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PROPERTIES OF CONVOLUTIONAL NEURAL NETWORKS.

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Annotation. *Convolutional neural networks are widely used in artificial intelligence and machine learning in image analysis, natural language processing, and other complex data processing. The main characteristics of CNNs are automatic feature learning, extraction of important elements in images and data, invariance, hierarchical feature detection, and efficient parameter sharing. This article provides detailed information on the working principle of convolutional neural networks, their layers (convolution, pooling, fully connected), as well as how they are used in real-world problems.*

Key words: *Convolutional neural network, artificial intelligence, machine learning areas, natural language processing, images and data, invariance, hierarchical feature, neural network, layers, convolution, pooling, fully connected.*

Аннотация. *Сверточные нейронные сети широко используются в искусственном интеллекте и машинном обучении при анализе изображений, обработке естественного языка и другой сложной обработке данных. Основными характеристиками CNN являются автоматическое обучение признакам, извлечение важных элементов из изображений и данных, инвариантность, иерархическое обнаружение признаков и эффективное совместное использование параметров. В этой статье представлена подробная информация о принципе работы сверточных нейронных сетей, их слоях (свертка, объединение, полная связность), а также о том, как они используются в реальных задачах.*

Ключевые слова: *Сверточная нейронная сеть, искусственный интеллект, области машинного обучения, обработка естественного языка,*

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изображения и данные, инвариантность, иерархический признак, нейронная сеть, слои, свертка, объединение, полная связность.

In the fields of artificial intelligence and machine learning, convolutional neural networks (CNNs) play a very important role. They are mainly used in image processing and classification, but are now also used in natural language processing, voice data, and many other areas. CNNs differ from other neural networks in their structure and operating principle, as they are multilayered and adapted for automatic feature learning. This article analyzes the main characteristics of convolutional neural networks and their operating principles.

Basic concepts of convolutional neural networks. Convolutional neural networks are a special type of artificial neural networks, the main purpose of which is to automatically learn features from images or other data sets. CNNs often consist of the following parts:

Convolutional Layers. The most important component of a CNN is the convolutional layers. These layers divide the image into small parts and analyze each part independently. Each convolution layer contains a small matrix called a "kernel" or "filter" that operates on each pixel of the image. The purpose of the filter is to extract important features in the image (such as edges, corners, structures, etc.).

Activation Function. After the convolution operation, the results are passed through an activation function. The most commonly used activation function is ReLU (Rectified Linear Unit), which activates a specific feature, and if it is negative, it is equal to 0. The ReLU function helps reduce the uncertainty of the model and speed up the calculation.

Pooling Layers. After the convolution layer, pooling layers are often used. Pooling is mainly used to reduce the dimensions of the image, which reduces the calculation time and is effective in training the model. Techniques such as max pooling or average pooling help in extracting important features from an image. Max pooling, for example, preserves the important features of an image by selecting the largest value within a small portion of the image.

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Fully Connected Layers. At the end of a CNN, there are fully connected layers. These layers connect each neuron to all neurons in the network and are used to make final decisions. Their job is to transform the features extracted from the image into the final classification or regression result.

Normalization. Techniques such as batch normalization are used for CNNs to speed up learning and increase the generalization ability of the model. This technique normalizes the data at each layer of the network, so that the learning process of the network becomes more stable and efficient.

Features of Convolutional Neural Networks. Automatic feature learning. The biggest feature of CNNs is that they can automatically learn features from images or other data. This is useful, for example, in image classification, because the network learns the specific features in the image, such as edges, colors, textures, and other important elements. As a result, CNNs do not require much manual feature extraction, and they are very effective in solving complex classification problems.

Invariance. CNNs are invariant to the dimensions, rotations, and stresses in images or other data. For example, even if the same image is shown from different angles, a CNN can still be highly accurate in identifying it. This increases the network's generalization ability and provides flexibility to various changes.

Hierarchical feature learning. CNNs often have a multi-layer architecture, with different features detected in each layer. The initial layers detect simple features (such as edges and corners), while subsequent layers combine these features and learn more complex features. This allows you to create a hierarchical structure, which is important for object recognition in an image.

Dimensionality reduction. The use of pooling layers in a convolutional network reduces the dimensions of the image, which increases computational efficiency. Pooling is especially useful when working with large images, as it compresses the information and allows the network to train more quickly and efficiently.

Sharing parameters between layers. In CNNs, convolutional layers share parameters with each other through filters. This reduces the number of parameters in

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the model, making the network more efficient and faster. This feature makes CNNs very suitable for working with large amounts of data.

Convolutional neural networks are widely used in the following areas:

Image recognition. CNNs are most commonly used in image classification and recognition. They are used in image classification, face recognition, object detection, and also in the analysis of medical images (such as X-ray and MRI images).

Video analysis. CNNs are also used in video data analysis. They are used to detect objects in videos, analyze movements, and so on. For example, CNNs are used in analyzing video streams from security cameras to detect moving objects or people.

Natural language processing. In recent years, CNNs have also been used in natural language processing. They are used for tasks such as text classification, emotion recognition, and machine translation.

Automated driving systems. CNNs are also used to create automated drivers in changing environments. By analyzing the image of a car, they help to identify objects, recognize obstacles, and determine the right path.

Convolutional neural networks play an important role in the fields of artificial intelligence and machine learning. Their properties such as automatic feature learning, invariance, and hierarchical feature detection make them effective in solving image analysis, natural language processing, and other complex problems. CNNs are widely used in various fields and are working as very effective and powerful tools in solving real-world problems.

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