le Cun (this idea was developed by him). Let's view his ANN's.

The input of a convolutional ANN (CNN) is an image, which is typically preprocessed. The second layer contains the so-called feature maps. Each cell in one of these feature maps contains a set of incoming weights; this set is known as the convolution filter, or template. The location of the map in the input image corresponds to the location of the cell in the feature map. This is what is meant by receptive fields: cells react to the same pattern at different locations in the input image.

The next layer isthe sub-sampling layer. This layer is included mainly to reduce the number of free parameters (which includes different connections), and has the same principles as feature maps.

The fourth layer is hidden and fully connected with the previous one.

The output layer is completely connected to the hidden layers, and forms the results of the work. It consists of 10 cells, and the cell with the highest activation value is chosen as a result.

Researchers can use ANNs that differs from Le Cun's slightly, but the principle will remain the same.

CNNs have some advantages over classic ANNs. Their architecture has fewer weights than an ANN model. This is because CNN uses one filter with weights for the whole image, whereas ANN uses weights for each pixel. This means that CNNs will generalize the results instead of storing information for each pixel.

The next advantage that CNNs have is better parallelization (i.e. executing the same command in multiple threads, potentially in different processor units).

The disadvantage of CNNs is in their limited applications in image recognition due to their architecture. But, in some subjects, as we will see, CNNs are quite applicable.

Why do we need convolutional neural networks? They are mainly used in image recognition, and they have one of the best recognition and image classifying algorithms with an error rate of only 0.23 percent.

The next application is in video analysis. Video analysis is more complex than image analysis since it has another dimension (time). The common way to address this is to fuse the features of different convolutional neural networks. These additional features are responsible for spatial and temporal streams.

We can also use CNNs in natural language processing, playing Go and drug discovery (predicting the interaction between molecules and biological proteins can be used to identify potential treatments that are more likely to be effective and safe).

Nowadays the image recognition is the topical theme. The convolutional neural networks are very useful for people because we often deal with different images. This is actually the main reason why the field is growing fast today.

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